Hugo R. M. Moeller

(Watson)

THE VIRGINIA JAMESTOWN EXPOSITION COMMISSION

MINERAL RESOURCES

OF

VIRGINIA

BY

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PREFACE

This volume, Mineral Resources of Virginia, authorized by the Governor of Virginia and the Virginia Jamestown Exposition Commission, has been published in order to direct attention to the economic value, location, and commercial possibilities of Virginia's varied mineral wealth. The evidence here presented shows that the State is well supplied with a great variety of mineral resources, many of which are being rapidly developed. There is probably no state in the Union of the same area as Virginia that can show a greater diversity in geologic resources. This most important fact taken in connection with the mildness of the climate, which permits of a long season of outdoor work, and the cheapness of labor, are conducive to a very extensive mining industry. The total value of production of the mineral resources of Virginia for the year 1906 has been estimated at $30,000,000.

At the July (1906) meeting of the Virginia Jamestown Exposition Commission, it was agreed that a handbook illustrative of the vast mineral resources of Virginia was a necessity. The writer was accordingly authorized to prepare a handbook setting forth, as completely as our present knowledge permitted, the vast and varied mineral resources of the State. He was further authorized to devote several months in the field to a study of the mineral resources in those portions of the State where information was most needed for the purpose of collecting the necessary data for this volume. The work has proved far more exacting than was at first contemplated, in that the widely scattered literature on the geology of Virginia had to be overhauled in the preparation of the volume.

The principal sources of information, forming the basis of this volume, are "A Reprint of the Geology of the Virginias," by Professor William Barton Rogers, State Geologist of Virginia from 1835 to 1841, inclusive; "The Virginias," a monthly journal edited by Major Jed Hotchkiss from 1880 to 1885, inclusive (six volumes); the numerous excellent publications of the United States Geological Survey; and the published and unpublished reports of the recent Geological Survey of Virginia conducted jointly for two years by the Board of Visitors of the Virginia Polytechnic Institute and the State Board of Agriculture. In addition to the above publications much valuable information has been obtained from general treatises on special geologic subjects, such as from Merrill's "Non-Metallic Minerals,"

careful field study of the areas by the authors, made possible by the recent Geological Survey of Virginia in coöperation with the United States Geological Survey, especially in the study of the Cement and Cement Materials by Doctor Bassler, and of the Iron Ores by Professor Holden. The contribution on Clays by Professor Ries was extracted by him from his report on the Virginia Clays published as Bulletin No. II of the Geological Survey of Virginia.

The general interest manifested in the work by many people in the State, especially the mine and quarry operators, and by many residing outside of the State but who have mining interests in Virginia, aided greatly in the preparation of this volume. To all of these the writer is under deep obligation for many courtesies extended. Acknowledgments are also due to Messrs. Joel H. Watkins and Henry F. Day, former students in geology at the Virginia Polytechnic Institute, for valuable services rendered. Mr. Watkins prepared the line drawings and maps illustrating this volume. Mr. Day assisted the writer in the field during a part of the summer of 1906.

To Governor Claude A. Swanson and the members of the Virginia Jamestown Exposition Commission, especially Hon. W. W. Baker of Chesterfield county, who made this work possible and have rendered every assistance during its preparation, the writer makes most grateful acknowledgment.

With a full realization of the deficiencies in this volume, it is published with the hope that it will supply a widespread and increasing demand among our people and among others for information on the mineral resources of Virginia.

THOMAS LEONARD WATSON.

University of Virginia, Charlottesville,
September 30, 1907.

PART I.

GENERAL GEOLOGY OF VIRGINIA.

GEOGRAPHIC POSITION OF VIRGINIA.

The State of Virginia is situated on the Atlantic slope of the Appalachian Mountains, halfway between Maine and Florida. It is included between the parallels 36° 31′ and 39° 27′ north latitude, and between the meridians 75° 13′ and 83° 37′ west longitude, and extending from the sea-coast westward beyond the Great Valley to the Alleghany Front. The extreme length of the State from the Atlantic border to Kentucky is 476 miles, and greatest width from north to south is 192 miles; its area is 42,450 square miles. Of this area 2,325 square miles are covered with water, giving 40,125 square miles of land surface. Its principal inland waters are the Chesapeake and Mobjack bays, Hampton Roads, and Lake Drummond. Except in the eastern section no navigable streams traverse the State, and transportation is necessarily limited to railways.

SURFACE FEATURES.

Considered with reference to its surface features—physiography—Virginia is divided into three major provinces: (1) An eastern plain region usually designated the Coastal Plain or Tidewater region; (2) a central or plateau region, designated the Piedmont Plateau; and (3) a western or mountain region, designated the Appalachian Mountain province. The boundaries of these provinces are indicated on the map, forming figure 1.

As is indicated on map, figure 1, the western or Mountain province is divided into three well-marked physiographic belts, which extend the entire length of the province in the State from northeast to southwest. These are, named in order from east to west, (a) the Blue Ridge, (b) the Great Valley or Valley of Virginia, and (c) the Alleghany Ridges, known also as the Alleghany Mountains.

The three larger well-defined topographic provinces of the State differ markedly in the nature and origin of surface features, and in the age and kinds of rock. They are intimately related to the geologic

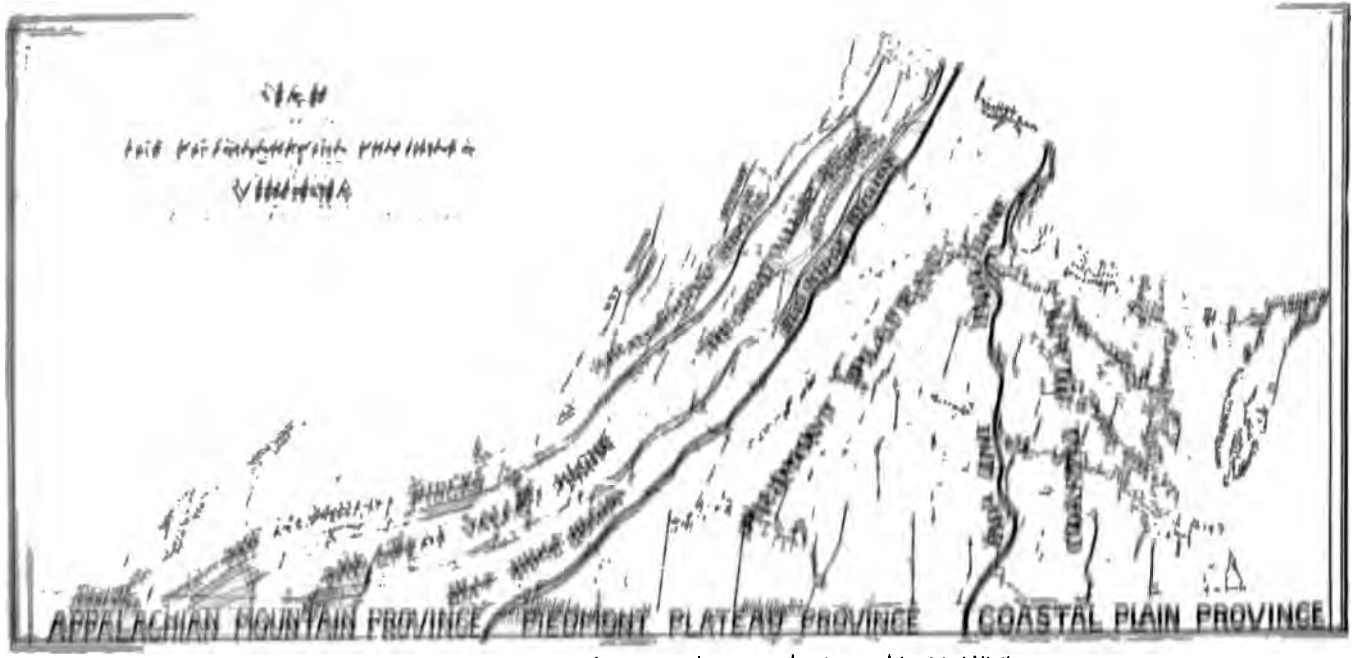


Fig. 1.—Sketch map of Virginia showing physiographic provinces

structure and hence have an important bearing upon the mineral resources of the State. These are therefore considered in order below.

THE COASTAL PLAIN PROVINCE.

The Virginia Coastal Plain province, the most easterly of the three larger physiographic provinces and comprising approximately one-fourth of the total area of the State, is separated from the higher-lying Piedmont Plateau province on the west and the deep Atlantic Ocean basin on the east. The boundary of the Coastal Plain to the eastward is marked by the steep slope of the continental shelf which lies from 30 to 50 miles east of the present shore line. The western limit of the Coastal Plain is defined by the belt of metamorphic crystalline rocks known as the Piedmont Plateau province. Figure 2 shows the relations of the Coastal Plain sediments along its western margin to the Piedmont crystalline rocks. The Virginia

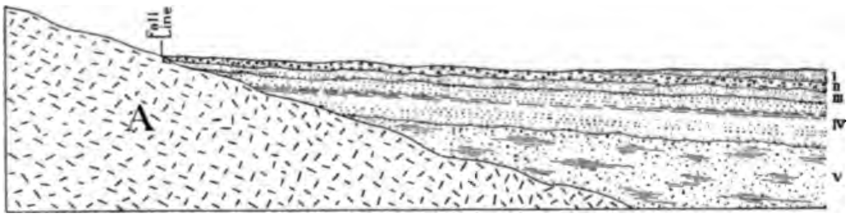


Fig. 2.—Diagrammatic section illustrating the relationship between the Piedmont Plateau and the Coastal Plain. A. Crystalline rocks of the Piedmont Plateau. I, II, III, IV, and V. Coastal Plain formations.

Coastal Plain region is more than 100 miles wide and includes approximately 9,500 square miles of territory or about one-fourth the area of the State.

Because of marked geologic differences in the two provinces, most of the largest streams and many of the smaller ones, are characterized by falls or rapids where they cross the western margin of the Coastal Plain, and they always show a marked decrease in the velocity of their currents from this point eastward. For this reason, the name "fall-line" has been given to this boundary, the position of which is marked on the accompanying map, figure 1. The position of the "fall-line," near the head of navigation and the source of water-power, has been an important factor in determining the location of many of the towns and cities of the Atlantic Coast. In Virginia, the "fall-line" passes near to or through the following important cities or towns: Washington, D. C., Fredericksburg, Richmond, Petersburg, and Emporia. As indicated on the map, figure 1, the line drawn through these places approximately separates the Coastal Plain from the Piedmont Plateau. Outliers of the Coastal Plain are frequent along the eastern margin of the Piedmont province, and the older crystalline rocks of the Piedmont can be followed along the valleys of the larger streams for some distance into the Coastal Plain sediments, where the mantle of the latter has been cut through.

The Coastal Plain region, characterized by broad, level-topped stretches of country of low relief, gradually declines in slope from the Piedmont Plateau border to the shore line. In the vicinity of Washington elevations of over 400 feet are reached. Southward the western margin gradually declines in altitude to less than 200 feet in the southern portion of the State. Because of these differences in elevation the topography is more diversified in the northern than in the southern portion of the State. Passing from these elevations along the "fall-line" or western margin, the Coastal Plain declines in slope eastward to sea-level elevations along the Coastal border. Probably the average elevation of the Virginia Coastal Plain is but slightly more than 100 feet above tide.

According to Professors Clark and Miller, the formations comprising the Virginia Coastal Plain are given in the following table:

Formations of Virginia Coastal Plain.

CENZOIC:		
Quaternary.		
Recent.		
Pleistocene	Talbot, Wicomico, Sunderland,	Columbia group.
Tertiary.		
Pliocene............ ...	Lafayette, Norfolk.	
Miocene................	Yorktown, St. Mary's, Choptank, Calvert,	Chesapeake group.
Eocene........	Nanjemoy, Aquia,	Pamunkey group.
MESOZOIC:		
Cretaceous.		
Lower Cretaceous........ ..	Patapsco,	Potomac group.
Jurassic?		
Upper Jurassic?...	Arundel, Patuxent,	

The deposits of the Coastal Plain consist chiefly of unconsolidated beds of sand, gravel, clay, and marl, which may be locally indurated by a cement either of iron oxide or carbonate of lime. These indurated

Fig. 1.—View from Richmond-Manchester bridge looking down the James river in flood. Granite boulders and reefs not entirely covered by the high water.

Fig. 2.—View from Richmond-Manchester bridge looking down the James river during low water stage. Rocky (granite) character of river bed is conspicuously shown.

HIGH AND LOW WATER STAGES IN JAMES RIVER AT RICHMOND.

ledges in the vicinity of Acquia creek and, in places, southward along the western margin representing the oldest formation of the Coastal Plain series, have afforded sandstone suitable for building purposes. The beds strike in general from north to south, although some variation occurs, with a low but variable easterly dip. Although not actually horizontal, except locally, the beds generally appear so in any given section, because of this relatively low dip. Figure 2 is a diagrammatic section, which illustrates the relations of the Coastal Plain beds to each other. In age the Coastal Plain beds range from Lower Cretaceous to Quaternary.

The broad and deep estuary of the Chesapeake Bay, which crosses the Coastal Plain region, finds an outlet seaward between the Capes Charles and Henry. This sheet of water affords unparalleled transportation facilities, and its principal tributaries, the Potomac, Rappahannock, York, and James rivers, give access to vessels as far westward as the Piedmont border—the "fall-line."

THE PIEDMONT PLATEAU PROVINCE.

The Piedmont Plateau province lies between the Coastal Plain and the Appalachian Mountains. It extends from the eastern slope of the Blue Ridge eastward to the western margin of the Coastal Plain, and it widens southward (map, figure 1). Its width increases from about 40 miles in the northern portion along the Potomac river to nearly 175 miles along the Virginia-Carolina boundary. The nearly horizontal and unconsolidated sediments of the Coastal Plain lie across the bevelled edges of the highly crumpled crystalline rocks of the Piedmont, presenting such marked stratigraphic and lithologic contrast that the geologic boundary between the two provinces is sharply defined (figure 2). The transition on the west is less sudden and well-marked.

The Piedmont province contains a greater variety of mineral resources than that of either of the other two provinces. In general, the surface of the plateau has a gentle southeastward slope from an average altitude of 1,000 feet along the western margin to from 200 to 400 feet on the east, where the plateau rocks pass beneath the Coastal Plain sediments. The western border of the region is an irregular one, marking the change to the steeper slopes of the Blue Ridge and its outliers. The topography of the plateau is much older and more varied, and its geology more complex than of the Coastal Plain. Its topography is of a more or less smooth, broadly rolling or undulating upland, of moderate elevation into which the streams have rather deeply sunk their channels. Scattering hills and ridges—unreduced residuals—rise in some cases several hundred feet above the general level of the upland surface of the Plateau. Below the upland surface, deep and narrow gorges have been carved by the streams.

The drainage of the region is to the southeast into the Atlantic waters, and the major streams which traverse the Plateau are the Potomac, Rappahannock, James, and Roanoke rivers. All of these have their sources without the area, and, with the exception of the Rappahannock, they take their rise west of the Blue Ridge. The smaller streams rise within the area and lie between the major rivers, draining either into the latter or directly into the Chesapeake Bay. These streams usually flow in more or less deep rocky gorges, and have rapid currents as far as the eastern border of the Piedmont Plateau, where they debouch on to the Coastal Plain.

Lack of systematic study of the Virginia Piedmont region forbids more than a general description of its geology at this time. The rocks composing the region are the oldest in the State and, excepting the areas of Newark (Juro-Trias) rocks, they are all crystalline. They comprise both sedimentary and igneous masses so greatly altered from metamorphism, chiefly through pressure and recrystallization, that many of them bear but slight resemblance to the original masses. This metamorphism has induced secondary foliation in the rocks by arranging the mineral constituents along somewhat parallel lines or planes, the foliation of which, in many cases, bears little or no relation to the original bedding planes in many of the sedimentary masses.

The Plateau region is made up of a complex of schists, gneisses and granites, with, in places, areas of slate, quartzite, and limestone. This complex is further intersected by intrusions of basic eruptive rocks belonging, so far as they have been studied, to the [illegible] and gabbroic types. To the east of [illegible] in the extreme southern portion of the region is an area of altered volcanic masses—[illegible]—which extends southwestward into North Carolina.

Over the eastern [illegible] portions of the Piedmont are areas of Newark [illegible] shale, sandstone, and conglomerate, and, in some [illegible]. These areas of Newark rocks, of which [illegible] in the Virginia Piedmont, are shown [illegible] on the accompanying color geologic map. [illegible] areas of these rocks are quite extensive.

The rocks of the Plateau region [illegible] general northeast [illegible] which varies within [illegible] and [illegible] and, in cases, steeper, sometimes almost or quite vertical. In general they strike approximately northeast and southwest. Variations, however, in both dip and strike are frequent over the region.

The age relations of the rocks of the region are largely unknown. Excepting the areas of Newark rocks, the crystalline rocks were regarded as Archean by the older geologists, and they were so mapped by Professor Rogers. More recent studies, however, based in part on fossil evidence, reveal the fact that a part of them are as late as Ordovician in age.

THE APPALACHIAN MOUNTAIN PROVINCE.

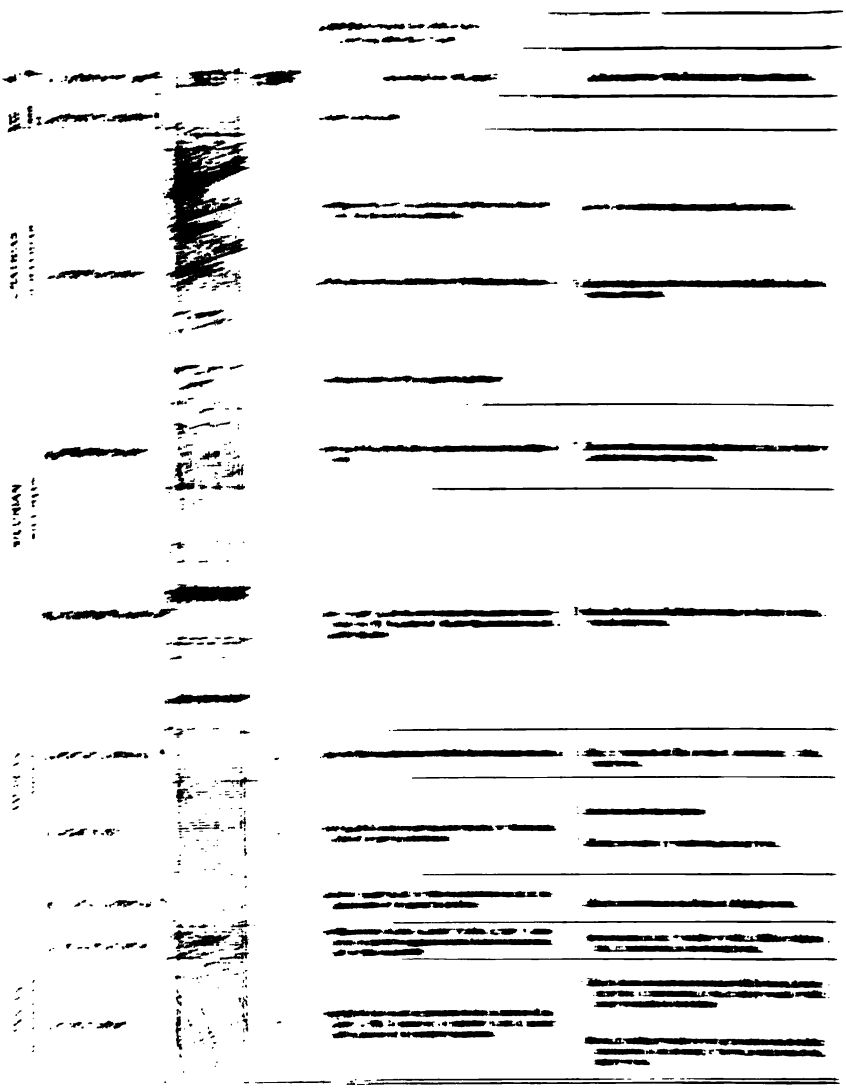
The Appalachian Mountain province embraces the western portion of the State. Its eastern boundary, the southeastern slope of the Blue Ridge, forms in places not a gradual transition but an abrupt change from plateau to mountain conditions, and is reasonably well-defined. In other places the change is not so abrupt and the boundary is less well-defined. The western limits of the province are artificially drawn in the western boundary of the State. This province, like the Piedmont Plateau and Coastal Plain, extends northeast and southwest far beyond the limits of Virginia.

The topography of the Appalachian province is varied and picturesque, and on the basis of topographic types represented, three subdivisions of the province are recognized which, named from east to west, are: (1) The Blue Ridge; (2) the Great Valley; and (3) the Alleghany Ridges. The limits of these subdivisions are indicated on map, figure 1.

The Blue Ridge, which forms the eastern boundary of the Appalachian province, maintains an uneven and knobby crest entirely across the State, in a northeast-southwest direction, and has an average elevation of not less than 2,000 feet above tide-level. At Harper's Ferry the altitude of the Blue Ridge above tide is less than 1,000 feet, but southward through Virginia the ridge becomes higher and broader, and opposite Luray, Stony Man, and Hawks Bill, 4,031 and 4,066 feet respectively, are the highest summits of the Blue Ridge north of North Carolina. Plate LXV, figure 1, and plate LXXIV, figure 1, indicate the uneven, knobby crestline of the Blue Ridge at different points in Virginia.

The Blue Ridge is composed largely of pre-Cambrian rocks, represented in part, at least, by various igneous types, but sandstones and shales of Cambrian age are exposed along the western slope. It is a natural dividing line between the Paleozoic sediments comprising sandstones, limestones, and shales on the west, and the pre-Paleozoic and other rocks on the east. Figure 3, adopted from the Harper's Ferry folio of the

[illegible]



[illegible] generalized section of rocks covered by the Harpers Ferry folio, U. S. [illegible]

[illegible] Geological Survey, is a generalized section of a part of the [illegible] province in northern Virginia and southern Maryland, including [illegible] of the Blue Ridge. Figure 3, plate III, is a structure section [illegible] part of the Blue Ridge and the Valley region on the west, in [illegible] Virginia.

The James and Roanoke rivers flow eastward through the Blue Ridge from the Alleghany Ridges, while the New river heads east of the Blue Ridge in North Carolina and flows northwest in Virginia across the Blue Ridge, the Alleghany Ridges, and the Alleghany Front, into the Ohio.

The two most westerly sub-provinces, the Valley and the Alleghany Ridges, bounded by the two principal ranges, the Blue Ridge and the

Period.	Formation Name.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
CARB.	Pocono sandstone.		700+	Shale. Coarse sandstone of light color, with sandy shale and thin coal beds.	Sharp ridges, with thin, sandy, and rocky soils.
DEVONIAN	Hampshire formation.		1000-1400	Thinly bedded, gray and reddish sandstone, with more-massive beds of fine-grained sandstone, all interbedded with thin layers of shale.	High mountains, with thin, sandy soils.
	Jennings formation.		2800-3400	Shales, varying from olive color to buff, interstratified with massive, mainly fine-grained sandstone.	Mountain slopes and moderately high ridges, with thin, sandy soils.
	Romney shale.		600-1000	Dark shale, black below	Wide valleys and low, rounded ridges. Thin soils, usually clayey. The valleys usually contain alluvial deposits of varying width.
	Monterey sandstone.		0-200	Sandstone, in part calcareous	Knobs and ridges along the base of higher hills.
SILURIAN	Lewistown limestone.		300-500	Cherty limestone Pure limestone.	Knobby ridges and elevated valleys. Thin but rich soils.
	Rockwood formation.		150-200	Gray quartzite Sandy shale.	Mountain slopes, overplaced by sandy soils.
	Massanutten sandstone.		500-600	Reddish sandstone. Gray quartzite Red and gray sandstones.	High rocky ridges, with thin, sandy soils.
	Martinsburg shale.		800-1400	Gray shale, with sandy beds above and calcareous beds below.	Low, rounded hills in the Appalachian Valley, and the eastern slope of Little North Mountain. Thin, sandy clay-soils.
	Shenandoah limestone.		1300+	Massive fossiliferous limestone Cherty limestone. Dolomitic (magnesian) limestone, varying from light gray to dark gray.	Moderately steep ridges in the Appalachian Valley. The undulating surface of the Appalachian Valley, with clay-soils of variable depth.

Fig. 4.—Generalized section of area covered by the Staunton folio, U. S. Geol. Survey. (After N. H. Darton.)

Alleghany Front, on the southeast and northwest, respectively, are here treated together under the Greater Valley region. These two bounding nearly parallel ranges are separated in Virginia by a distance varying from 75 to more than 100 miles. Considered broadly, the Greater Valley region is composed of narrow valleys and linear ridges arranged in more or less complex relations. Some of the ridges, rising to considerable elevations, are narrow, of even crestlines, and of great length. Others are less persistent and have less regular crests, while others still, which make up the minor irregularities of the surface, such as, the hills, knobs, and lower ridges, are of lower elevations.

At Harper's Ferry on the Potomac the Valley proper is less than 300 feet above tide, but it gradually rises southwestward until it reaches the height of 1,700 feet in southwest Virginia. It will average from 20 to 30 miles wide and is higher along the western side next to the Alleghany Ridges than on the eastern side. The Alleghany Ridges vary in average elevation from 1,000 to 3,000 feet above tide. Many of the ridges exceed 3,000 feet in height, and Elliots Knob, 20 miles west of Staunton, has an elevation of 4,473 feet.

Ordinarily the ridges are unsymmetrical, one slope being much steeper than the other. In some cases the two slopes are more nearly equal and, in cross-section, the ridge approaches that of symmetry.

The Greater Valley region is composed throughout of Paleozoic sediments, which range in age from Cambrian to Carboniferous. The principal rock-types include limestone, shale, and sandstone. Four generalized sections, adopted from the Geologic folios of the U. S. Geological Survey, in the northern, central, and southwestern portions of the Greater Valley region, are shown in figures 3, 4, 5, and 6. These include formation name, columnar section, thickness in feet, character of rocks, and character of topography and soil. The principal formations of the Greater Valley region or western Virginia, especially those of the Cambrian and Ordovician systems, are described in some detail by Dr. Bassler under Cement and Cement Materials on pages 86-167, to which the reader is referred. The distribution of the formations over the Greater Valley region are shown on the accompanying color geologic map, and in part on the section maps, figures 16, 17, 20, 25, and 28, and on plate XVII.

The simple horizontal arrangement of alternating hard and soft beds of the Greater Valley region which prevailed at the time of deposition, have been greatly complicated by folding and faulting. The present attitude of the beds indicates that in general they have been arched into

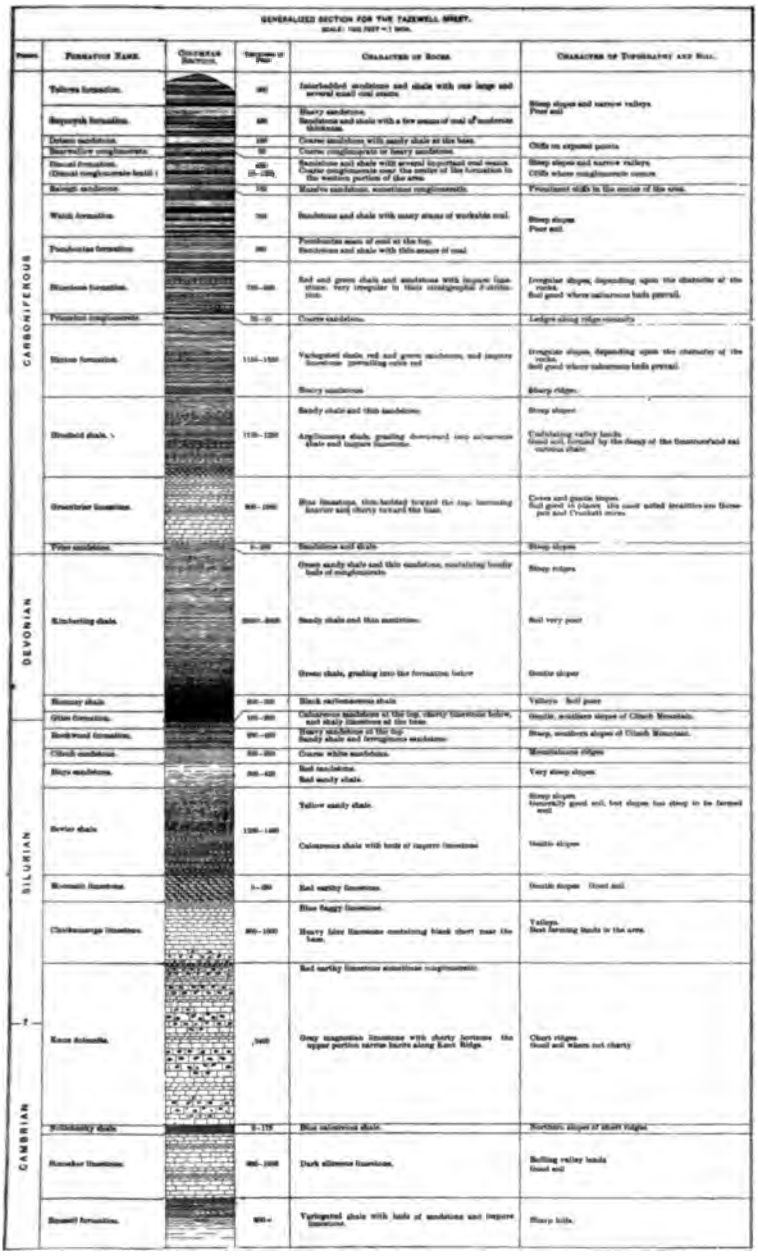


Fig. 5.—Generalized section of the area covered by the Tazewell folio, U. S. Geol. Survey. (After M. R. Campbell.)

great folds and troughs whose axes extend, as a rule, in a northeast-southwest direction. Sufficient time has elapsed since the folding and faulting occurred for the rocks to be greatly eroded. The softer or less resistant rocks like shale and limestone were lowered more rapidly by erosion than the harder and more resistant rocks like sandstone, hence the former rocks are in general valley-making while the latter are ridge-forming. The formations are now exposed in long, narrow belts, the widths of which depend on the thickness of the formation and the angle of dip. As a result of the bending into arches and troughs of the beds and of subsequent erosion, the edges of the formations have developed as linear ridges and valleys, developing the well known Appalachian type of topography. This dependence of topography on structure and lithologic character of the rocks is well illustrated in the present surface configuration of the Greater Valley region.

As indicated in the recent study of the Greater Valley region of Virginia, certain differences in the general geology of the region are shown, which have resulted in Bassler's dividing the entire region in Virginia west of the Blue Ridge into three areas, designated as the northwestern, central-western, and southwestern areas. In each of these the geologic sequence differs to some extent and the structure is progressively more complex southwestward. The differences in these three areas are discussed by Dr. Bassler on pages [illegible].

Structurally the southwestern Virginia area is more complex than either of the other two by reason of great folds and overthrust faults. Study of the region shows that it is traversed in a northeast-southwest direction by not less than seven major faults and by a number of minor ones. The major faults are named in order from east to west: (1) The Holston and Iron Mountain fault; (2) the Walker Mountain fault; (3) the Saltville fault; (4) the Copper Creek fault; (5) the Hunter Valley fault; (6) the Wallen Valley fault; and (7) the Poor Valley faults. Structure section, figure [illegible], page [illegible], shows the relations of these faults to each other and to the rocks.

The structural relations of the rocks of the Greater Valley region in Virginia are shown in structure sections on pages [illegible], and [illegible]. As discussed elsewhere in this volume, the mineral resources occurring in the region west of the Blue Ridge bear an intimate relation to the structure of the rocks.

EFFECTS OF WEATHERING AND EROSION

Through the various combinations of external agents grouped under the comprehensive term weathering, rocks and surfaces when exposed for

GENERALIZED SECTION FOR THE PORTION OF THE QUADRANGLE SOUTH OF CLINCH MOUNTAIN.
SCALE: 1000 FEET = 1 INCH.

Period.	Formation Name.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soil.
CARBONIFEROUS	Pennington shale		900+	Green sandy shale and thin bedded sandstone.	Forms the rugged region between Walker Mountain and the North Fork of Holston River. Soil very thin and poor.
	Newman limestone		2000–2600	Blue calcareous shale, grading downward into impure limestone. Heavy bedded blue limestone.	Rough, rolling lands with fairly productive soil.
CARBONIFEROUS / DEVONIAN	Grainger formation		1400–1900	Dark argillaceous shale with interbedded calcareous shale and impure limestone. Sandy shale. Sandstone containing locally beds of quartz conglomerate. Green shale.	The valley of the North Fork of Holston River. Sharp, serrate ridge separating the Holston River Valley from the Poor Valley at the foot of Clinch Mountain.
DEVONIAN	Chattanooga shale.		300–800	Black carbonaceous shale which merges with the green shale above.	The Poor Valley. Soil unproductive.
SILURIAN	Hancock limestone		30–175	Cherty limestone.	The base of the southern slope of Clinch Mountain.
	Rockwood formation		200–400	Sandy shale and ferruginous sandstone.	Southern slope of Clinch Mountain.
	Clinch sandstone.		220–450	Coarse grained white sandstone.	Sharp mountainous ridges.
	Bays sandstone.		250–450	Red sandstone and sandy shale.	Steep slopes.
	Sevier shale.		200+	Sandy shale.	Gentle slopes.
	Tellico sandstone.		800+	Sandstone and sandy shale.	Caps the highest ridges in the southeastern corner of the quadrangle.
	Athens shale.		1000–1200	Sandy shale and thin sandstone with occasional beds of impure limestone and limestone conglomerate. Dark argillaceous shale at the base.	Groups of barren hills in the vicinity of Bristol. The soil is extremely poor and the hills are generally uncultivated.
SILURIAN / CAMBRIAN	Knox dolomite		2800–3500	Blue and gray limestone. Very cherty along Walker Mountain, but farther toward the southeast the chert disappears and the formation merges with and becomes indistinguishable from the Honaker limestone beneath, and the whole is called the Shenandoah limestone.	Forms low ridges where it is cherty, but under other conditions it produces a gently rolling country well adapted to agricultural pursuits. Soil generally fertile, unless covered with chert.
CAMBRIAN	Nolichucky shale		0–300	Blue calcareous and sandy shale. Toward the east this changes to limestone.	Gently rolling country and the northern slope of Walker Mountain.
	Honaker limestone		1200–1400	Blue and gray limestone. Toward the east the formation merges with the Knox dolomite, and the whole is known as the Shenandoah limestone.	Gently rolling country in the southeastern quarter of the quadrangle and Rich Valley along the northern side of Walker Mountain.
	Russell formation		400+	Red and green shales and thin-bedded sandstones.	Sharp hills along the north side of Rich Valley.
	Hampton shale		800+	Sandy shale.	The northern slope of Holston Mountain, which passes through the southeast corner of the quadrangle.
	Unicoi sandstone		1000	Quartzite or fine, bluish, feldspathic conglomerate.	Forms a subordinate ridge on the northern face of Holston Mountain.

Fig. 6.—Generalized section for the portion of the area south of Clinch Mountain covered by the Bristol folio, U. S. Geol. Survey. (After M. R. Campbell).

a sufficient length of time are attacked and gradually lowered in elevation, not equally but unequally, some areas more rapidly than others and some parts of the same area more rapidly than other parts. All conditions being equal, that area which has been continuously above water for the longest time has suffered the greatest effects from the atmospheric agents.

Accordingly an examination of the surface rocks over all parts of Virginia shows some effects from atmospheric action. Of the three major provinces of the State described above, the Coastal Plain, on account of its very recent geologic history, has suffered the least. The remaining two provinces, on the other hand, Piedmont Plateau and Appalachian mountains, bear striking evidence over all their parts of profound decay and erosion, which have resulted in the removal of vast quantities of rock material. Just how much of their surface has been lowered or what vertical thickness of material has been removed from these land areas and carried seaward, would probably be very difficult to say, but that it has been large cannot be doubted. Because of its greater geologic age and the vast length of time it has been a land area, the Piedmont Plateau has probably suffered the removal of the greatest thickness of material, which contributed in part to the building of the Appalachian province on the northwest, and to the Coastal Plain on the southeast.

Through this process of degeneration—weathering—which has been going on for many thousands of years, a mantle of varying thickness of decayed rock material overlies the still fresh or sound rock, except where the erosive action has not been too excessive and the slopes too steep for its accumulation. This decayed product is loose and porous or incoherent, consisting usually of clay, sand, and gravel, and on the immediate surface forms soil. On depth it passes by imperceptible gradation into the hard and fresh unaltered rock. The thickness of this mantle of rock decay in Virginia varies from a few inches to 50, 60, and, in extreme cases, 100 feet. Over many parts of the State, so profound is this decay, that exposures of the hard rock are rare except along the stream courses where the mantle has been cut through by erosion.

This process of rock decay is of very great economic importance. Apart from the consideration of the great variety of soils resulting therefrom, which forms perhaps Virginia's most valuable asset, workable ore-deposits have been formed by it from sparsely disseminated and non-workable mineral matter in the original rocks. This is best illustrated in the manganese deposits, in a part of the iron and zinc deposits, and in other ore-deposits described in the following pages of this volume.

DIVERSITY OF RESOURCES.

There is probably no state in the Union of the same area as Virginia, that can show a greater diversity in geologic resources. This is confirmed by the actual exploitation thus far made; and it might be naturally inferred from the position which the State occupies with reference to disturbed and undisturbed areas as described above. As indicated above and from an examination of the geologic map, the State stretches from the Atlantic Coast westward nearly entirely across the Appalachian Mountain System. Within this area are found rocks ranging in geologic age from pre-Cambrian to Recent, and representing all the principal divisions of geologic time. Equally as great a variety of rock-types, both sedimentary and igneous, of structure which characterizes both profoundly disturbed and undisturbed rock masses, and of topography, is shown.

VALUE OF RESOURCES.

The total yearly value of production in mineral resources of Virginia for 1902 to 1906, inclusive, has been estimated as follows:

Year	Value
1902	$10,500,000
1903	12,633,000
1904	12,606,000
1905	21,752,000
1906	30,000,000

The above figures have been compiled from the most authoritative sources, but they must be regarded only as approximate. They probably represent under- rather than over-estimates of the true total value of Virginia's mineral production. The figures of production for 1906 are based on those of 1905, and when the exact value of the mineral production for 1906 becomes available it may show some variation in either direction from the estimated value given above. A very striking feature in the above compilation is the enormous increase in the value of mineral production for the years 1905 and 1906 over the preceding years. In 1905 the production nearly doubled that of 1904, and for 1906 a marked increase is shown over that for 1905.

PART I.

BUILDING AND ORNAMENTAL STONES, CEMENT AND CEMENT MATERIALS, AND CLAYS.

BUILDING AND ORNAMENTAL STONES.

GENERAL STATEMENT.

[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Total.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	379,610
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	3,522	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

DESCRIPTION OF GRANITE AREAS.

The Petersburg Area.

The Petersburg granite area includes the extreme northeast part of Dinwiddie county and the contiguous southeast corner

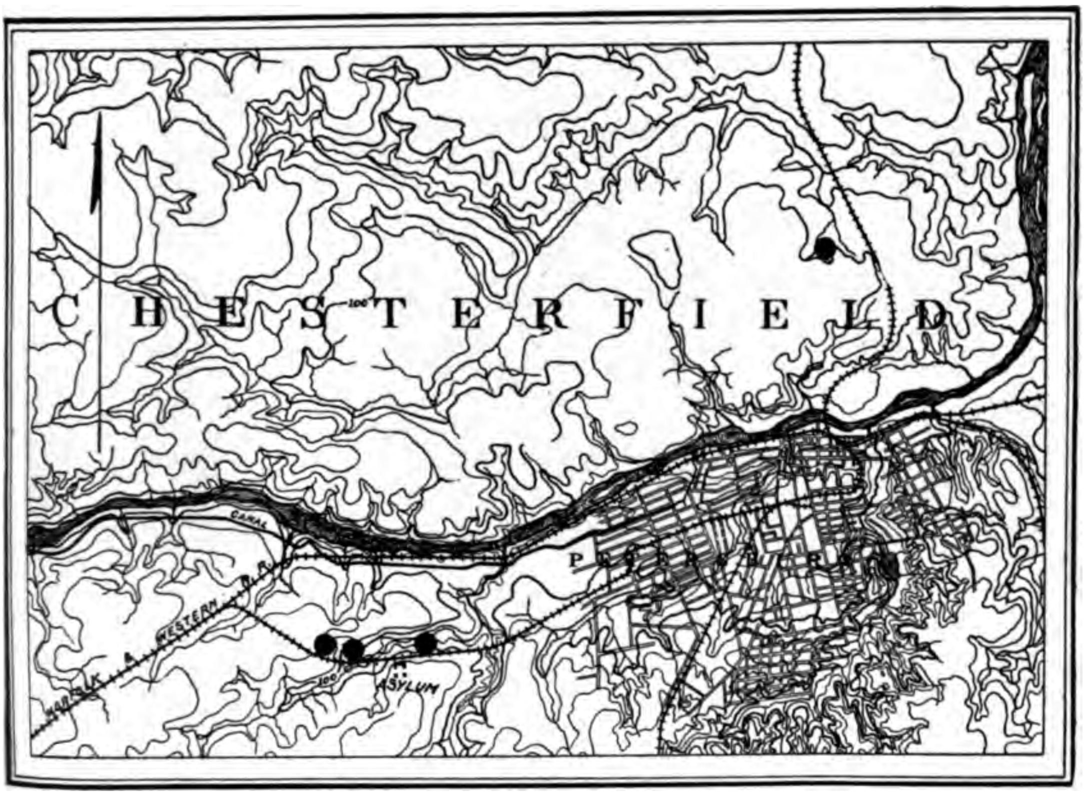


Fig. 7.—Map showing location of granite quarries in the Petersburg area. Quarries indicated by heavy dots. Based on the Bermuda Hundred and Petersburg topographic sheets, U. S. Geol. Survey. Scale, ⅝ inch equals 1 mile, approximately. Contour interval, 20 feet.

of Chesterfield. Granite quarries are opened and operated about 2 miles west of the city of Petersburg and at a similar distance north of the city. The principal quarries, shown on the map, figure 7, include the Lassiter and the Petersburg Granite Company's on the west side of Petersburg, and the Cook quarry on the north side of the city.

The rock from these quarries is a closely similar biotite granite, of

[illegible] along the eastern border of the Piedmont region. They include (1) the Petersburg area; (2) the Richmond area; and (3) the Fredericksburg area. The principal counties composing these areas are Dinwiddie, Chesterfield, Henrico, and Spotsylvania. In addition to these there are several minor areas, chief among which are those of Fairfax, Prince Edward, Fluvanna, and Amherst counties. These are [illegible] minor areas chiefly because of the lack of development in them. Granite occurs in other Piedmont counties but it has not yet been quarried.

MINERAL COMPOSITION.

In the most important areas, the Virginia granites are mixtures of feldspar, quartz, and biotite, with usually more or less of the white mica, muscovite. Hornblende is an important constituent in a part of the granites in the Falls Church area, near Washington, in Fairfax county. Epidote is a principal constituent in the variety of granite known as unakite, which is found near Luray in Page and Madison counties, and near [illegible] in Grayson county. In addition to the principal feldspar, [illegible], microcline, and plagioclase occur in widely variable amounts.

Besides the minerals mentioned, there occur apatite, zircon, sphene, magnetite, and other occasional ones.

KINDS OF GRANITE.

Based on [illegible] and structure three types of granite occur in Virginia: (1) [illegible] granites; (2) porphyritic granites; and (3) [illegible] granite-gneisses. Based on mineral composition [illegible] types of Virginia granite: (1) Biotite granite, under which a majority of the granites of the State may be grouped; (2) [illegible] granite; (3) hornblende-biotite granite; and (4) epidote granite.

The granites of the vicinity of Richmond, Petersburg, and Fredericksburg [illegible] economically, in the State, and they best illustrate the [illegible] granite. I have elsewhere discussed these [illegible] (1) The Richmond-Fredericksburg light [illegible] Fredericksburg dark blue-gray; and (3) the [illegible] are added the Falls Church dark [illegible] and the yellowish green and pink epidote [illegible] found but not quarried in other parts [illegible] one or the other of the above types.

DESCRIPTION OF GRANITE AREAS.

The Petersburg Area.

The Petersburg granite area includes the extreme northeast part of Dinwiddie county and the contiguous southeast corner

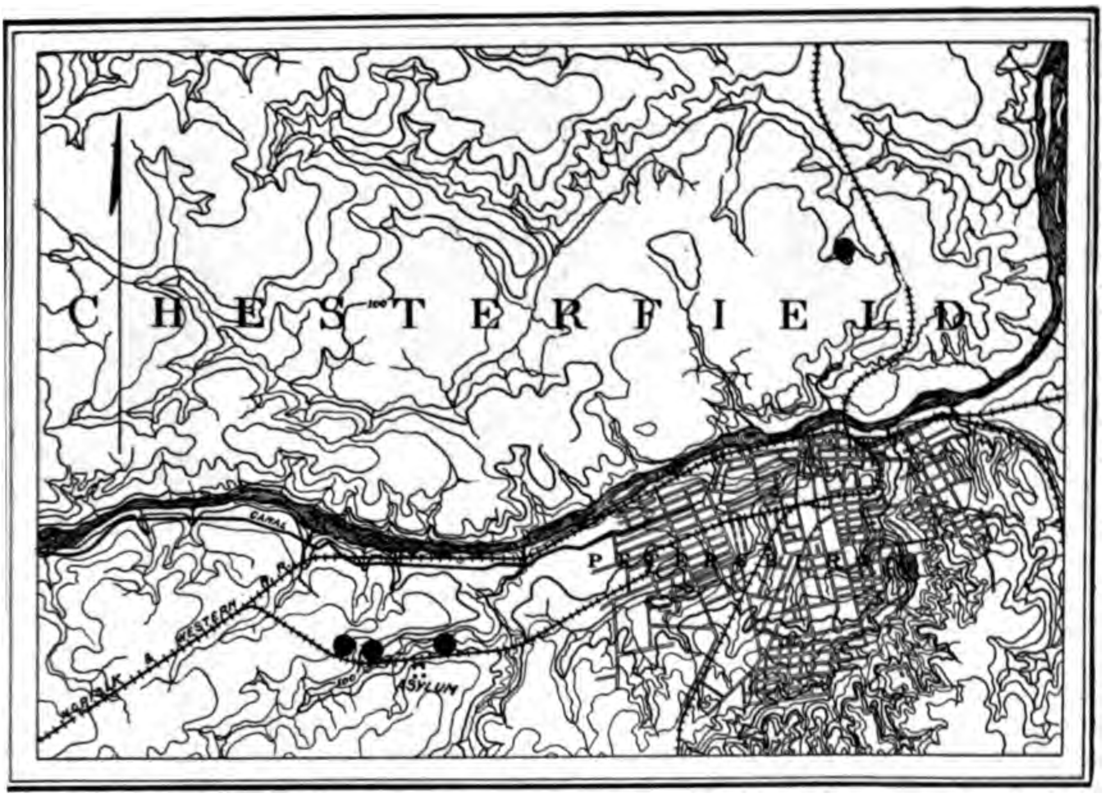


Fig. 7.—Map showing location of granite quarries in the Petersburg area. Quarries indicated by heavy dots. Based on the Bermuda Hundred and Petersburg topographic sheets, U. S. Geol. Survey. Scale, ⅝ inch equals 1 mile, approximately. Contour interval, 20 feet.

of Chesterfield. Granite quarries are opened and operated about 2 miles west of the city of Petersburg and at a similar distance north of the city. The principal quarries, shown on the map, figure 7, include the Lassiter and the Petersburg Granite Company's on the west side of Petersburg, and the Cook quarry on the north side of the city.

The rock from these quarries is a closely similar biotite granite, of

north-south direction, along the eastern border of the Piedmont region. They include (1) the Petersburg area; (2) the Richmond area; and (3) the Fredericksburg area. The principal counties composing these areas are Dinwiddie, Chesterfield, Henrico, and Spotsylvania. In addition to these there are several minor areas, chief among which are those of Fairfax, Prince Edward, Fluvanna, and Amherst counties. These are designated minor areas chiefly because of the lack of development in them. Granite occurs in other Piedmont counties but it has not yet been quarried.

MINERAL COMPOSITION.

In the most important areas, the Virginia granites are mixtures of feldspar, quartz, and biotite, with usually more or less of the white mica, muscovite. Hornblende is an important constituent in a part of the granites in the Falls Church area, near Washington, in Fairfax county. Epidote is a principal constituent in the variety of granite known as unakite, which is found near Luray in Page and Madison counties, and near Troutdale in Grayson county. In addition to the principal feldspar, orthoclase, microcline and plagioclase occur in widely variable amounts.

Besides the minerals mentioned, there occur apatite, zircon, sphene, magnetite, and other occasional ones.

KINDS OF GRANITE.

Based on texture and structure three types of granite occur in Virginia: (1) Massive, even-granular granites; (2) porphyritic granites; and (3) schistose or foliated granites—granite-gneisses. Based on mineral composition, we have the following types of Virginia granite: (1) Biotite granite, under which a majority of the granites of the State may be grouped; (2) muscovite granite; (3) hornblende-biotite granite; and (4) epidote granite.

The granites in the vicinity of Richmond, Petersburg, and Fredericksburg, are the most important, economically, in the State, and they best illustrate the types of mica granite. I have elsewhere discussed these under the three following types: (1) The Richmond-Fredericksburg light gray; (2) the Richmond-Fredericksburg dark blue-gray; and (3) the Fredericksburg light gray. To these are added the Falls Church dark gray hornblende-biotite type, and the yellowish green and pink epidote type, known as unakite. Granites found but not quarried in other parts of the crystalline area belong to one or the other of the above types.

DESCRIPTION OF GRANITE AREAS.

The Petersburg Area.

The Petersburg granite area includes the extreme northeast part of Dinwiddie county and the contiguous southeast corner

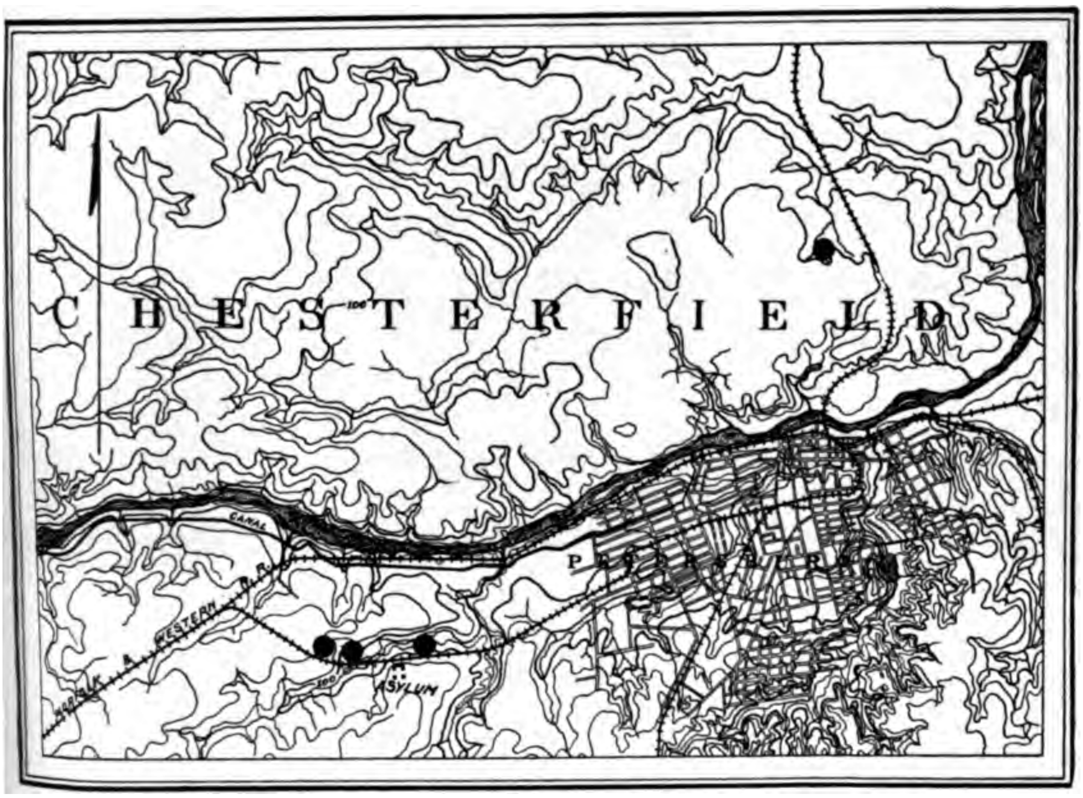


Fig. 7.—Map showing location of granite quarries in the Petersburg area. Quarries indicated by heavy dots. Based on the Bermuda Hundred and Petersburg topographic sheets, U. S. Geol. Survey. Scale, ⅝ inch equals 1 mile, approximately. Contour interval, 20 feet.

of Chesterfield. Granite quarries are opened and operated about 2 miles west of the city of Petersburg and at a similar distance north of the city. The principal quarries, shown on the map, figure 7, include the Lassiter and the Petersburg Granite Company's on the west side of Petersburg, and the Cook quarry on the north side of the city.

The rock from these quarries is a closely similar biotite granite, of

medium texture, and gray color. The granite from the Cook quarry contains less mica (biotite) than that from the west side quarries, and is accordingly lighter in color. The stone from these quarries is of excellent quality and is used for all purposes made of granite. It is of homogeneous texture, good permanent color, and contains no harmful mineral. The joint-planes are widely spaced, readily admitting of the quarrying of dimension stone.

Cook quarry.—This quarry is located about 2 miles north of Petersburg, immediately on the west side of the Seaboard Air Line Railway, and within 300 feet of the crossing of this road by the Belt Line. Some stone was quarried as early as 1887, but systematic quarrying was not begun until 1887. Plate II, figure 1, is a view of this quarry.

The stone is admirably adapted to the uses made of it, which are for building purposes; in street work of all forms, including blocks and curbing and crushed stone; and in wall, bridge, and culvert work in the rough and dressed state. A crusher is operated at the quarry for working up the quarry-waste, mainly for concrete purposes. The largest size waste is made into paving blocks, the second into rubble paving, and the balance is crushed for concrete work. The granite from this quarry is shipped to the principal points, including New York and as far west as Cincinnati. Practically no shipments are made south of Virginia.

The Lassiter quarries.—These quarries are located about 1.5 miles west of Petersburg, immediately on the car line of the Virginia Passenger and Power Company, and within a quarter of a mile of the Seaboard Air Line Railway. Three or four openings are made close together which were first worked more than 50 years ago. During the summer of 1906, 2 of the openings were being operated by separate parties. The largest one of these was operated by C. M. Walsh of Petersburg, exclusively for monuments. Blocks 20 feet and more in length are constantly being quarried from the Walsh opening. The granite is of medium gray color, the feldspars of which have a decided pinkish cast. It works well under the hammer and is susceptible of a high polish. It is extensively used in the monument and building trade, principally in the former. The quarry waste is broken up and used for rubble. As monumental stock this granite is marketed over a wide territory, shipments being made as far west as Denver, Colorado.

The Petersburg Granite Company's quarries.—The quarries of this company include two large openings several hundred yards apart, located immediately along the car line of the Petersburg Passenger and Power

Fig. 1.—Cook's granite quarry, north of Petersburg.

Fig. 2.—Granite quarry near Richmond, showing massive ledges of superior monumental granite.

GRANITE QUARRIES IN PETERSBURG AND RICHMOND, VIRGINIA, AREAS.

Company, 2 miles west of Petersburg and a half mile west of the Lassiter quarries. The 2 openings are designated as Quarry No. 1, known as the Asylum quarry, and Quarry No. 2, known as the Dibble quarry. The openings are large and are made in flat surface exposures of the granite. About 5 feet of stripping, comprising sand and gravel of the Coastal Plain and decayed granite, must be removed before the quarrying of fresh granite can be carried on.

During the summer of 1906, Quarry No. 1 was being operated under lease by Baltimore parties, and the stone was being used almost exclusively for building purposes in Petersburg. Some of it is used for coping in cemetery work. Quarry No. 2 has not been operated for four or more years. A large quantity of stone has been quarried and used for the various purposes made of granite. The joint-planes are widely spaced and dimension stone of almost any size can be readily obtained.

The Petersburg Passenger and Power Company's quarry.—During the summer of 1905, the Petersburg Passenger and Power Company was operating a quarry at the dam across the Appomattox river, 7 miles west of Petersburg.

The Richmond Area.

The Richmond granite area, covering parts of Chesterfield and Henrico counties, in the immediate vicinity of the cities of Richmond and Manchester, is the largest producing area in the State. The quarrying of granite in this area dates back to the early part of the last century, and a large number of quarries have been worked from time to time. These are opened largely in the granite bluffs along the James river, extending in a general westerly direction from the city of Richmond for a distance of more than 5 miles. To a smaller extent quarries have been opened to the north and south of Richmond in the low granite ledges exposed along smaller streams and in the flat surface exposures on the inter-stream areas. Many of the quarries are very extensive openings, and have been worked to a depth of nearly 200 feet, from which an enormous quantity of excellent stone has been obtained. In some of the larger quarries, the depth reached in quarrying is below that of the river level. The quarries opened are well located with reference to transportation facilities, and admit of easy working.

The location of this granite area at the head of navigation in the James river affords cheap transportation of the stone by water north and south.

The quarried granites are feldspar-quartz-biotite rocks, which vary from fine to medium granular in texture, and from dark to light gray in color. Near Midlothian, 13 miles west of Richmond, and extending for a north-south distance of about 30 miles, is a beautiful coarse, porphyritic, biotite granite, which has not yet been quarried to any extent.

Jointing is usually well developed in the granites but the planes are spaced sufficiently far apart to admit of almost any size stone being quarried. Pegmatite veins or dikes, coarse crystallizations of quartz and feldspar, are not sufficiently numerous to cause waste in quarrying.

Two grades of the granite occur and are quarried, one a fine-grained dark blue-gray rock extensively used as monument stock, the other a coarse

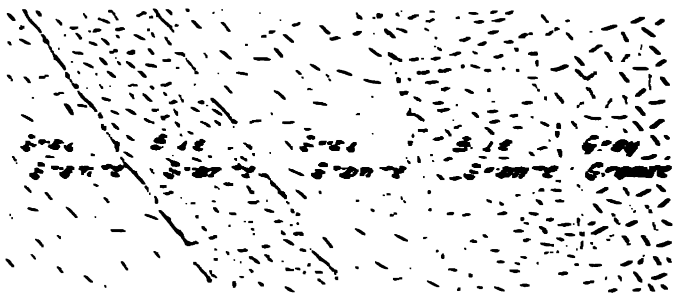


Fig. 5.—Relations of the blue to the gray granite as shown at the Netherwood quarry west of Richmond. Scale 1 inch equals 150 feet.

and lighter gray rock [illegible] suited for building purposes. Both are homogeneous even-grained granites possessing good working qualities. The fine-grained blue-gray granite is susceptible of high and permanent polish [illegible] stone, possessing as it does [illegible] steel and unpolished rough or dressed surface. Figure 5 shows the structural relations between the two granites as exposed in the Netherwood quarry west of Richmond. The Richmond granites are [illegible] classes of work in which granite is used.

[illegible] quarry and the [illegible] granites is the [illegible] Richmond granite.

Map of the Richmond gra
sheets, U. S. Geol. Sur
Richmond sheet, 20 1

The quarried granites are feldspar-quartz-biotite rocks, which vary from fine to medium granular in texture, and from dark to light gray in color. Near Midlothian, 13 miles west of Richmond, and extending for a north-south distance of about 20 miles, is a beautiful coarse, porphyritic, biotite granite, which has not yet been quarried to any extent.

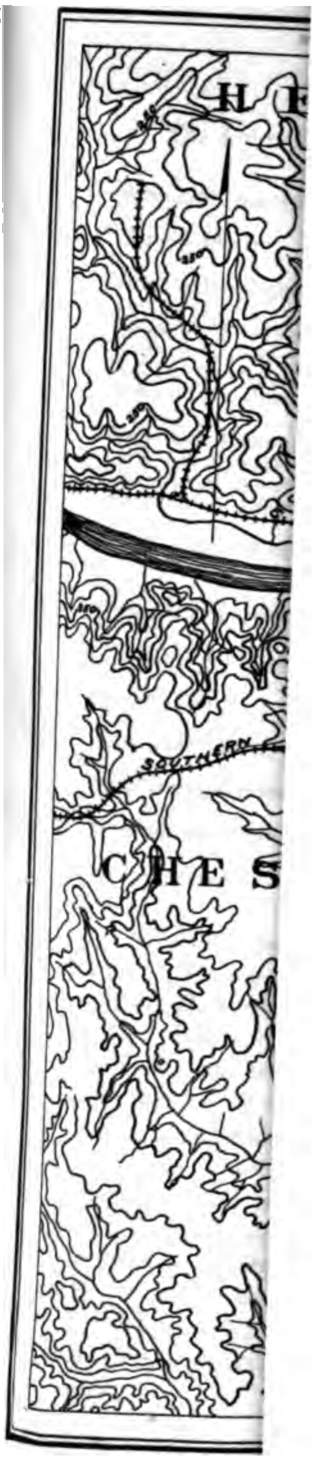
Jointing is usually well developed in the granites but the planes are spaced sufficiently far apart to admit of almost any size stone being quarried. Pegmatite veins or dikes, coarse crystallizations of quartz and feldspar, are not sufficiently numerous to cause waste in quarrying.

Two grades of the granite occur and are quarried, one a fine-grained dark blue-gray rock extensively used as monument stock, the other a coarse

Fig. 8.—Relations of the blue to the gray granite as shown at the Netherwood quarry west of Richmond. Scale, 1 inch equals 150 feet.

and lighter gray rock admirably suited for building purposes. Both are homogeneous even-granular granites, possessing good working qualities. The fine-grained dark blue-gray granite is susceptible of high and permanent polish and is a superior monumental stone, possessing as it does that strong contrast in color between the polished and unpolished rough or dressed surface. Figure 8 shows the structural relations between the two granites as exposed in the Netherwood quarry west of Richmond. The Richmond granites are thoroughly suited for all classes of work in which granite is used.

Probably the most elaborate granite structure in the country and the most important building yet constructed of the Virginia granites is the State, War, and Navy building in Washington, built of the Richmond granite.



Map of the Richmond gra
sheets, U. S. Geol. Sur
Richmond sheet, 20 f

The following is a list of the principal quarries in the Richmond area:

Name.	Location.
Belle Isle Quarry,	**Belle Island, above Richmond—Manchester bridge.**
Donald Quarry,	Half mile E. of Belt Line Railway, S. side of James river.
Granite Development Company's Quarry,	One-eighth mile E. of Granite, S. side of Southern Railway.
Hawkins Quarry,	North side of So. Railway at Granite.
Krim Quarries,	Three-eighths mile S. W. of Granite.
McCloy Quarry,	One-quarter mile W. of new reservoir.
McGranigan Quarry,	One-eighth mile W. Belt Line Railway, on James river.
McGowan Quarry,	Two miles S. of Manchester.
McIntosh Quarries,	Half mile S. W. of Granite.
Middendorf Quarries,	One-quarter mile S. W. of Granite.
Netherwood Quarries,	Two miles W. of Richmond, on S. side of James river.
Old Dominion Granite Company's Quarries (Middendorf),	One-fourth mile N. 30° E. of Granite.
Philadelphia Quarries,	East end of Settling Basin, on N. side of James river.
Richmond Granite Company's Quarries,	4.5 miles N. of Richmond, near R. F. & P. Railway.
Smith Quarry,	Canal locks W. of Richmond, N. side of James river.
Tidewater Quarry Company's Quarry,	Two miles S. E. of Manchester, on James river.
Westham Quarries,	4 miles W. of City Hall in Richmond, on S. side of James river.
Winston and Company's Quarry,	North side of James river, at Settling Basin.
Wray Quarry,	Three miles W. of Richmond, on S. side of James river.

Of these, the following quarries were being operated during 1905 and 1906: *McCloy, McGowan, McIntosh, Middendorf, Netherwood, Richmond Granite Company, Winston and Company,* and *Wray.* Some of the others have not been operated for some time, and in part they include the most extensive openings in the area. This is particularly true of the Westham quarries out of which stone the War, State, and Navy building in Washington was constructed, and the quarries of the Old Dominion Granite Company, known at present as the Middendorf quarries. Only those quarries which are mentioned above as operating during 1905 and 1906 will be described. The other quarries are equally as important and are capable of producing unlimited quantity of excellent stone, but many of the openings were partially or entirely filled with water at the time of my examination and were not entirely open to study. Map, plate III, shows the distribution and location of granite quarries in the Richmond area.

McCloy quarry.—The McCloy quarry is opened in a flat surface exposure of granite, located about 300 yards from the James river branch of the Richmond, Fredericksburg, and Potomac railroad, and about a quarter of a mile west of the new reservoir. The quarry opening includes about 1 acre of ground. At several places about the edges of the opening the granite is decayed to a depth of 3 or 4 feet, which must be stripped before fresh stone can be obtained. The rock is cut by several well-defined sets of joints which vary in direction, from N. 5° to 85° W. and N. 10° to 75° E., and in dip from vertical to 55° N. W. The rock is a very fine-grained and even-textured, dark blue biotite granite, admirably suited for monumental stock. The principal uses made of it are for monuments and building, and for street purposes as blocks and curbing. The quarry waste is crushed and utilized for street concrete or cement work. It is marketed in a number of states, including Virginia.

McGowan quarry.—This quarry has been worked for about 10 years exclusively for monumental stone. It is located 2 miles south of Manchester, about 300 yards east of the Petersburg turnpike, and 600 feet west of the Seaboard Air Line Railway, with which the quarry is connected by a spur track for shipping. The opening, which is a large one, is made in a flat surface exposure of granite, and the average depth of stripping, including soil and partially decayed granite, necessary to the quarrying of fresh stone, is about 5 feet. It is a fine-grained dark blue-gray biotite granite, of uniform texture and color, and a most desirable monumental stone. The quarry waste is utilized largely for paving purposes. It has an extensive sale in the monument trade in many states, including Virginia. Views of this quarry are shown in plates IV, V, and VI.

McIntosh quarry.—The McIntosh quarry, formerly known as "flat-rock," is probably the most extensive working granite quarry in the State. It is located near Granite, a station on the Southern Railway, 5 miles west of Richmond. A spur track for shipping connects the quarry with the Southern Railway at Granite. It has been operated for about 15 years. About 2 acres have been stripped from the flat ledge exposure to a depth of 37 feet. The fresh rock is exposed at the surface and no stripping of decayed material is necessary. All work is done by compressed air machinery. The stone is of excellent quality and is used for all classes of building and monumental work, and for all purposes for which granite is handled, except in the form of crushed stone. The principal directions of jointing are N. 10° W. and N. 65° E. All the approaches, steps, etc., to the new Capitol building in Richmond are from the granite of this quarry. It has an extensive market in and out of Virginia.

Fig. 1.—McGowan granite quarry, south of Richmond, showing horizontal jointing.

Fig. 2.—Granite quarry near Richmond, showing jointing as in Fig. 1.

GRANITE QUARRIES IN THE RICHMOND, VIRGINIA, AREA.

Middendorf quarry.—The Middendorf quarry is located on the Belt Line Railway west of Manchester, and 760 feet north of the crossing of the Petersburg turnpike by the above railroad. The rock is a banded biotite granite-gneiss, penetrated by many pegmatite dikes and veins which vary in width from a fraction of an inch to several feet. Directions of jointing are N. 65° E. and N. 45° W. Strike of the gneissic structure or banding is N. 65° E. Several acres of the gneiss have been stripped to a depth of about 25 feet. The stone is used for ballast and paving blocks, largely the former.

Netherwood quarry.—This is one of the most extensive quarries in the Richmond area, and it is reported as having been worked as early as 65 years ago, although operated under the present management for about 8 years. The quarry opening is made in the high granite bluff on the south side of James river and immediately on the Southern Railway, about 2.5 miles southwest of Richmond. The greatest depth reached in quarrying is 65 feet of fresh granite covered by about 2 feet of red clay on top. The ledges of granite average from 20 to 22 feet in thickness. Two grades of granite are produced, a medium coarse light gray for general building purposes, and a fine-grained dark blue-gray for monumental purposes. Neither joints nor pegmatites are too closely spaced nor too numerous to prevent the quarrying of dimension stone—any size blocks of both the gray and the blue stone being readily obtained. It has an extensive market in and out of the State; and is used for general constructional and monumental purposes, curbing and blocks for paving, and crushed stone for all purposes made of granite. Its principal use, however, is for building and city (street) work, which comprises mostly the light gray coarse granite.

The Richmond Granite Company's quarries.—The quarries of this company, owned and operated by Copeland and Brown, are located 4.5 miles north of Richmond, near and on the east side of the Richmond, Fredericksburg, and Potomac Railway. It was first operated about 15 years ago. The dimensions of the principal opening are 500x100 feet and 50 feet deep. A spur track is operated between the opening and the Richmond, Fredericksburg, and Potomac Railway. Two principal sets of joints, spaced at distances of 2, 6, 8, and more feet apart, intersect the granite, with directions varying from N. 10° to 70° W. and N. 30° to 35° E. These dip from the vertical to 35° S. E. The rock is not sheeted but is perfectly massive, and is an excellent grade of biotite granite. Pegmatite dikes or veins varying in width up to 8 feet occur, but are not numerous and do not interfere with the quarrying of dimension stone. A crusher is operated at the quarry for working up the quarry waste for the various uses made of crushed stone. The principal uses made of the granite are for street work in the form of blocks and curbing, for building and monuments, and for crushed stone in its various forms.

Winston and Company's quarry.—This quarry, formerly known as the Mitchell and Copeland quarry, under whose management it was first opened and worked for 12 years, many years ago, is located west of Richmond at the city settling basin, just completed. The quarry is opened in the granite bluff on the north side of James river, and is of large dimensions. The present operators, Winston and Company, contractors for the construction of the settling basin, began working the quarry about 3 years ago to supply crushed stone (concrete) and rip-rap for building the settling basin. The stone was quarried by blasting. The principal joints strike N. 5° W. and N. 30° to 70° E. Pegmatites are not numerous. The granite is sheeted to the entire depth of working, the sheets being thickest at the bottom and thinnest at the top.

Wray quarry.—This quarry, operated since 1895 for monumental stock exclusively, is opened in the high granite bluffs on the south side of the James river and immediately on the Southern Railway, about 3 miles southwest of Richmond. The stone is of the excellent dark blue-gray biotite granite, of uniform color and texture, and is admirably suited for the use made of it. The joint-planes are widely spaced, admitting of almost any size stone being quarried. The working face in 1905 had a depth of about 75 feet. Occasional pegmatites not exceeding 3 inches in width occur in the granite but give no trouble in quarrying. Its sale is practically limited to the principal cities in the State for monumental stock.

The Fredericksburg Area.

The Fredericksburg area includes the region to the west and north of the city, in Spottsylvania county, in which granite quarries have been opened. The granite exposed along the Rappahannock river north of Fredericksburg extends into Stafford county, but no quarries have yet been opened in that county.

Two types of granite have been quarried in the Fredericksburg area, one a very light gray, medium-textured, muscovite granite, the other a dark blue-gray, very fine-textured, biotite granite. In texture and composition. the latter is identical with the fine-grained dark blue-gray granite quarried in the Richmond area and so extensively used for monument stock. The

Fig. 1.—Granite quarry near Richmond, showing joint structure.

Fig. 2.—McGowan quarry near Richmond, showing large inclusion of banded gneiss. The hammer spans contact between granite and gneiss.

GRANITE QUARRIES IN THE RICHMOND, VIRGINIA, AREA.

Fredericksburg granite is a shade darker in color than the Richmond stone and it is a superb monumental stone for which it has a wide usage. Map, figure 9, shows the location of the quarries in this area.

Fig. 9.—Map showing location of granite quarries in the Fredericksburg area. Quarries indicated by heavy dots. Based on the Fredericksburg topographic sheet, U. S. Geol. Survey. Scale, ⅝ inch equals 1 mile, approximately. Contour interval, 50 feet.

Hazel Run light gray granite.—A very light gray muscovite granite of medium texture is exposed along Hazel Run, a tributary of the Rappahannock river, and about 1 mile west of Fredericksburg. It somewhat resembles the Stone Mountain light gray muscovite granite 16 miles east of Atlanta, Georgia, which is so extensively used for general constructional purposes. In the spring of 1879 an opening was made in the flat ledge immediately on the south side of Hazel Run, about 1 mile west of Fredericksburg, and enough stone quarried to build the Presbyterian Memorial Chapel in Fredericksburg. No stone has been quarried since. The joint-planes are widely spaced, two sets of which strike N. 75° W. and N.-S.

Cartwright and Davis quarries.—The quarries of Cartwright and Davis, located along the Rappahannock river 3 miles north of Fredericksburg, are the only ones operating at present in Spottsylvania county. The quarries comprise 8 openings, 6 of which are made in the granite bluffs along the south side of the Rappahannock river, for a distance of nearly half a mile. The granite, an excellent grade of monumental stone, is a massive uniform dark blue-gray colored and fine-textured rock. It is intruded into an irregular banded gneiss of similar mineral composition. Strike of gneissic banding or schistosity is N. 25° to 40° E. The granite is cut by several sets of joints so spaced as to admit of any size blocks of stone being quarried. The principal joint-planes strike N.-S. with a dip of 40° E.; N. 60° to 80° E., dipping 10° to 30°, and N. 20° to 80° W. In places, pegmatites are abundantly developed in the granite, which occasion at times considerable waste in quarrying.

No dimension stone is sold in the rough but it is all worked up at the "yards" located in the northern limits of Fredericksburg, and is used exclusively in the monument trade. The yards are commodious and well equipped with the necessary modern machinery for all grades of polish and dress work. The stone is conveyed from the quarries to the yards, a distance of 3 miles, by canal. A crusher is operated at the yards for sizing the waste which is utilized for local purposes.

The monuments made from this granite have an extensive market in and out of the State.

The Fairfax County Area.

Granite has been quarried in Fairfax county at the following localities: South of Falls Church and west of Annandale. The quarried rock is similar in the two localities and is taken from less schistose portions of the granite mass. It is homogeneous, of even texture and good color. It is not materially effected by schistosity, and works out readily in stones of moderate size. Some of the beds in the Falls Church area are colored by pink feldspar. Many portions of the granite-gneiss furnish good material for foundations and similar rough work. This stone is schistose and consequently not obtained in large masses. It is easy to quarry and is strong and durable. Many portions contain pyrite, which unfits it for ornamental use. Many of the more massive beds of mica-gneiss are suitable for building and resemble the more schistose portions of the granite mass. They are used locally in the construction of dams and foundations. From the thinner and more micaceous beds flagstone can readily be obtained.

The granite quarried in the Fairfax county area has been used entirely for local purposes.

Falls Church area.—The granites in the vicinity of Falls Church are of two varieties. One is a medium- to fine-grained crystalline rock and is a biotite granite carrying a variable quantity of muscovite. The other, a light and dark speckled rock, is a fraction more coarsely crystalline and is a hornblende-biotite granite. It is the only representative of a hornblende granite yet found in the State and it is closely associated with diorite masses on the one hand and with foliated mica-granites on the other.

The *Trip* quarry, located about 1 mile south of Falls Church, was first opened about 1872, and has supplied considerable stone for local purposes, principally for foundations and buildings. The granite is massive, of medium texture and of variable light gray color, depending upon the amount of mica present. Several sets of joints are developed which usually cut the granite at close intervals and limit the size stone that can be quarried. The directions of these joints vary from N. 10° to 80° E., and N. 10° to 80° W.

The Presbyterian and Catholic churches at Falls Church were built of the granite in the rough from this quarry.

Annandale area.—The *Hoffman and Miller* quarry, located about 2 miles west of Annandale, directly on the west side of Accotink creek, has not been operated for 12 or 13 years. The opening is made in a boulder ledge exposure on the above stream and at water level. A stripping of 8 to 12 feet of soil and red clay is necessary for the quarrying of fresh granite. The rock is a massive biotite granite of uniform medium texture and light gray color. Good dimension stone can be readily quarried. The joint-planes strike N.-S. and N. 50° to 80° W.

The Nottoway—Prince Edward Counties Area.

In the northwestern corner of Nottoway county and in the adjacent portion of Prince Edward county is a very promising area of massive gray granite of fine texture and uniform color, which has been opened and a little stone quarried for local use at a single point in both counties. The granite is exposed at the surface in flat-doming masses and as boulders. This area lies close to the Southern, and the Norfolk and Western Railways.

The *Wingo* quarry in Nottoway county, located 3.5 miles north of Jennings and 2.5 miles south of Jetersville, on the east side of the Southern Railway, was operated some years ago for ballast. The rock is a fine-grained massive, medium gray, biotite granite, of uniform texture and color. It is a desirable stone and can be used for any purpose made of granite.

In the vicinity of Rice's Depot, Prince Edward county, granite was quarried some years ago for use in bridge construction along the Norfolk and Western Railway.

Granite, suitable for general building and other purposes, occurs in other counties of the crystalline area, but in none of these has it been developed. A beautiful coarse-grained granite is found in Buckingham county, near the Court-House, but no quarries have been opened. Likewise a coarse-grained light gray biotite granite occurs 3 miles west of Tharxton, a station on the Norfolk and Western Railway. A red granite, well suited for ornamental and general building purposes, but undeveloped, is reported from Saxe in Charlotte county.

The Blue Ridge Area.

In the mountain district of Loudoun county, extending northward across the Potomac into Maryland and southward into Fauquier county, Virginia, granite is widely distributed in long belts up to six miles wide. The outcrops increase in extent and number southward from the Potomac in Virginia.

According to Keith, the minerals composing the granites are chiefly quartz, and orthoclase and plagioclase feldspar; besides biotite, garnet, epidote, and blue quartz occur, forming four types of granite in different areas. The granite is light gray in color and has been extensively altered by pressure. According to the degree of alteration the rock is a granite, gneiss, or quartz schist. No quarries have been opened in the granite, but where boulders could be obtained without much labor local use has been made of the granite.

Unakite.

The name unakite was proposed for a unique variety of granite, composed of the essential minerals, yellow-green epidote, pink feldspar, and quartz, from the Unaka range of the Great Smoky Mountains, in North Carolina. The effect of the rock in either rock-faced or polished work is quite pleasing and it might be used to good effect in certain forms of ornamental work.

Unakite occurs in two localities in Virginia, namely, near Luray, at Milam's Gap in Page and Madison counties, in the Blue Ridge; and about 2.5 miles south of Troutdale along the Marion-Jefferson public road, in Grayson county.

The Milam's Gap unakite is a moderately coarse but irregular crystallization of red feldspar, quartz, and green epidote. Irregular crystallization of the rock is shown in the variation of masses composed of more than two-thirds of the red feldspar through all gradations to masses composed of quartz and epidote without feldspar. Thin sections of the unakite from Milam's Gap show epidote, orthoclase, quartz, iron oxide, zircon, and apatite. The epidote is secondary, replacing pyroxene and feldspar, both plagioclase and orthoclase. The unakite from Grayson county shows deeper colored feldspar and epidote than that from Milam's Gap.

As shown by the analysis below of the Milam's Gap unakite, made by Phalen, the rock is relatively basic for a granite:

	Per cent.
Silica	58.32
Alumina	15.77
Ferric oxide	6.56
Ferrous oxide	0.89
Magnesia	.09
Lime	11.68
Soda	0.32
Potash	4.01
Water	1.73
Phosphorous pentoxide	.48
Manganese oxide	.13
Zirconia	trace
Total	99.98

2. SYENITE.

Under the name syenite is included a crystalline granular rock which consists essentially of orthoclase, with or without one or more of the accessory minerals, mica, hornblende, or augite. It is sold on the market as granite and is used for the same purpose but differs from granite only in the absence of quartz. Most of the known areas of syenite in Virginia contain hornblende as the chief accessory mineral, and the rock is accordingly a hornblende syenite.

In Charlotte county, an exposure of hornblende syenite has been traced from Drakes Branch, a station on the Southern Railway, to within 2 miles east of Charlotte court-house, a distance of about 5 miles. The rock is entirely massive, varying from gray to deep pink in color, and in texture from medium to coarse-grained. It would make a desirable stone for the various uses to which granite is put. No attempt has been made to quarry this rock.

In Carroll county, extending northward from the northwest edge of Sylvatus, is an area of hornblende syenite, the exposures of which show pronounced crushing and shearing from pressure metamorphism. The rock in this vicinity could only be used for the rougher grades of work. Northeastward from Sylvatus along the Carroll county line and on Big Reed Island creek, an area of coarse-grained pink hornblende-biotite syenite, carrying more or less quartz, occurs. Study of this area will probably show the rock to grade into a true granite.

Along the west side of the Blue Ridge and topographically below the basalt, a coarse-grained, massive, dark gray syenite has been observed in Warren, Madison, and Greene counties. This rock has been found along the west side of Dickey's Hill, 4 miles south of Front Royal in Warren county; at Milam's Gap in Madison county where it forms the unakite-bearing rock; and between Elkton and the High Top Copper Company's mine, in Greene county. Where observed, the syenite appears entirely massive except at one or two points in the Greene county locality, where a schistose structure has been developed in it. In the Warren county area the rock varies from medium to coarse texture. The syenite of the above localities has nowhere been quarried, but it should prove a desirable stone for general constructional work and many other purposes for which granite is employed.

According to Phalen, the syenite of Milam's Gap, Madison county, the unakite-bearing rock, a hypersthene-quartz-diallage syenite, is a coarse-grained dark grayish-green aggregate of essentially feldspars and black pyroxenes. The microscope shows the following minerals: Orthoclase, plagioclase, orthorhombic and monoclinc pyroxene, quartz, microcline, iron ore, apatite, and zircon, with the alteration products epidote, chlorite, and sericite. Phalen gives the following analysis of the syenite from Milam's Gap:

	Per cent.
Silica	60.52
Alumina	16.99
Ferric oxide	.60
Ferrous oxide	6.53
Magnesia	1.59
Lime	4.58
Soda	2.83
Potash	3.91
Water	.88
Phosphorus pentoxide	.74
Manganese oxide	.25
Chromium oxide	trace
Zirconia	trace
Total	99.42

A syenite occurring in the northwestern corner of Floyd county on Lick Fork and Flat Run, and closely similar to the northern Blue Ridge rock, has recently been described by me. The area is a large one, and the rock, both in hand specimens and in thin sections, is strikingly similar to the syenite of Warren, Madison, and Greene counties. The microscope shows the following minerals: Orthoclase, plagioclase, microcline, pyroxene, biotite, hornblende, garnet, quartz, and some minor accessories. The rock is typically exposed in the nickel openings on Lick Fork.

Additional areas of syenite are referred to by the older writers in a number of other counties in the crystalline area. Although admirably suited for many uses, practically no development of the syenite areas in Virginia has been made.

3. GNEISSES.

The Lynchburg Area.

On the north and east sides of the city of Lynchburg is an extensive belt of gneiss cut across by the James river and lying partly in Amherst and partly in Campbell county. Excellent exposures of the gneiss are found along the James river and some of its tributaries, near the city, and numerous quarries have been opened and stone supplied for general building and street purposes in Lynchburg. The quarries are located along the north side of James river, in Amherst county, opposite Lynchburg, where the river has cut directly across a broad anticline of gneiss; and to the east of Lynchburg, in Campbell county, along the tributaries of the James river.

The stone is a fine-grained dark blue-gray biotite gneiss well suited for the uses made of it. It splits out readily into slabs of any desired thickness, is hard but easily dressed, and very resistant to atmospheric agents. Plate VI, figure 2, is a view in one of the quarries east of Lynchburg.

The Fairfax-Alexandria Counties Area.

Extending southward from the Potomac river and covering much of Fairfax and Alexandria counties, are two extensive belts of gneiss, one of which is a metamorphosed granite, the other of doubtful origin. The former rock, known as granite-gneiss, is of fairly uniform color and texture; the latter, which is of doubtful origin, is quite irregular both in color and texture, and composition as well. The granite-gneiss has been quarried quite extensively from time to time for local use, from the ledges along and on the south side of the Potomac river.

When fresh the rock is a dark bluish-gray gneiss of rather fine but uniform texture. The principal minerals are quartz, orthoclase, plagioclase, muscovite, and biotite, with frequently small amounts of garnet, chlorite, hornblende, tourmaline, and pyrite.

The gneiss of doubtful origin has been designated by Keith, the Carolina gneiss, and is composed of alternating layers of gneiss and schist of a prevailing gray color, dark bluish-gray when fresh. The bands vary in thickness. Quartz and mica are the predominant minerals in the schist; and quartz, feldspar, and mica, in the gneiss. So far as I am aware the Carolina gneiss has not been quarried in this area.

Other Gneiss Areas.

Gneisses of granitic composition form one of the most widespread rock-types in the Virginia crystalline area, and large areas occur in many of the Piedmont counties of the State. Like their granite equivalents, from which they have been derived in part, at least, they are usually of the biotite type, although hornblende occurs in the gneisses of the Richmond and Fredericksburg areas. Structurally the gneisses vary from irregular banded rocks like those of the Richmond and Fredericksburg areas described above, to regular banded forms like the gneiss of the Lynchburg area. Texturally they vary from fine- to coarse-grained rocks. The more regularly banded ones of uniform texture and color are suitable for general building purposes, and all of the Virginia gneisses are well adapted to the rougher grades of work, such as for all forms of street work, for concreting and ballast, retaining walls, and foundations, and as metal for road construction.

Fig. 1.—McGowan granite quarry and dressing yard, south of Richmond.

Fig. 2.—Gneiss quarry just beyond the southeast limits of Lynchburg, Campbell county.

GRANITE AND GNEISS QUARRIES IN VIRGINIA.

In addition to the quarries of gneiss opened in the Lynchburg area, gneiss has been quarried in Fluvanna, Bedford, and Pittsylvania counties. A gray biotite gneiss has been quarried at Columbia in Fluvanna county, and a large area of dark gray biotite gneiss is exposed for some distance along the Norfolk and Western railroad at Bellevue. A similar gneiss in color, texture and composition, has been quarried near the depot at Chatham. on Cherrystone creek, in Pittsylvania county.

4. MICA SCHIST.

Mica schist is probably the most abundant type of crystalline rock occurring in the Virginia Piedmont region. It is usually thinly foliated, composed essentially of mica and quartz with or without feldspar, and is quite variable in character. Because of its thinly foliated and irregular character, its uses are limited to the lower grades of constructional work. Ordinarily the rock is more or less deeply decayed and fresh exposures of it are not very common. It has been quarried in several localities in the Piedmont region for strictly local use.

One of the best grades of mica schist yet quarried in the State is in the vicinity of Rocky Mount, Franklin county. Quarries have been opened in the schist belt, near Rocky Mount, which yields a gray rock well adapted for flagging and other purposes. The stone can be quarried in smooth slabs of any desired thickness. It has been used in Rocky Mount and to some extent in the city of Roanoke for street work. The strike of the schist is 40° east of north, with a dip of 80° to the southeast.

Production.

Value and uses of granite produced in Virginia from 1900 to 1905 inclusive.

Year.	Sold in the rough for building and monumental purposes.	Dressed for building and monumental purposes.	Paving blocks, curbing and flagging.	Crushed Stone.	Rubble, rip-rap, etc.	Total.
1900	$54,225	$76,757	$25,415	$38,850	$15,833	$211,080
1901	49,293	98,141	25,230	60,008	43,029	275,701
1902	33,658	80,452	45,191	78,275	44,470	282,046
1903	39,785	58,585	38,101	110,005	52,859	299,335
1904	50,933	104,060	67,806	239,335	48,654	510,788
1905	41,639	67,130	30,718	256,899	57,004	452,390

5. TRAPPEAN ROCKS.

DIABASE AND BASALT.

Trap is the common name given to a class of basic eruptive rocks and it has no distinctive significance in mineralogical composition. It is a useful field name for any dark, finely crystalline, igneous rock. Some of the rocks included under this heading are quarried and known commercially as black granite. The ordinary trap rock, such as that composing the Palisades of the Hudson in New York, is a crystalline granular mass of plagioclase feldspar (labradorite usually), augite, and magnetite, with or without olivine. It is frequently of finer crystallization than granite and varies in color from dark gray through dark green to almost black. It is exceedingly hard and tough, and on account of its toughness it makes an admirable material for macadamizing roads.

In addition to its use as road metal, trap or diabase forms an excellent material for paving blocks and general building and ornamental work, including monumental purposes. Owing to the lack of definite rift in this group of rocks, their compact texture and hardness, they can, as a rule, be worked only with difficulty and usually at a cost greater than that of granite. Diabase has, however, of late years come into more general use for paving purposes, and still more recently for building and monumental work.

Trap or diabase occurs widely distributed over parts of the Blue Ridge and the crystalline area of Virginia. It occurs in great abundance in the Newark (Jura-Trias) beds, which are shown on the accompanying color geological map, and in scattered dikes penetrating the older rocks of the crystalline area. The fissures in the Jura-Trias strata, filled with diabase, are irregular in trend, sometimes following and sometimes crossing the beds of sedimentary rock, and in the Loudoun county area the thickness of the diabase ranges, according to Keith, from 10 feet to possibly 800 feet. The diabase dikes in the crystalline rocks are traced for many miles in extreme cases in the direction of their trend and they vary in width from a few inches up to several hundred feet. One of the best illustrations of the larger dikes in the crystalline rocks is found in Pittsylvania county. The dike is crossed by the Dan river at Neapolis and thence it can be traced northward from the river at Danville along the Southern Railway to and beyond Sycamore Station, a distance of more than 20 miles. Other dikes of the same material and equally as large as the Pittsylvania county dike are found in other counties of the crystalline area.

The following analyses made by me of the rock from the Pittsylvania county dike, and from nearby smaller ones west of Chatham depot, show their composition:

Constituents.	Olivine Diabase Per cent.	Olivine Diabase Per cent.	Quartz Diabase Per cent.
Silica	45.73	47.87	52.06
Alumina	13.48	14.43	13.67
Ferric oxide	11.60	11.55	15.97
Lime	9.92	10.45	8.15
Magnesia	15.40	10.58	5.01
Soda	3.24	3.47	3.36
Potash	0.47	0.61	0.86
Water	0.94	1.82	1.05
Total	100.78	100.78	100.13
Specific gravity	3.026	———	2.953

In the Blue Ridge region of northern Virginia, extending from the Potomac river southward through parts of Loudoun, Clarke, Fauquier, Warren, Page, Madison, and Greene counties, are extensive sheets or flows of basalt and diabase. The basaltic rock is dense, heavy and dark-colored, and varies texturally from a basalt to a diabase, parts of which are usually altered and sometimes schistose. According to Keith the schistose character prevails in the Harper's Ferry region, and the rock is known as catoctin schist on account of its great development in Catoctin Mountain in Maryland. The schistose character of the rock further south in Virginia, from Front Royal southward, is much less well-defined. As a whole it appears more massive than schistose, though in places it is sheeted vertically from close jointing along shear zones.

Two varieties of the basic rocks are recognized near Harper's Ferry by Keith, a lower diabase sheet, and an upper basaltic sheet, both altered, with the upper one largely epidotized. Thin sections of the rock show variations from fine-grained basalt to, in the coarser varieties, diabase with pronounced ophitic or diabasic texture. The principal minerals are augite, plagioclase, magnetite, some olivine, much secondary epidote and chlorite, and in many of the sections leucoxene. The following analysis made by C. H. Henderson of specimens of the rock from South Mountain, Maryland, shows the chemical composition:

	Per cent.
Silica	41.280
Alumina	18.480
Ferric oxide	9.440
Ferrous oxide	8.200
Lime	7.040
Magnesia	7.486
Soda	3.523
Potash	2.208
Ignition	2.740
Total	100.397

The silica was determined by George Steiger of the U. S. Geological Survey in 2 samples of the basaltic rocks, collected from the following localities in Virginia: 6 miles southeast of Harper's Ferry, and east of Browntown. The results were 45.66 per cent. and 46.04 per cent., respectively.

According to Campbell and Brown, about 3 miles north of Rapidan, a station on the Southern Railway, are to be seen two rounded knolls of similar shape and size, forming rather conspicuous objects in the landscape. These are sometimes called the "Twins," although known by other names in the neighborhood. On top of the knob nearest to the railroad, beautiful perpendicular, pentagonal and hexagonal basaltic columns form the face of a cliff. Some of these columns are 60 feet high and from 20 to 25 feet in diameter. The stone from the side of the "Twins" is quarried under the name of granite, but it is in reality a hypersthene diabase.

Along the railroad, between Rapidan and Mitchell stations, for a mile or more, the same rock appears in the cuts. A few miles east of Culpeper court-house, Mount Pony, an isolated peak, stands out so prominently that it has been used as a signal station upon various occasions. The greater part of this peak is composed of rock of the same character as the "Twins." Other knobs and dikes of diabase occur in this region.

The composition of the diabase from the quarry on the "Twins," and from a dike in the railroad cut not far from the "Twins," is shown in the following analyses, made by W. G. Brown:

	I	II
	Per cent.	Per cent.
Silica	51.31	50.88
Alumina	13.64	13.17
Ferric oxide	0.52	1.11

	I.	II.
Manganous oxide	trace	trace
Lime	12.41	10.19
Magnesia	12.73	13.05
Potash	0.32	0.31
Soda	1.40	1.17
Titanium oxide	trace	——
Phosphoric oxide	trace	——
Ignition	——	0.14
Total	100.82	99.67
Specific Gravity	3.09	3.10

I. Hypersthene diabase from the "Twins" quarry.
II. Olivine-hypersthene diabase from dike in railroad cut not far from the "Twins."

Notwithstanding the wealth of diabase of excellent quality found in Virginia, only a few quarries have as yet been opened. The principal quarries opened in this rock are in Loudoun, Fauquier, and Culpeper counties. In the former county, Loudoun, diabase has been quarried near Goose creek, about 3 miles from Leesburg. Excellent stone was found at the surface and few natural joints appear, the rock splitting with ease in any direction. Its texture is coarse and uniform, but it is darker in color than ordinary granite. The stone from this locality has been found to stand a pressure of 23,000 pounds per square inch, and, according to Merrill, the stone undergoes no change on an exposure of 25 years, other than a slight and in no way objectionable darkening of color.

In Fauquier county, near the Prince William county line a short distance east of Catlett, a station on the Southern Railway, diabase has been quarried. The rock is of coarse texture, dark gray color, very strong, and apparently durable.

As yet the stone quarried at the above localities has only been used for paving purposes and for bridge abutments, although it is apparently well adapted to all kinds of work for which its color and hardness qualifies it.

In other parts of the crystalline area surface boulders of diabase have been worked up for strictly local use. Apart from the utilization of this stone in the better grades of work for which it is well adapted, it should have an extensive use, on account of its general excellence, as road metal, in the construction of permanent good roadways over the crystalline area.

DIORITE.

Diorite is the name given to a granitoid igneous rock consisting essentially of plagioclase feldspar and hornblende. More or less black mica (biotite) is present, and quartz is a constituent in the more acid varieties when the rock is called *quartz-diorite*.

Diorite occurs east of the Blue Ridge in the crystalline area in the form of dikes of varying width penetrating the crystalline rocks. It is less abundant in Virginia than diabase. The only locality in the State known to the writer where this rock has been quarried at all is in the vicinity of Annandale and Falls Church in Fairfax county. The quarrying of diorite in this locality has been extremely limited, although it readily works out into blocks on account of its more or less gneissoid structure.

GABBRO.

The word gabbro is employed to designate a granitoid igneous rock composed of plagioclase feldspar and pyroxene. As yet very little is known of the occurrence of this rock in Virginia. Like diorite it is limited in its occurrence to the crystalline area east of the Blue Ridge. It has been found in Amherst county, east of Lynchburg, and in the northwestern corner of Floyd county, but so far as the writer is aware it has not been quarried at any point in the State.

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6. SLATE.

INTRODUCTION.

Slate suitable for roofing and other purposes is found in many localities in Virginia, and quarries have been opened and worked in Buckingham, Albemarle, Amherst, and Fauquier counties. Slate of commercial value but of which no producing quarries have been opened is found in Prince William, Stafford, Fluvanna, and Craig counties. Along the northeastern base of Massanutten Mountain in the upper or northern part of the Shenandoah valley a little prospecting in the Paleozoic black shales encourages the possibility of obtaining a reasonably good grade of black slate. Of the slate areas worked, that of the Arvonia belt in Buckingham county is the most important. The several slate belts are separately described in some detail below.

DESCRIPTION OF SLATE AREAS.

The Buckingham-Fluvanna Counties Belt.

In his annual reports of the Virginia Survey from 1835 to 1841, Professor W. B. Rogers called attention to the slate deposits east of the Blue Ridge in Buckingham, Fluvanna, and Fauquier counties. His reference to the Buckingham-Fluvanna slate belt follows: "This [roofing slate] makes its appearance on both sides of the James river, dipping east at an angle of about eighty degrees with the horizon. In Buckingham the bed is largely exposed in the neighbourhood 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. This quarry was first opened to procure slate for roofing the capitol; and notwithstanding it has been thus long known, and its value established, but little further use has been made of it, until the activity of the present proprietor has again brought it into notice. The buildings of the University will soon be furnished with a complete covering of slate from this quarry."

Map, figure 10, in part adopted from Dale, shows some of the important features of this belt. The belt is crossed by the James river a short distance west of Bremo and lies partly on the north side of the river in Fluvanna county and partly on the south side in Buckingham county. On the north side of the river the belt is approximately 1.5 miles wide and strikes N. 20° E. On the south side of the river at Arvonia, in Buckingham county, the belt of commercial slate is less than 1 mile in width and strikes N. 35° E.

On the north and south sides of the river the slate belt is limited on the east by a micaceous quartzite interbedded in places with thin leaves of slate. Slate also occurs on the east side of the quartzite. The strike of the quartzite is N. 13° to 23° E. and dips 65° to 90° E. On the west side of the belt at Virginia mills there are schists largely chloritic, sericitic and quartzose in composition, which strike N. 25° E. and dip 90°. The belt is frequently traversed by dikes of olivine diabase which range in thickness up to 12 feet. Several of these larger dikes are exposed in some of the larger quarries at Arvonia.

The finding of fossils (crinoids, brachiopods, and trilobites) in the slate by Darton at some of the Arvonia quarries shows it to be of Ordovician age. Ulrich referred the slate on the above fossil evidence to the Upper Ordovician. The dikes of diabase are of Mesozoic age.

Fig. 1.—Slate quarry in the Arvonia area, Buckingham county, showing the nearly vertical slaty cleavage.

Fig. 2.—Slate quarry in the Arvonia area, Buckingham county.

SLATE QUARRIES, ARVONIA, BUCKINGHAM COUNTY, VIRGINIA.

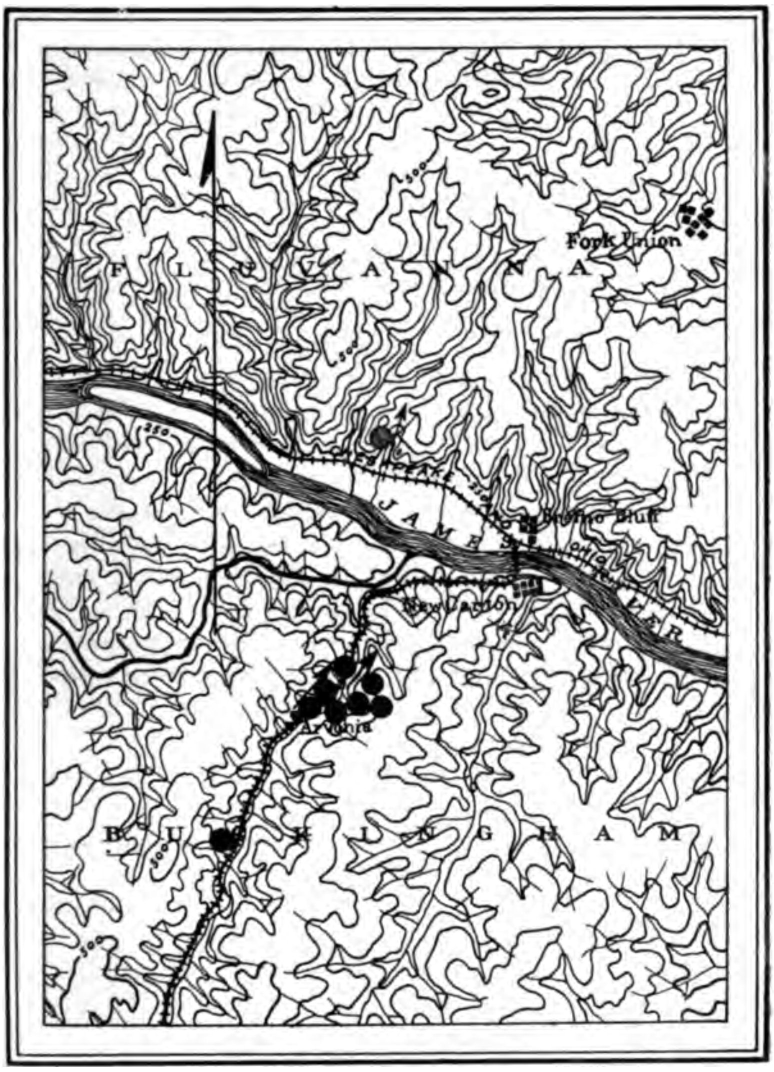

Fig. 10.—Map of the Arvonia slate area, Buckingham county. Quarries shown by heavy dots; strike of commercial slate by arrows. Based on the Palmyra topographic sheet, U. S. Geol. Survey. Scale, ½ inch equals 1 mile, approximately. Contour interval, 5C feet.

Fig. 1.—View in one of the Williams Slate Company's quarries at Arvonia, Buckingham county.

[illegible] slate quarry at Arvonia, Buckingham county.

[illegible] BUCKINGHAM COUNTY, VIRGINIA.

micaceous and the more quartzose beds are crystals, lenses, and particles of pyrite, numbering about 25 to each square millimeter and measuring up to 0.09 millimeter, rarely 0.15 and 0.42, with their longer axes parallel to the cleavage. These probably include a little magnetite. There are also biotite scales transverse to the cleavage, about 22 per square millimeter, and measuring up to 0.12, rarely 0.2 millimeter. Almost, if not quite, as abundant are plates and rhombs of carbonate. There are occasional scales of chlorite interleaved with muscovite, a few grains of plagioclase feldspar 0.047 millimeter, rarely one of zircon, some tourmaline prisms 0.014 millimeter long, much extremely fine graphitic (or carbonaceous?) material, a few particles of hematite, and some rutile needles. Sections parallel to the cleavage are unusually brilliant in polarized light, owing to the abundance of quartz, biotite, and carbonate."

Recent tests made by Professor Merriman on the slate from the Williams and Pitts quarries are given by Dale as follows:

Color and firm.	Mark on Specimen.	Strength, modulus of rupture in pounds per square inch.	Toughness, ultimate, deflection in inches on supports 22 inches apart.	Density, specific gravity.	Softness, amount in grams abraded by 50 turns of a small grindstone.	Porosity, per cent. of water absorbed in 24 hours.	Corrodibility, per cent. of weight lost in acid solution in 63 hours.
Blue.	W 1	8,590	0.17	2.788	0.073	0.105	0.281
Williams	W 2	8,250	.19	2.754	.038	.090	.801
Slate	W 3	10,700	.31	2.795	.097	.209	.223
Company	W 4	8,620	.24	2.788	.033	.167	.270
	Means	9,040	.227	2.781	.060	.143	.394
Blue.	P 1	8,540	0.25	2.805	0.095	0.332	0.248
A. L. Pitts	P 2	9,010	0.18	2.790	.159	———	0.552
Quarries	P 3	11,970	.25	2.788	.138	.154	.275
	P 4	9,880	.22	2.781	.038	.163	.218
	Means	9,850	.225	2.791	.108	.216	.323

Although Dale's results on the microscopic study of the Arvonia slates show the presence of some carbonate, an appreciable amount of ferrous carbonate cannot be present, for the use of these slates on buildings in Richmond more than 60 years ago, and on buildings near the quarries for more than a century, show no discoloration whatever. Strength and durability would naturally follow from the highly crystalline character of this slate.

Bremo.—Slate has been prospected at several places north of the James river several miles west-northwest from Bremo in Fluvanna county. The strike and dip of the slate are approximately the same as south of the river at Arvonia—the strike being N. 18° to 23° E. and dip nearly 90°. A dike of olivine diabase about 10 feet wide cuts the slate about 2 miles northwest of Bremo.

The slate from near the surface is dark gray, which color will probably prove darker on depth. It differs from the Arvonia slate in finer texture, possibly lighter shade, and slightly increased pyrite; but less biotite and no carbonate. It contains a little graphite, does not effervesce in cold dilute hydrochloric acid, is sonorous, and very fissile. Arranged in order of abundance the chief constituents are, according to Dale, muscovite, quartz, pyrite, kaolin, chlorite, graphite (or carbonaceous material), rutile, with accessory tourmaline, zircon, biotite, and hematite.

A microscopic examination of this slate by Dale gave: "There are abundant quartz grains up to 0.09 by 0.03 and 0.13 millimeter long, the larger ones surrounded by secondary quartz, radiating along the cleavage; about 50 lenses and crystals of pyrite per square millimeter, measuring up to 0.09 by 0.02 (exceptionally the lenses are 1.5 millimeter long), with their longer axes in the cleavage. There are also square and rhombic spaces lined with secondary quartz, measuring up to 0.6 millimeter, left by the dissolution of cubes or distorted cubes of pyrite. In some specimens there are 65 such cavities to the square inch, in others none. There are lenses up to 0.56 by 0.11 millimeter, consisting of quartz and muscovite or of these and chlorite and pyrite, or of chlorite and muscovite, the folia of muscovite and chlorite lying across the cleavage; also muscovite scales up to 0.09 by 0.02 millimeter. Throughout the matrix much dark gray material occurs in exceedingly fine dots (graphite?). There are also some dots of hematite. Rutile needles are not very plentiful up to 0.01 millimeter long; also a number of very irregular particles of rutile up to 0.05 millimeter, consisting of a network of crystals ("sagenite twinning") forming angles of 120° and 60°. A few fragments of zircon, an occasional crystal of dark tourmaline up to 0.05 by 0.02 millimeter, rare flakes of biotite, no carbonate."

The Albemarle County Belt.

The Albemarle county slate belt lies about 20 miles west-northwest of the Arvonia belt. It is reported as being crossed by the James river at Manteo, a station on the Chesapeake and Ohio Railway, and near the

Nelson and Buckingham county line. It has been opened at Keswick, Esmont, and Buck Island creek. At the latter place the Albemarle slate quarries were operated many years ago. Slate has recently been prospected near Keswick. During the summer of 1906 a company begun operating a quarry near Esmont. Slate of black, green and red colors is reported from the Esmont quarry.

The Amherst County (Snowden) Belt.

An extensive belt of slate is found on the southeast side of the Blue Ridge, in the vicinity of Snowden station in the southwest part of Amherst

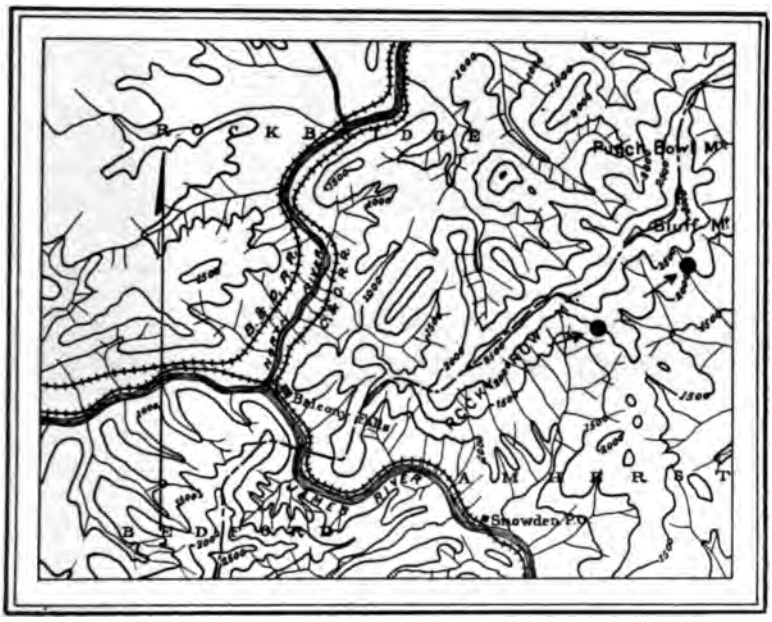

Fig. 11.—Map showing location of Snowden slate quarries, Amherst county. Quarries shown by black dots; strike of commercial slate by arrows. Based on the Lexington typographic sheet of the U. S. Geol. Survey. Scale, ⅝ inch equals 1 mile, approximately. Contour interval, 500 feet.

county. The belt has been prospected in a number of places in the county but only one quarry was operating during 1906, located about 3 miles north-northwest of Snowden. It is known as the Williams Brothers slate quarry on the property of the Virginia Slate Mining Company. The quarry is further situated on the southwest side of Rocky Row Mountain just under Saddle Gap and about 1,200 feet above the James river, as shown on the accompanying map, figure 11. The slate strikes

N. 65° E. and has quartzite southeast of it which has been referred to the Cambrian. The structure, a flat-topped anticline, indicates a possible overturn.

The Williams Brothers' quarry was opened in 1880. The production was steady from 1893 until the burning of the mill in October, 1904. Rebuilding of the mill was in progress during the summer of 1906 and the production was expected to begin by September of the same year. The cleavage strikes N. 45° E. and dips 30° S. 60° E. The bedding is strongly marked by finely plicated ribbons of quartz and calcite several inches wide and is cut by the cleavage at an angle of 45° and more, as shown in figure 1, plate IX. Joints are well developed, striking N. 15° to 20° E. and dipping about 70° W., and a second set intersecting the first at approximately right angles, and dipping at about 65° east.

The slate is very dark gray, has a minutely granular texture, moderately smooth cleavage, but with little luster. It resembles the Arvonia slate in not effervescing with cold dilute hydrochloric acid and in being quite sonorous, but differs from it in not being graphitic nor magnetitic. Arranged in order of abundance, the chief constituents of this slate are, according to Dale, muscovite (sericite), quartz, chlorite, kaolin, pyrite, carbonate, rutile, and carbonaceous matter. It is used exclusively for roofing and is a superior slate though less crystalline than the Arvonia slate.

Dale gives the following results of a microscopic examination of this slate: "Under the microscope it shows a matrix of muscovite (sericite), with aggregate polarization not very brilliant owing partly to the coarseness of many of the other constituents. Quartz fragments measure up to 0.08 millimeter; chlorite scales and lenses up to 0.28 in length, rarely 0.42 by 0.2 millimeter, numbering about 6 per square millimeter; also muscovite scales up to 0.09 millimeter; some carbonate, but in exceedingly minute rhombs and plates; grayish carbonaceous (?) matter; about 55 spherules and pyritohedrons of pyrite per square millimeter, measuring up to 0.005 millimeter; abundant rutile needles, and occasional fragments of zircon."

Slate was prospected some years ago on the Thompson property, less than 2 miles northeast of the Williams Brothers quarry. The slate closely resembles that of the latter quarry. According to Dale the strike of bedding is N. 58° E. and dips 20° E., with cleavage nearly horizontal; strike of joints N. 38° E. and dips 20° W.

Fig. 1.—View in the Williams Brothers slate quarry, near Snowden, Amherst county.

Fig. 2.—A second view in the Williams Brothers slate quarry, near Snowden, Amherst county.

SLATE QUARRIES, SNOWDEN, AMHERST COUNTY, VIRGINIA.

The Fauquier County Belt

As shown on the accompanying map, figure 12, slate has been quarried to the north and south of White Sulphur Springs on the Rappahannock river, about 6 miles southwest of Warrenton. In his *"Reprint of the Virginias,"* Professor Rogers referred to the quarrying of this slate as early as 1837. The slate outcrops about 1 mile south of the springs and is

Fig. 12.—Map of the Fauquier county slate area. Quarries shown by heavy dots. Based on the Warrenton typographic sheet, U. S. Geol. Survey. Scale, ½ inch equals 1 mile, approximately. Contour interval, 50 feet.

traced northward for a distance of 2 miles, and has a minimum width of a half mile. The strike of the cleavage over most of the belt is N. 25° to 30° E., with a reported change in strike to an east-west direction about three-quarters of a mile south of the springs. The slate is associated with a muscovite quartzite and with altered eruptives of the hornblendic and epidotic types.

Openings have been made at a number of places which are indicated on the map, figure 12. At the two openings northeast of the springs the strike of the cleavage is N. 25° to 30° E., with dip to the west of 20° to 25° Two sets of joints cut the slate in the opening nearest the springs; on set, strike joints, strike about N. 15° E. and dip about vertical; the other set, dip joints, strike N. 70° to 75° W., within most cases, nearly vertica dip.

The slate is black, of moderately fine texture, and has but little luster It varies from a clay slate to a mica slate. According to Dale it is ver carbonaceous, shows much pyrite, has no magnetite, does not efferves with cold dilute hydrochloric acid, and has an argillaceous odor. In th northeasterly opening Dale gives the chief constituents of the slate, ar ranged in the order of abundance, as carbonaceous matter, quartz, musco vite, feldspar, pyrite, and chlorite. In the opening nearest to the springs the same author gives the chief constituents of the slate as muscovit (sericite), quartz, carbonaceous matter, and pyrite.

At the opening about half a mile south of the springs, the cleavag of the slate strikes about N. 80° E. and dips south at about 15°. Th slate is bluish-black, has a coarsely crystalline texture, and a wrinkl surface.

According to Dale this slate is properly a graphite-quartz-muscovite schist, the chief constituents of which, arranged in the order of abundance are carbonaceous matter and graphite, quartz, muscovite, kaolin, pyrite, an feldspar.

Dale further says that this slate has very little luster, is carbonaceou or graphitic, shows pyrite, has very little magnetite, does not efferves in cold dilute hydrochloric acid, has an argillaceous odor, and is ver sonorous. After a microscopic examination of this slate Dale remarks "Under the microscope it shows a matrix of carbonaceous or graphiti material, quartz, and muscovite. As the first two predominate the aggre gate polarization is quite faint. The cleavage is serpentine, owing to th many large quartz grains (up to 0.14 millimeter) and the cubes and lense or distorted cubes of pyrite already referred to, most of which seem t be partial pseudomorphs of quartz and graphite after pyrite, the remainin pyrite having been oxidized and dissolved. There are some plagioclas feldspar grains almost as large as the quartz grains, with graphite inclusion parallel to the multiple twinning. There are veinlets of quartz and lense of secondary quartz usually about or on either side of the cubes and lense of pyrite; rare grains of zircon. No carbonate or rutile detected."

The pyritiferous character of all the Fauquier county slates is a ked feature.

The Prince William—Stafford Counties Belt.

A narrow belt of black slate, to which the name Quantico slate has been given from the creek by that name, is exposed along the "fall-line" in Stafford and Prince William counties. This belt of slate belongs to the crytalline rocks of the Piedmont region, and in its southern portion in Stafford county the slate is in contact on the east and west sides with granites and gneisses. North of Accokeek creek in Stafford county, the belt forms the easternmost rocks of the Piedmont crystallines. According to Darton the slate appears to grade on the west into siliceous mica schist or gneisses of greenish-gray color.

In Stafford county, the Quantico slate is exposed in the "fall-line" gorge of Acquia creek, northeast of Garrisonville, and on Austin river; they outcrop on the road a mile east of Garrisonville; and they reappear a mile and a half east, and half a mile south of Mountain View. Darton gives the average width of the slate belt in Stafford county as three-quarters of a mile.

The Quantico slate is exposed to the northeast of Dumfries in Prince William county, along the stream courses and wagon roads, and along the narrow-gauge railroad of the Cabin Branch Pyrite mine. On the west about 1 mile east of the Cabin Branch mine, the slate is in contact with crystalline schists. Large and small quartz lenses and stringers are interleaved with the slate. The width of the slate belt at Dumfries cannot be less than three-quarters of a mile. The cleavage strikes N. 10° to 20° E. and dips from 64° to 90° N. W. The slate is highly graphitic in places.

The Quantico slate has not been quarried to any extent and, so far as I am aware, it has not been tested. Lithologically it resembles the roofing slate quarried at Arvonia in Buckingham county.

Production.

Production of slate in Virginia by years, from 1897 to 1905.

Year	Roofing Slate, Squares	Value	Total Value	Year	Roofing Slate, Squares	Value	Other purposes	Total Value
1879	8,057	$32,228	$32,228	1893	27,106	$104,847	12,500	$117,347
1880	11,500	51,000	51,000	1894	33,955	118,851	19,300	138,151
1881	12,000	54,000	54,000	1895	27,095	92,357	19,000	111,357
1882	15,000	51,000	51,000	1896	26,863	92,163	15,700	107,863
1883	10,000	50,000	50,000	1897	38,375	130,495	14,875	145,370
1884	9,000	45,505	45,505	1898	43,745	142,446	8,500	150,946
1885	17,300	58,137	58,137	1899	52,550	174,950	8,160	183,110
1886	16,600	59,800	59,800	1900	56,365	185,211	5,000	190,211
1887	19,000	57,000	57,000	1901	53,630	178,979	——	178,979
1888	17,400	60,540	60,540	1902	42,731	160,951	——	160,951
1889	30,457	113,079	113,079	1903	29,646	115,356	——	115,356
1891	36,059	127,819	127,819	1904	31,852	130,208	——	130,208
1892	40,000	150,000	150,000	1905	36,102	146,786	——	146,786

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7. SANDSTONES AND QUARTZITES.

GENERAL PROPERTIES.

Sandstones are sedimentary rocks, composed of grains of sand bound together by a cementing material. With the sandstones are here included certain rocks of similar origin but which, through the deposition of siliceous cement, have become partially recrystallized and are known as quartzites—metamorphosed sandstones. The so-called Potsdam sandstone occurring along the western base of the Blue Ridge is a good example.

The sand grains in standstone may vary in size up to small pebbles and may be angular or more or less rounded in form. The cementing material varies greatly in composition, the usual ones being silica, iron oxide, and calcium carbonate. The color of the rock and its adaptability depends more perhaps upon the character of the cementing material than upon the grains themselves. If silica alone is present the rock is light colored, hard, and among the most durable of rocks, but hard to work. en composed largely or entirely of iron oxide, the stone is red or brown and usually works readily; and when calcium carbonate is the cementing material the stone is light-colored or gray, soft, and easy to work. Many sandstones contain little if any cementing material, but they owe their tenacity to the pressure to which they were subjected at the time of consolidation.

All sandstones are not composed entirely of quartz grains but frequently they contain a variety of minerals, such as feldspar, mica, and other mineral species common to sedimentary rocks. These accessory minerals often give character to the rock and form a basis for a division into feldspathic, micaceous, calcareous sandstone, etc. Sandstones are of a variety of colors, the various shades of gray, buff, brown, and red being the most common. They occur in beds of greater or less thickness and are said to be thick-bedded or thin-bedded.

In age sandstones occur from Algonkian down to the most recent, although the quarrying of them at present for building purposes in this country does not include any of later age than Cretaceous.

GENERAL STATEMENT.

Sandstones and quartzites are found in workable quantity in each of the three larger divisions of the State. Quarries have not been opened, however, in these rocks except in a few of the more favorably situated localities. Consequently there are large areas of stone of good quality in which there has not been any development.

In many areas of the Piedmont province, more or less remote from transportation facilities, small openings have been made from time to time, from which stone was obtained to supply an immediate local need. Most, if not all of these, are now abandoned. Practically the only sandstone formations in the State from which stone has been quarried for building purposes and shipped beyond the limits of the State are the Newark, and Jura-Cretaceous systems. Of these the latter has been much the most extensively quarried.

The principal sandstone and quartzite formations in the State are separately treated below under (a) the larger divisions of the State, and (b) in order of geologic age beginning with the oldest.

Coastal Plain	1. Jura-Cretaceous sandstones along the "fall-line."
Piedmont Plateau	2. Older crystalline quartzites of the Piedmont. 3. Newark (Jura-Trias) sandstones.
Appalachian Mountains	4. Cambrian sandstones. 5. Silurian sandstones. 6. Devonian sandstones. 7. Carboniferous sandstones.

THE COASTAL PLAIN REGION.

Jura-Cretaceous Sandstone.

Sandstones of various degrees of coarseness are found in many places along the eastern outcrop of the crystalline rocks and extending for some distance below the head of tide. Large exposures of these rocks are seen near Fredericksburg on the Rappahannock river. Other exposures are noted at Falmouth, at the head of the Pamunkey, at a short distance below Richmond, in the neighborhood of Petersburg, and at several other points in Chesterfield county, in the upper part of Greenesville county, and over a considerable portion of Brunswick county.

This rock is described by Professor Rogers as a rather loose mixture of quartz and feldspar, the feldspar often decaying rapidly on exposure. In size the rounded grains vary from birdshot up to several inches in diameter. In certain localities the sandstone has a fine close texture, and has been employed to a considerable extent in building. The quarries in the neighborhood of Fredericksburg and Acquia creek show beds of considerable thickness of a homogenous rock of light gray or buff color, which has had extended use in buildings in Washington, Richmond, and elsewhere.

The Acquia 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 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 quarrying of this rock has been discontinued largely, it is said, because of its unfitness for exposed work.

Among the most extensive quarries of this sandstone formerly worked in the vicinity of Acquia creek and on the Rappahannock river near Fredericksburg are the *Stone, Gallahorn, Towson, Beard,* and *Addis* situated near the head of Austin's Run; the *Wallace, Brooke, and Edwinton* adjoining Acquia creek; and the *Fitzhugh and Taliaferro* on the Rappanhannock river. According to Professor Rogers, the thickness of the strata exposed at these localities is very considerable, varying from 20 to 50 or more feet, presenting in the different beds of rock marked varieties of texture and composition. The sandstone quarried is light in color, nearly white, and of uniform texture. The beds lie nearly in a horizontal position and blocks of any required size are readily obtainable.

THE PIEDMONT PLATEAU REGION.

The Older Crystalline Quartzites.

Excepting the areas of Newark sandstones described below, the quartzites and sandstones found east of the Blue Ridge, in the crystalline area, are of unknown age. A great abundance and variety of this type of rock occur within the limits of this area. Variation is from fine- to coarse-grained and conglomeratic siliceous quartzites; and from thin to heavy bedded rocks of usually some shade of gray color. In some areas, more or less epidote occurs and imparts more or less of a greenish-yellow cast to the rock. Feldspar and mica are frequent associates, the latter imparting a dark color to the rock when present in any considerable amount. Gradation is from true quartz schists on the one hand to true mica schists on the other.

The rock has been quarried in many places in years past for use as a general constructional material; and at present, quarries are operated principally for crushed stone to be used for ballast and concreting. The stone ordinarily is firm, hard and compact, highly siliceous, very durable, and is admirably adapted to the many uses that have been made of it.

Distribution.—Quartzites of variable texture and structure are found at various points along the James river between Scottsville and Lynchburg in association with micaceous schists and limestones; and as far southwestward as Leesville, in Bedford county. To the east of Scottsville, belts of a similar rock, largely conglomeratic in places, are found on both sides of the James river in Buckingham and Fluvanna counties in the vicinity of Bremo, New Canton, and Johnson. On the eastern edge of New Market, in Nelson county, a fine to coarse granular white to red quartzite is found. At the mouth of Owens creek near Greenway the beds dip to the southeast and have a thickness of from 2 to 4 feet.

The area along James river in which this type of rock is found comprises the following counties: Fluvanna, Buckingham, Albemarle, Nelson, Appomattox, Campbell, and Bedford. In the southern part of the latter county, Bedford, at Lees Mountain about 1 mile west of Leesville, the principal rock is a fine granular slaty quartzite, which readily breaks out into masses or slabs of any regular thickness and length. Its dip is generally to the southeast 60° to 80°. Some layers are hard, others a soft. The summit of the ridge or hill is composed of the white siliceo rock in nearly vertical layers and it has been quarried in many place The rock consists of nearly pure quartz without feldspar and mica, an it possesses beauty and durability as a building stone.

In Albemarle county two approximately parallel belts of quartzi occur. The most westerly one of these is on the immediate west side o Green Mountain extending in a southwest direction toward Rockfis river and in a northeast direction a little west of Charlottesville. Th second belt occurs in Findlay's Mountain extending northeastward, Fa Hill Mountain, Applebury Mountain, and near Charlottesville in Ragge Mountain, and crossing the turnpike in a belt more than half a mile wid The rock is subject to great variation over the belts, that of the easter belt being usually of finer grain than that of the belt west of Charlotte ville. In many places large slabs and masses of the stone are easil quarried and it is said to possess great durability as a building material.

According to Professor Rogers, quarries were opened many years ag at the following localities: On the western flank of Green Mountai openings at various points were made and the stone was used in the co struction of the locks and culverts of the James river canal. The be dip steeply to the southeast and are from 3 to 4 feet thick. The sto is quite uniform, easy to quarry in large blocks, and it dresses readil It is of light gray color, hard and siliceous, and contains only a fe scales of mica. On Rucker's Run in the gap of Warwick's Mountain similar rock has been quarried. This stone is described by Professo Rogers as a hard siliceous sandstone of gray color containing both fel spar and mica, and is intersected by cross-joints. The beds dip to th southeast. At the end of Fall Hill Mountain on the east side of Rockfis river, quartzite has been extensively opened and used in the constructio of the James river canal. The principal opening, situated at the end o the mountain, exposes a hard, siliceous, light-colored sandstone containin some mica and pyrite. Professor Rogers describes the layers as being fro 10 to 12 feet thick, of uniform texture, and well adapted for architectur purposes. His description follows: "Beds of grey and yellow sandsto occasionally present themselves among the darker rock and these are un formly of a coarser texture, and in many cases are rapidly decomposed b exposure to the air and weather. Quarries of the dark greenish and bluis rock have been opened in many places, and furnish a material for buildin which can hardly be excelled either for strength or permanency under exposure. Much of this rock, however, is so hard as to prove difficult of separation in the quarry. This is remarkably the case with the green variety, which occurs very abundantly for a mile or two east of Meriweather's bridge on the Rivanna.

"The grey and yellowish-red sandstone, occurring in beds sometimes of considerable breadth, and traversing the country in the general range of rocks to a considerable distance, are found in many places to furnish quarries of very valuable building material. Such of these beds as are intersected by frequent veins of quartz, are found to be by far the hardest and most valuable. In the same bed examined at points some distance asunder, a great difference in the hardness and consequent value of the material, may frequently be observed. Thus, the bed which on the eastern flank of Peter's mountain, near Gordonsville, yields a building stone which comes from the quarry in long quadrangular blocks of great hardness and durability, presents at the distance of several miles to the south a crumbling mass. . ."

In Prince William county a schistose quartzite traceable for many miles is described as occurring in Bull Run and Pond Mountains and in Baldwin's Ridge. Some of the layers are reported to be from 2 to 4 and more feet thick, are highly micaceous, and separate with great regularity into slabs of large size.

A gneissoid sandstone of light gray color is found in Orange county. Some of the stone has been quarried and used for steps, sills, and other purposes in the neighborhood. Exposures of the rock are seen at intervals along the eastern base of Southwest Mountain. The rock is penetrated by regular joints which facilitate the quarrying of large and thick slabs.

In Fauquier county less than 1 mile east of Warrenton a somewhat similar rock to that described above in Orange county is exposed over a considerable area and has been quarried for local use. Again, 4 miles west of Warrenton at the western base of Watery Mountain is a gray sandstone which has been quarried for local building purposes and for flagging.

In Nelson county at Fabers and Rockfish, stations on the Southern Railway, quarries opened in an irregular micaceous conglomerate are extensively operated at present for crushed stone used as ballast.

The Newark (Jura-Trias) Sandstones.

Seven areas of Newark rocks of Mesozoic age are distributed ove the crystalline region east of the Blue Ridge. These are shown on th accompanying geologic map and are here designated as follows:

(1) The New York-Virginia area. This represents the southern poı tion of a continuous belt of Mesozoic rocks which extends south westward from New York into Virginia, crossing the Potoma river from Maryland, west of Washington, and comprising part of the following counties in Virginia: Loudoun, Fauquieı Prince William, Culpeper, and Orange.

(2) The Richmond area, located about 13 miles east of Richmond an including parts of Amelia, Chesterfield, Henrico, Powhatan and Goochland counties.

(3) The Danville area, which extends northeastward throug Pittsylvania county into Campbell and Appomattox counties.

(4) The Farmville area in Prince Edward, Buckingham, and Cumbeı land counties. The greatest length of this area is 22 miles an its greatest width is about 4 miles.

(5) The Scottsville area, lying mostly in Albemarle county, but cov ering small parts of Buckingham and Nelson counties.

(6) The Barboursville area in Orange county.

(7) The Taylorsville area in Hanover county.

The general shape and size of these areas are shown on the accom panying geologic map. The main portion of the beds forming these area is composed of conglomerates, breccia, sandstone, shale, and slate. Of thes sandstone and shale are by far the most abundant. Besides these there ar a few thin limestone layers, and deposits of coal. The rocks are usuall more or less disturbed by faulting and with two exceptions they show a persistent dip to the west and northwest at angles varying from 15° up to 70° in extreme cases, with an average much nearer the former. In th central portion of the Richmond area the rocks have a nearly horizonta position.

The greater part of the sandstone of the Newark system in Virgini is brown or brownish-red, although occasional layers of gray sandston occur with yellow and mottled sandstones found in some of the areas. Th beds show considerable variation in thickness up to many feet with grada tion into thin ferruginous shales. Likewise, wide variation in texture is shown but in many places the beds are sufficiently thick and compact and uniform in color and texture to afford valuable building stone. It is the same reddish-brown sandstone of the Newark system that has been so extensively quarried in some of the northern and eastern states, and used so extensively for architectural purposes in the Atlantic Seaboard cities under the name brown stone.

A few quarries of this sandstone have been opened and worked in Virginia, which yielded a stone that could be used with pleasing effects in a variety of combinations, and in quality not inferior to any of that in the more northern and eastern states. The principal quarries so far worked in this sandstone are in the vicinity of Manassas on the Southern Railway, and were opened about 1868. The stone is fine-textured, light reddish-brown in color and is said to closely resemble the lighter varieties from Seneca creek in Maryland. The beds vary in thickness from 1 to 6 feet, with the usual thickness of 5 to 6 feet, and are separated by a greenish-colored shale. Blocks 40 by 20 by 4 feet in thickness have been loosened in the quarry, and a block containing 88 cubic feet was shipped. According to Dr. Merrill the quarries are located near the top of a low eminence, the strata being nearly horizontal, but with a slight dip toward the south. Only the surface of the ledge has been quarried and to a depth not exceeding 40 feet. Up to the time of the taking of the Tenth Census some 400,000 cubic feet of the stone had been removed.

In Loudoun county, the red and brown Newark sandstones have been quarried east of Leesburg, and to the south of Leesburg and east of Oatlands. The sandstone beds are separated by frequent beds of shale. Quarries can be readily opened and the stone has been tested by long exposure and does not deteriorate.

THE APPALACHIAN MOUNTAIN REGION.

Introductory Statement.

The Paleozoic sediments comprise a vast thickness of rocks, principally sandstone, shale, and limestone, which make up the Mountain province west of the Blue Ridge. An abundance of sandstone of variable composition, color, texture, and structure, is widely distributed over many parts of the province, but up to the present time no special investigation has been made of the qualities of the sandstones as to their adaptability and desirability for general building and constructional purposes. Stone has been quarried in places over the region to meet an immediate and strictly local need.

The various sandstones and quartzites of the Mountain province are discussed below, so far as we have knowledge of them, under the geologic systems to which they belong, beginning with the oldest. These systems are the Cambrian, Silurian, Devonian, and Carboniferous.

The Cambrian Sandstones.

The Potsdam sandstone (quartzite).—The so-called Potsdam sandstone or quartzite of Cambrian age, formation No. I of Rogers, is largely confined in distribution to the western slope of the Blue Ridge, and the narrow belt of rugged hills and mountains which extend westward and northwestward to the commencement of the Shenandoah or Valley limestone. According to Keith a belt of Weverton sandstone, which is an equivalent part of the Potsdam, occurs on the east side of the Blue Ridge in Loudoun county, extending across the Potomac from Maryland into Virginia in a slightly west of south course, passing a short distance west of Leesburg.

In general the Potsdam sandstone consists largely of a compact, close-grained, white or light gray rock, containing in some places, beds of a rather coarse conglomerate of white siliceous pebbles. A brownish slaty sandstone occurs in places near the bottom alternating with the former, and towards the top it passes into reddish, brownish and olive-colored argillaceous slates or shales.

Its white or light gray color, the closeness and fineness of grain, and the almost exclusive siliceous composition, make it generally well adapted for a durable building material. In many places, the joint-planes, of which there are several sets cutting the rock, are very closely spaced, subdividing it into somewhat rhombic forms, do not permit of dimension stone being quarried. Where spacing of the joints does not prevent the quarrying of any size stone, the rock is so highly siliceous, compact, and close-textured, that it is difficult and expensive to quarry. So far as the writer is aware, stone for local consumption only has been quarried from the beds of this horizon.

When crushed, the Potsdam sandstone is admirably suited for ballast and concrete work. The closely-spaced joints in many places where the rock is found serve to break the stone into small sizes, much of which does not require further crushing. In Augusta county, about one mile east of Basic, an extensive quarry is in operation in this formation along the Chesapeake and Ohio Railway for crushed stone. The stone at this locality is broken by nature into sizes sufficiently small as not to require ing.

The Silurian Sandstones.

An examination of the accompanying geologic map, will show the distribution of Silurian rocks in Virginia. As there indicated these rocks are limited in their distribution to the area west of the Blue Ridge.

The formations comprised within this system of rocks in Virginia are made up in considerable part of sandstones. Two of these formations, the Medina and Clinton, are represented by a considerable thickness of sandstone, in many places, in the region west of the Blue Ridge. According to Darton and Campbell, the equivalent of the Medina formation comprises at least three different sandstones in places, each of which is designated and mapped by a separate name.

The Silurian sandstones show much variation in color, texture, and structure. In color, variation is from red ferruginous through various shades of gray to nearly white; in texture, from fine to coarse and conglomeratic; and in structure, from thin to massive and heavy-bedded rocks. In many places where these sandstones are found their quality is sufficient to make them valuable for general constructional purposes, but as yet the demand has not been sufficient to lead to their quarrying except for immediate and local needs.

The Devonian Sandstones.

The principal sandstone of the Devonian age found in Virginia is the Monterey or Oriskany which, so far as known, has its greatest development in the middle portion of the province west of the Blue Ridge, extending northeastward, and also recognized in places further southwestward. Darton gives the following description of this rock: "The prevailing material is a hard, fine-grained, calcareous sandstone of dark blue-gray color, which weathers to a dirty buff, porous, sandy rock of varying hardness."

The thickness of the sandstone in the Monterey folio, which covers parts of Bath and Highland counties, is estimated by Darton to vary from 50 to 200 feet, and over the greater part of the area it is between 100 and 165 feet. Coarser grained phases of this sandstone occur in places. In composition, it varies from a rock composed very largely of sand grains on the one hand, to a limestone containing but few sand grains on the other, with nearly all gradations between these extremes.

So far as the writer is aware, no quarries have been opened in this sandstone. The rock is generally too friable to make a good building stone.

The Carboniferous Sandstones.

The Carboniferous comprises much the greatest total thickness of sandstone of any geologic system in the State. The distribution of the rocks belonging to this system is entirely limited to certain parts of the region west of the Blue Ridge. For convenience of description the sandstones of this system may be treated separately under two divisions: (1) The Mississippian or Lower Carboniferous sandstones, and (2) the Pennsylvanian or Coal Measures sandstones. Like the sandstones of the preceding systems, those of the Virginia Carboniferous have not been investigated as to possibilities for constructional or building material.

The Mississippian group.—As is shown on the accompanying geologic map, the rocks of the Lower Carboniferous or Mississippian group are distrubuted along the middle and western portions of the Valley province, as single isolated, usually low, ridges, from Frederick county on the north to Smyth county on the southwest. In the southwestern part of the State the ridges are found near the middle portion of the Valley extending parallel to the Valley axis, while farther northward they are found on the west side of the Valley as smaller and less numerous areas. Geographically, these rocks are found to some extent in the following counties: Smyth, Wythe, Bland, Pulaski, Montgomery, Roanoke, Craig, Botetourt, Augusta, Rockingham, Shenandoah, and Frederick.

The group comprises a variable thickness of sandstone, conglomerate, and shale. A principal member of the group is the Price sandstone, which attains a thickness of as much as 300 feet in places. It varies from a fine- to coarse-grained rock, of yellow to dark gray and greenish color. In places, it is too badly fractured and otherwise intersected by closely spaced joints to permit of dimension stone being quarried. In other places the joints are sufficiently widely spaced to admit of quarrying stone of any desirable size. The rock apparently possesses those qualities in some localities which make it a desirable stone for building purposes. So far as I am aware, it has been used only occasionally and to a very limited extent for this purpose. It has been quarried in Pulaski county and used to a limited extent for building material in the town of Pulaski.

The Pennsylvanian group.—This group of rocks comprises a vast thickness (about 3,000 feet) of alternating beds of essentially shales and sandstones partly conglomeratic, with beds of coal. The rocks are limited in their distribution to the southwest corner of the State along the Kentucky-West Virginia line and include the whole or parts of the following counties: Lee, Scott, Russell, Wise, Dickenson, Buchanan, and Tazewell. The area lies west of the Valley region and forms the eastern portion of the Cumberland plateau. Its eastern and southern border portions occupy the transitional zone between the disturbed — folded and faulted — rocks of the Valley region and the nearly horizontal rocks of the Cumberland plateau. Excepting the more or less disturbed marginal zone, the rocks of the remaining and larger part of the area are almost flat-lying, observing a general northwest dip, as may be seen from the sections, figures 1, 2, 3, and 4, of plate LVI.

The several subdivisions of this group of rocks adopted by the U. S. Geological Survey for different parts of the Virginia area which are sandstone-bearing are given under Coal on pages 336-378. Also the character of each horizon is given in the same tables.

Sandstone is one of the principal rocks of the area. Variation in the sandstone is from fine to coarse grain in texture, thick massive-bedded to thin-bedded in structure, and from white to gray in color. Not all the sandstones of this area are desirable for constructional purposes, but some of them are sufficiently even-textured and of uniform color, over considerable areas, to render them economically important and valuable for building purposes, as well as for other forms of constructional work. As yet they have been but slightly quarried, owing largely to a lack of demand for the stone and to the lack of ample transportation facilities. They have been quarried, however, in places for strictly local use as a building stone and for heavy masonry.

Uses.

As indicated in the table of production below, the uses made of the sandstone quarried in Virginia are as a building material in the rough and dressed state, and as crushed stone for railroad ballast, concrete work, and road-making. From the description above of the various sandstone formations, it will be observed that the State possesses a great abundance and wide distribution of this type of stone, admirably suited in many cases for the uses made of it. With the recent creation of the new State Department of Highways and the increasing demand for stone in concrete work, a substantial increase in the production of crushed stone in the State may be reasonably expected. Many of the sandstone formations described above are capable of producing stone desirable in all respects for concrete work.

The quarrying of sandstone-conglomerates in Virginia for grindstones, and the mining of sand for the various uses, are not included here but are discussed elsewhere under the respective headings "grindstones" and "sand," to which the reader is referred.

Production.

Value of sandstone produced in Virginia from 1899 to 1905.

Year	Value
1899	$ 8,000
1900	6,000
1901	5,303
1902	2,500
1903	4,471
1904	13,522
1905	2,000

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8. LIMESTONES AND MARBLES.

GENERAL PROPERTIES, COMPOSITION, AND OCCURRENCE.

Limestone is the name commonly applied to that group of rocks which consists essentially of calcium carbonate. The rocks belonging to this group differ in color, texture, structure, and origin. They are often quite impure, the more common accessory constituents being silica, magnesia, clay, iron, and bituminous matter. These may be present in amounts sufficient to give character to the rock when it is designated as siliceous, magnesian, dolomitic, argillaceous, ferruginous, or bituminous. Likewise, they give rise to a variety of colors among which water-blue, green, yellow, pink, red, and shades of gray to black are common.

In chemical composition the limestones show great variation. Magnesium carbonate may be present from traces up to the full percentage of a typical dolomite; and silica may range from a trace up to the limit where the stone becomes a calcareous sandstone. Such silicate minerals as mica, talc, serpentine, tremolite, etc., are of frequent occurrence in the more crystalline limestones.

Variation in texture, strength, and durability is as great as in composition. They may be fine, medium or coarse-grained, and crystalline or sub-crystalline.

Those crystalline granular limestones which are susceptible of a fine polish and are adapted to decorative work are grouped as marbles. Ordinarily, the term marble is restricted to those limestones in which the sediments have been so altered and metamorphosed as to have a crystalline texture.

Limestones are found in stratified beds, among rocks of nearly all ages from the pre-Cambrian to the most recent. Most of those used for building and ornamental work belong either to the Cambrian, Silurian, Devonian, or Carboniferous ages.

DISTRIBUTION IN VIRGINIA.

Limestone has wide distribution in the State, and is found in each of the three larger divisions, namely, the Coastal Plain, the Piedmont Plateau, and the Appalachian Mountain province west of the Blue Ridge. It is not equally distributed in the three larger divisions or provinces, nor is it of the same degree of purity. It has greatest distribution in the province west of the Blue Ridge, where it is one of the dominant rock-types. Four principal limestones of considerable commercial importance are prominently though unequally developed in this province.

The limestone of the Coastal Plain region is of the impure earthy form, and in this respect it is unlike that of the Piedmont and Mountain provinces. As a rule, the limestone of the Piedmont province differs from that of the other two provinces in being more crystalline.

For convenience of description the limestones of the State may be treated separately under (a) the larger divisions or provinces, and (b) according to geologic age. On this basis we have the following classification of the limestones which is observed in the descriptions below:

I. The Coastal Plain limestones.
II. The Piedmont Plateau limestones.
  (1) The older crystalline limestones of unknown age.
  (2) The Newark (Jura-Trias) limestones.
III. The Mountain province or Paleozoic limestones.
  (1) The Shenandoah (Valley) limestone of Cambro-Ordovician age.
  (2) The Chickamauga limestone of Ordovician (Lower Silurian) age.
  (3) The Lewistown (Helderberg) limestone of Silurian age.
  (4) The Greenbrier limestone of Lower Carboniferous age.

THE COASTAL PLAIN LIMESTONES.

The Teritiary limestones called "marls" occur abundantly in eastern or Tidewater Virginia. They are unconsolidated or at best partially consolidated, impure earthy limestones in no wise suited for a building stone. Their distribution and compositon are but partly known at present, but they have been extensively used for agricultural purposes, and on investigation will probably prove to be of considerable value for the manufacture of Portland cement. A further description of these deposits is given under the heading Marls on pages 396-400.

THE PIEDMONT PLATEAU LIMESTONES.

The most abundant and commercially important limestones of the Piedmont province are the older and highly crystalline ones of unknown geologic age. More or less impure limestones of limited extent occur in the Jura-Trias area of the Piedmont region, but so far as known, they are of doubtful commercial value.

The Older Crystalline Limestones.

General properties.—The crystalline area or Piedmont province, extending eastward from the Blue Ridge, includes numerous areas of pure and impure crystalline limestones, much of which is of workable grade marble. The limestone beds of this area show much variation in color, texture, structure, and composition. Blue, gray, white, and pink, are, in the order named, the commonest colors. Texturally, variation is from fine- to coarse-grained, and from thin-bedded or schistose to massive in structure. In composition the beds vary from nearly pure limestones, calcium carbonate, through magnesium limestones to pure dolomites, calcium-magnesium carbonate.

The limestones of this area are associated with crystalline schists, largely of the micaceous, talcose, and steatitic types. They do not form continuous belts as in the Valley region and are therefore not persistent or continuous, but form greatly drawn out lenses intercalated with the schists. The calcareous rock is sufficiently pure to be well adapted to the manufacture of lime, for architectural and other purposes, and in many places possesses the requisite properties of a desirable ornamental stone, for which uses the rock has been quarried in the past.

Distribution, mode of occurrence, and general characters.—In Albemarle and Orange counties, a belt of slaty rocks containing embedded deposits of limestone occurs to the west of Scottsville in Albemarle county, and extends in a northeasterly course, showing at intervals the limestone masses on Buck Island, Limestone, and Meechump, creeks. According to Professor Rogers, the limestone at Meechump contains 83.2 per cent. of calcium carbonate.

Exposures of the limestone are again shown about one and a half miles east of Gordonsville, in Orange county, and also on the road from Gordonsville to Orange court-house. According to Professor Rogers the limestone beds at these localities are dark blue and slaty, presenting smooth talcose surfaces and occasional thin veins of carbonate. West of and between the last locality and Montpelier is found a bed of fine-grained marble, which bears a striking resemblance to that extensively exposed on the James river opposite Warminster, in Nelson county. The width of the exposure is about 90 feet. The rock is white, shaded with pink, and contains occasional green talc.

Doctor Henry Froehling gives the following analysis of limestone from the Buford property, near Manteo station, on the Chesapeake and Ohio Railway, in the vicinity of Warminster, Nelson county:

	Per cent.
Calcium carbonate	54.833
Magnesium carbonate	33.524
Alumina, Iron oxide	3.600
Silica	5.500
Phosphoric oxide	.170
Organic matter	.827
Water	1.240
Total	99.704

Exposures of a similar rock, some of considerable extent, are found on the Rapidan river, nearly in the general line of bearing of those referred to above. The westernmost of these occurs nearly opposite the mouth of Summerduck creek. The rock is pinkish, sometimes gray, fine-textured, and parted into thin layers of from 1 to 2 inches thick. It burns into white lime and has been used for domestic purposes and for building. Two other ledges of limestone of considerable extent are found lower down the river; the uppermost one, about 1 mile above the mouth of Brooke's run, is mostly blue, fine-granular with little or no quartz, mica or other impurities, and exists in layers several feet thick. The strike is between northeast and north-northeast with a steep southeast dip. Width of the exposure on the river is about 60 feet. About 300 yards further east is another bed about 120 feet thick where exposed, of blue and pink shades intersected by white veins of carbonate. The beds are separated into thin layers which have the same general dip as those above.

In the same general direction, limestone shows near the mouth of and on Mountain creek, in Culpeper county; and on the Rappahannock river at the mouth of Marsh run, in Fauquier county. The rock is slightly talcose and micaceous, of bluish color, veined with carbonate and of slaty structure. It has been quarried and burnt for lime in both counties. Similar interrupted limestone beds appear in Fauquier and Loudoun counties, associated with slaty and gneissoid rocks. One of the most extensive of these is traced along the western base of Rappahannock Mountain and thence to the vicinity of White Plains. The rock is of variable color and texture, sometimes light blue and coarse-grained, and sometimes light gray with films of talc. It has been quarried at several points and burned for lime.

Further towards the northeast, a narrow bed of limestone occurs near Dover Mill on Little river, about 2 miles west of Aldie, in association with micaceous and argillaceous slates. Beyond this and in the same direction are several exposures north of the road leading from Aldie to Snickers Gap in the Blue Ridge. More or less extensive exposures are found to the northwest and near Goose creek. The rock is fine-textured, of blue color, about 20 feet wide, and has been quarried quite extensively at several places.

Marble.—Calcareous masses occur at Taylortown in Loudoun county enclosed in greenish, slaty talcose rocks. West of this are several layers of beautifully white marble of fine and uniform texture, free from veins, and can be obtained in blocks from 1 to 2 feet thick, and several feet long. Both the blue and the white crystalline limestone of these localities appear to be susceptible of good polish.

Concerning the marble of the Goose creek area in Loudoun county, Doctor Merrill says: "White and pink marbles of excellent quality also occur in the vicinity of Goose Creek, in Loudoun county. I have seen samples of the white, which for purity of color, fineness of grain, and general excellence, are not excelled by any marble now quarried in the United States, but the extent of the deposit is as yet unknown."

Concerning the limestones of Loudoun county which Keith groups as of Cambrian age, he says: "The limestones occur in the form of lenses in the slate, and are developed along two lines, one being the axis of South Mountain, the other lying immediately west of Catoctin Mountain. Those of the eastern line are thicker and more continuous. Most of the outcrops have been worked for lime but the chief value of the limestones lies in the beds of marble along the line of their eastern outcrops. The marbles are interbedded with slate and schists, sometimes in one bed, sometimes in two, but the beds are generally too small to work. At Goose Creek the marble bed is about 52 feet thick and has been worked to a considerable depth. The varieties there shown are chiefly white, but there occur also, banded blue and white, serpentinized white and green, pink and white, and green and white. These beds are pure, and the stone is of great beauty, and takes a good polish; thus far, however, the lack of transportation has prevented extensive quarrying. Farther south along its range the limestone is less metamorphosed into marble and increases in thickness.

"Ornamental stones of great beauty are worked in the Newark conglomerate and Loudoun marbles. The Loudoun marbles have not been developed for commercial use, but for beauty and variety they compare favorably with any in the country."

An analysis of a medium crystalline, pure white, marble from Mr.

Henry Fairfax's place, in Loudoun county, gave Mr. J. R. Eoff, Jr., in the laboratories of the Virginia Polytechnic Institute, the following results:

	Per cent.
Insoluble matter	2.12
Alumina / Iron oxide	0.60
Lime	44.26
Magnesia	8.10
Lime equivalent in calcium carbonate	79.00
Magnesia equivalent in magnesium carbonate	17.01

Verd Antique Marble.—Concerning some of the beds of marble in the vicinity of Goose creek, in Loudoun county, Doctor Merrill says: "These same beds also produce a green or very antique marble of great beauty. The stone is an impure magnesian limestone, admixed with a large amount of serpentinous matter. The prevailing hue is green but the stone is streaked and blotched in various shades and often brecciated. It is well adapted to interior work but the presence of abundant pyrite renders it unfit for exterior application."

In Grayson county, near the North Carolina line, a belt of coarsely-crystalline white to pink limestone (marble) is traceable in a southwest direction for several miles. The belt as exposed will average several hundred feet wide in places and the stone has been quarried at several points and used for making lime and as a building stone. It is quite freely streaked with large and small enclosures of a greenish silicate, which on a polished surface should give a pleasing effect and could be used to advantage as an ornamental stone and for the same purposes as the true verd antique marble. Figure 2, plate X, is a view in one of the openings made in this belt of limestone.

Extending from Mount Athos, 5 miles east of Lynchburg, in Campbell county, northeastward to Riverville, in Amherst county, is an extensive belt of sedimentary rocks known as the "James River Iron Belt," composed of alternations of quartzites, micaceous, talcose, and chloritic schists, and limestones. Parts of Campbell, Amherst, and Appomattox counties are included in this belt, which has a general northeast direction. Within this belt have been located a number of different limestone beds having an aggregate thickness of more than 1,200 feet. The stone is crystalline-granular of white, gray and darker colors, and usually contains more or less magnesia in its composition. It was largely quarried and used as a flux in the old furnaces once in operaton in that section. It has also been quarried and used to some extent for making lime.

Fig. 1.—View in quarry of crystalline schists at Faber, Nelson county.

Fig. 2.—View in opening of marble in Grayson county.

CRYSTALLINE SCHIST AND MARBLE QUARRIES IN VIRGINIA.

Samples of the limestone from Campbell and Appomattox counties were collected and analyzed by J. B. Britton with the following results:

Constituents.	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.
Calcium carbonate	77.67	67.85	82.45	65.10	91.51
Magnesium carbonate	3.78	6.02	2.10	2.96	2.59
Silica	15.88	20.42	10.98	26.90	2.56
Alumina	0.97	1.20	0.70	0.86 }	
Iron oxide	1.16	3.80	2.90	3.94 }	2.77
Manganese oxide	0.07	trace	trace	trace }	
Iron sulphide	———	0.22	0.19	——— }	
Phosphoric oxide	0.003	0.006	trace	0.004	———
Water	0.27	0.41	0.16	0.21	0.41
Total	99.803	99.926	99.48	99.774	99.84

I. Blue limestone from nearly vertical stratum, about 3 feet wide, on the north side of the Norfolk and Western Railway. Supposed to be an outcrop of a stratum 40 feet wide exposed in the bed of a branch to the south of the railroad.
II. Light blue limestone from stratum about 25 feet wide, about 300 yards from railroad bridge, 7 miles from Lynchburg.
III. Same as II but of dark blue color.
IV. Blue limestone from stratum about 50 feet wide exposed in branch a little south of the railroad.
V. White crystalline limestone from stratum about 40 feet wide.

To the east of the Southwest and Green Mountains, in Albemarle county, the belt of rocks including beds of limestone exposed on Mee-chump's creek and at other places is traced with but little interruption in a general southwestward course through several counties.

Professor Rogers gives the following analyses of limestone found below Raccoon ford at the end of Southwest Mountain:

	I Per cent.	II Per cent.	III Per cent.
Calcium carbonate	77.48	90.40	75.44
Magnesium carbonate	5.20	6.44	5.04
Alumina } Iron oxide }	1.20	.52	.92
Silica	15.72	2.00	17.92
Water	.40	.64	.63

I. Deep pink limestone with gray white spots, compact and crystalline. Gibson "vein."
II. Gibson quarry, south side of the Rapidan river. Grayish-blue, compact, semicrystalline limestone, cut by white veins.
III. Deep blue compact limestone from Rapidan river, 300 yards east of Gibson "vein."

At Warminster, in Nelson county, the structure of the limestone is more or less slaty and the general color of the stone is bluish-gray, frequently veined with white crystallized carbonate. At this locality the limestone is associated with talcose schist and a white and hard siliceous rock of fine texture. According to Professor Rogers: "Near the mouth of Tye river and on the Rockfish, a true marble is found of beautiful whiteness, and of a texture which renders it susceptible of a fine polish, as well as being readily wrought by chisel. A few miles from Lynchburg, in Campbell county, a good marble is likewise found, and limestone is abundant in the same neighborhood." The limestone at Warminster contains according to Professor Rogers 81.4 per cent. of calcium carbonate.

About 2 miles east of Evington, on Captain Saunders' place, on the waters of Back and Troublesome creeks, are several parallel beds of medium granular crystalline limestone, which are traceable in a general southwesterly direction through Campbell county into Pittsylvania, in the vicinity of Toshes and Sandy Level.

This rock is associated with fine- and coarse-grained micaceous schists and in the Evington portion of the belt a hard- and fine-grained quartz schist. Valuable deposits of an excellent grade of barite described on pages 309-318, are directly associated with the crystalline limestone in both Campbell and Pittsylvania counties, and extensive mines of the mineral have been operated at various localities in the two counties.

The limestone beds vary in thickness up to 60 and more feet. The stone is fine to coarsely granular, beautifully white with pink and darker shades shown in places, and contains in some places more or less black mica and greenish tremolite. Some pyrite and chalcopyrite disseminations occur in the stone in many localities. In structure the stone varies from schistose to massive, and it has been quarried in places to a limited extent for making lime.

The following analyses of this stone made by Dr. Walter B. Ellett of the Virginia Experiment Station shows its composition to be:

	I Per cent.	II Per cent.	III Per cent.
Insoluble matter	1.66	0.87	1.10
Barium sulphate	0.62	0.65	1.62
Barium oxide	0.40	0.42	1.62
Alumina / Iron oxide	0.24	0.30	0.96
Lime	50.04	52.60	51.00
Magnesia	3.28	1.40	1.85
Calcium carbonate	89.36	99.33	91.07
Magnesium carbonate	6.61	2.82	3.73
[illegible] sulphide	——	——	0.36

ine limestone from the Hewitt mine, Campbell county.
lline limestone from the Ramsay mine, Pittsylvania

Newark (Jura-Trias) Limestones.

Some of the rocks of the Newark areas in the Piedmont area east of the Blue Ridge, include thin layers of deposits of impure limestone, but up to the present time no use has been made of the limestone. The doubtful quantity and quality of this type of rock in the Newark areas render it of little or no commercial value.

In describing the Newark formation in Loudoun county, Keith says: "They [Newark rocks] consist for the most part of red and brown sandstone and shale, beds of gray sandstone and conglomerate and limestone conglomerate being present in smaller amount. The limestone conglomerate is made up of worn pebbles of limestone of various colors usually blue, interbedded in a reddish, calcareous matrix. Rarely pebbles of slate and gray sandstones also occur with those of limestone. The pebbles were deposited in their matrix in a very irregular manner, and in sharply limited areas."

The limestone conglomerate has been quarried on the Maryland side east of Point of Rocks and extensively used for interior decoration under the name of "Potomac Marble," and is of great beauty.

THE MOUNTAIN PROVINCE (PALEOZOIC) LIMESTONES.

The Paleozoic series of rocks comprises a vast thickness of sedimentary types which make up the entire Virginia area, Mountain province, west of the Blue Ridge. The principal rock-types are limestones, shales, and sandstones. Of these, limestone forms one of the most important rocks in each of the larger geological time divisions, represented in the area. A variety of texture, structure, and color, is shown, which are brought out in the separate description of the individual limestones below.

There are inexhaustible supplies of limestone in the Mountain province of Virginia suitable for the various uses made of this rock. It has been extensively quarried over many parts of the area for use as a furnace flux, for lime-making in building and agriculture, for building stone, for road metal and ballast, and for the manufacture of cement, both Portland and natural.

The limestones which have been quarried to a greater or less extent over the area west of the Blue Ridge and used for one or more of the purposes enumerated above, are the Shenandoah, Chickamauga, Lewistown, and Greenbrier. The geographical distribution of these is given in the following descriptions and in the order of geological succession, from the lowest to the highest.

The Shenandoah (Valley) Limestone.

The Shenandoah limestone, Formation No. II or Valley Limestone (Rogers, is the most persistent limestone formation in the State. It is tl underlying or basement rock of the Great Valley (Shenandoah) of Vi ginia, which extends from the Potomac river on the north to the Tenness boundary on the southwest, and lying immediately west of and parallel the Blue Ridge. It includes parts of the following Valley countie Frederick, Clarke, Warren, Shenandoah, Page, Rockingham, August Rockbridge, Botetourt, Roanoke, Montgomery, Pulaski, Wythe, Smyth, ar Washington. Besides these it is found in Lee, Scott, Russell, Tazewe Bland and Giles counties, in southwest Virginia. The Knox dolomite (eastern Tennessee is the correlative of a part of the Shenandoah limeston

In its normal development the Shenandoah limestone is probably n less than 4,000 feet thick and in places it is much thicker. It is separab into several different members, which are described in some detail by D Bassler under "Cement and Cement Materials" on pages 93-99. Profess H. D. Campbell makes 5 distinct divisions of the Shenandoah limestone the middle Valley portion of Virginia. These are:

Period.	Name of formation.	Thickness in feet.
Ordovician.............	Liberty Hall limestone	1000 ±
	Murat limestone	100—150
	Natural Bridge limestone	3500+
Cambrian.........	Buena Vista shale	600—900
	Sherwood limestone	1600—1800

According to Darton, the eastern portion of the Staunton quadrangle underlain by the Shenandoah limestone, which comprises several membe The lowest of these is described as a thick series of dark magnesian lim stone, grading upward into a series of lighter colored beds, which conta nodules and layers of chert irregularly distributed. The upper memb of the limestone is described as a purer and more thickly bedded formatio having a thickness of from 200 to 350 feet and very fossiliferous. Accor ing to Campbell, there appears to be no way of distinguishing the top fro the bottom of the Shenandoah limestone where exposed in the Brist quandrangle.

The Shenandoah limestone shows considerable variation in characte It usually contains much chert in the form of nodules and layers irregular distributed through the limestone, and in some beds the chert is entire absent. The chert varies much in color and texture. The limestone much folded and crushed in places, when it is usually interlaced with i numerable vein-like lines and knife-edge stringers of white crystalliz calcite and dolomite. The rock has been frequently crushed and broken along certain lines into smaller masses and fragments and recemented as a limestone breccia.

Variation in the Shenandoah limestone is from a fine-granular, dark-blue, nearly black rock, to a fine and fairly coarse crystalline light-gray, nearly white limestone. In places there appear bands of a homogeneous compact and dense-textured, light-gray limestone within the formation. The formation is marked in other places by bands or streaks of a nearly pure limestone well suited for the making of lime, for which it has been quarried at many localities. The principal member of the Shenandoah limestone, named by Professor Campbell the Natural Bridge limestone, is usually a heavy-bedded, dark-blue to gray magnesian limestone, frequently dolomitic. This is the most important member of the Shenandoah limestone for the production of building stone. Quarries have been opened in it in many places through the Valley region, especially in southwest Virginia, and the stone used locally for building purposes. On account of its high magnesian content this member of the formation has no value as a material for the manufacture of Portland cement. The other members of the formation contain desirable material for cement manufacture, and, for this purpose, they are discussed on pages 93-99.

The following chemical analyses serve to indicate the general character of the magnesian member of the Shenandoah limestone in Virginia:

	I Per cent.	II Per cent.	III Per cent	IV Per cent.	V Per cent.
Insoluble residue	2.90	0.594	0.45	0.20	——
Silica (SiO_2)	trace	.073	trace	trace	7.37
Titanium oxide (TiO_2)	none	none	none	none	.09
Alumina (Al_2O_3)	0.43	0.344	0.24	0.37	1.92
Ferric oxide (Fe_2O_3)	0.94	0.19	0.17	0.22	0.29
Ferrous oxide (FeO)	——	——	——	——	0.63
Manganese oxide (MnO)	none	0.193	0.37	trace	none
Lime (CaO)	30.06	29.085	29.50	30.71	28.39
Magnesia (MgO)	18.41	20.54	19.93	21.56	18.30
Baryta (BaO)	none	none	trace	none	——
Potash (K_2O)	0.24	0.22	0.56	0.12	1.09
Soda (Na_2O)	0.21	0.38	1.03	0.10	0.09
Water (H_2O) 100°C.— } Water (H_2O) 100°C.+ }	3.30	2.58	3.73	3.92	0.09 / 0.49
Carbon dioxide (CO_2)	43.98	45.40	44.01	43.88	41.85
Phosphorus pentoxide (P_2O_5)	none	none	none	none	0.03
Sulphuric anhydride (SO_3)	none	none	none	none	——
Total	100.47	99.599	99.99	101.08	100.63

I. Limestone. Massive, grayish-black, fine-granular, crushed and recemented with stringers of white calcite. Two and three-quarter miles southwest of Roanoke City, Roanoke county, Virginia. Dr. W. E. Barlow, analyst.

II. Limestone. Grayish white and moderately close crystalline. From the 190-foot level in the Austinville Zinc and Lead mines, Wythe county, Virginia. Dr. W. E. Barlow, analyst.

III. Limestone. White, coarsely crystalline and crushed. Bottom of open-cut in the Austinville Zinc and Lead mines, Wythe county, Virginia. Dr. W. E. Barlow, analyst.

IV. Limestone. White and medium crystalline. Bottom of open cut in the Austinville Zinc and Lead mines, Wythe county, Virginia. Dr. W. E. Barlow, analyst.

V. Limestone. Staunton, Augusta county, Virginia. George Steiger, analyst. U. S. Geological Survey, Bulletin No. 228, p. 306.

Numerous analyses made of specimens of the limestone, collected by Dr. R. S. Bassler, throughout its extent in Virginia, are given under Cement and Cement Materials, pages 93-99, of this volume.

The Chickamauga Limestone.

Above the white argillaceous limestone at the top of the Knox dolomite, the equivalent of the Shenandoah limestone except the basal portion of the latter, is a series of blue, flaggy limestones, known as the Chickamauga, named from Chickamauga creek in Walker and Catoosa counties, Georgia, where the rocks of this formation seem best developed. The limestone is of Ordovician age. Dr. Bassler discusses the stratigraphic sequence and limitations of the Chickamauga limestone in Virginia on pages 133-137. It becomes heavier bedded toward the base and at times is, with difficulty, separated from the underlying Shenandoah limestone. Campbell states that its base is generally marked by a heavy blue bed carrying black chert which serves to fix the boundary in many places.

The Chickamauga limestone in Virginia is confined to southwest Virginia and to the counties on the west side of the Valley. So far as it has been studied, the Chickamauga limestone occurs in the following southwest Virginia counties: Lee, Scott, Russell, Tazewell, Smyth, Washington, and Bland. The average thickness of this limestone for southwest Virginia is probably less than 1,000 feet.

The chief economic importance of the Chickamauga limestone lies in the fact that it is the great marble-producing formation of the South. It is this formation that carries the famous marbles of East Tennessee. The marble of this formation (Holston) in Virginia has received little or no attention as yet and the developments are very meagre.

Along the northern base of Clinch Mountain, in Scott county, the Chickamauga limestone (Holston) carries near the bottom a variable bed of gray and red mottled marble. The marble is extremely variable in character and in thickness. In places it is highly crystalline and of good color. No developments have been made in this belt. At the northern base of Big Walker Mountain, Bland county, in the great bend between Bland and Sharon Springs, the Chickamauga limestone carries marble of coarse crystallization and of light gray color. It is found in massive beds and should prove to be a desirable building stone. It has not been developed except for local use.

A coarsely crystalline marble of light color, collected by Bassler from the base of the Holston formation at Speer Ferry, Virginia, gave Mr. J. H. Gibboney on analysis:

	Per cent.
Insoluble residue	0.86
Alumina } Iron oxide }	1.10
Lime	55.00
Magnesia	.08
Calcium carbonate	98.21
Magnesium carbonate	0.17
Total	100.34

Concerning the marble beds of the Chickamauga limestone in the Bristol folio, Campbell says: "A marble of this age [Chickamauga] is found in the Bristol quadrangle in the vicinity of Moccasin Creek, near the western margin of the quadrangle. It is the eastern extension of a belt of gray, coarsely crystalline marble which is particularly well shown in the vicinity of Gate City. Its texture is so coarse that it can be used only for structural purposes.

"In the great syncline south of Clinch Mountain there occur, in the carboniferous limestone, one or two narrow bands of red or mottled marble which greatly resembles the red marble of East Tennessee. Much of this Carboniferous rock is merely red, earthy limestone, but some bands are highly crystalline and full of fossils, like the best Tennessee marble."

The Lewistown Limestone.

The Lewistown limestone, the equivalent of Professor Rogers' Formation VI, and the Lower Helderberg, Salina, and Niagara, of the older geologists, has wide distribution in the Mountain province of Virginia, west of the Blue Ridge. It can probably be traced entirely across the State in an approximate northeast-southwest direction, developed for the most part at the present time along the west side of the Valley, although found well within the limits of the Valley proper in many places. Further distribution and description of the Lewistown limestone are given on pages 151-156. In southwest Virginia, Campbell has described and mapped the Lewistown limestones under the names, Giles, for the area covered by the Pocahontas and Tazewell folios, and Hancock, for the area covered by the Estillville and Bristol folios.

The Lewistown limestone is usually a pure, thickly bedded, fossiliferous limestone, containing some cherty members and occasional sandy beds, and calcareous shales. It is especially fossiliferous in its middle beds and in thickness varies up to 400 feet. It has its greatest development in Virginia in the middle Valley or Clifton Forge district, and thins considerably to the northeast and southwest of this district. The thinning appears to be greatest towards the southwest. It weathers rapidly on the outcrop and exposures of the fresh limestone are comparatively few. Geologic sections and chemical analyses of the Lewistown limestone for different parts of the State are given on pages 151-156.

The two following sections, in Alleghany county, were measured by Mr. R. J. Holden at Clifton Forge and at the ford of Potts creek:

Clifton Forge Section, Alleghany County.

		Thickness in feet
Devonian.	Shale	?
Oriskany.	Thin bedded Sandstone	12
Lewistown	Good limestone	3
	Sandy limestone	5
	Good limestone	15
	Limestone with chert nodules	50
	Limestone with Bryozoa	18
	Sandstone	32
	Limestone, residual clay with probable limestone	22
	Thin bedded shaly limestone	24
	Sandstone	4
	Limestone, shaly	11
	Total	196

Section at ford of Potts Creek, 0.5 mile above Aritts, Alleghany County.

		Thickness in feet
Devonian.	Shale	?
Oriskany.	Sandstone	6
Lewistown	Pure limestone (sandy in upper layers)	45
	Cherty limestone	55
	Massive sandstone	10
	Coarse reddish limestone	10
	Total	126

Concerning the Lewistown formation in the Monterey folio, covering parts of Bath and Highland counties, Darton says: "The formation consists of limestones which are cherty, shaly, and sandy above, more massive in the middle, and thin-bedded or shabby below. The proportion of chert in the upper beds diminishes to the south, but the presence of a cherty member at the top of the formation is always characteristic. Next below there are usually alternations of shaly limestones, which to the southeast contain some very sandy layers. There are also included some thicker layers of purer limestone. The middle members are irregular in character and vary greatly from place to place. A very characteristic member near the center of the formation is a dark-blue, wavy-bedded, massive limestone 50 to 60 feet thick, merging upward into harder, sandy limestone and hard, massive limestone with thin streaks of chert. At its base there is usually a distinct coralline bed. The lower half of the formation consists of slabby limestone merging downward into an irregular series of alternations of calcareous shales and impure limestones. . . The series of flaggy beds which constitute so large a portion of the formation are quite pure limestones, dark on fresh fracture, but weathering lighter on exposure. The beds are mainly from one-half to 2 inches thick, with smooth surfaces, along which the layers readily separate. To the southeast the upper part of the formation includes, just below the cherty beds, a very pure, massive, fossiliferous, semicrystalline limestone."

"The thickness of the Lewistown limestone averages about 900 feet over the greater part of the Monterey quadrangle, but to the extreme southeast it decreases to about 600 feet." The limestone includes abundant fossils.

Along the western base of Little North Mountain, in Augusta county, a complete cross-section is opened near Ferrol exposing, according to Darton, 200 feet of pure limestone, and farther north at Buffalo the same authority states that there are several partial exposures in which about 150 feet of thickly bedded, pure limestone is seen.

In southwest Virginia, Campbell describes the Hancock limestone (Lewistown) in the Bristol folio as follows: "Along the southern slope of Clinch Mountain the Rockwood (Clinton) formation is overlain by a blue or gray cherty limestone which is generally regarded as the uppermost member of the Silurian series and which is named from Hancock county, Tennessee." It is very thin as a rule but reaches in several places where measured a thickness of 30 and 175 feet.

In the Pocahontas and Tazewell Folios of southwest Virginia, Campbell describes the Lewistown limestone as the equivalent of a part of the Giles formation, names from Giles county, Virginia. He describes the Giles formation in the Pocahontas folio as consisting of shaly limestone, massive limestone, chert, and coarse yellow sandstone. The geographic distribution of the beds is uncertain, as they are generally covered on their outcrops.

According to Darton, both the Shenandoah and Lewistown limestones in the area covered by the Staunton folio are often suitable for marble, but the only attempts at its production has been in the Lewistown limestone at Craigsville and Bells Valley in Augusta county. The quarries at Craigsville were moderately extensive but the marble there was found to be too short and broken for profitable working.

Doctor Henry Froehling gives the following analyses of the Craigsville marble, in Augusta county:

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Calcium carbonate	95.75	94.95	96.47	96.43
Magnesium carbonate	1.10	.29	1.20	.14
Alumina Iron oxide	1.10	1.80	.60	1.12
Silica	.47	.20	.41	.80
Water and organic matter	1.52	2.60	1.21	1.35
Total	99.94	99.84	99.89	99.84

I. Light gray marble.
II. Dark marble.
III. Dark fossiliferous marble.
IV. Red fossiliferous marble.

In many places the Lewistown limestone possesses the requisite qualities of a desirable building stone, but its principal use up to the present time has been as a fluxing material in the iron furnaces. It has been and is still somewhat extensively quarried in the Clifton Forge district and used for flux. It is also quarried and used for the same purpose in Shenandoah county.

The Greenbrier Limestone.

The Greenbrier limestone, Lower Carboniferous (Mississippian) in age, is the limestone portion of Professor Rogers' formation No. XI and was subsequently named by him the Greenbrier limestone. Campbell mapped and described a Mississippian limestone in the Estillville and Bristol quadrangles as the Newman limestone, named from Newman Ridge in northern Tennessee. As yet full details concerning composition and local distribution of the Mississippian limestones in Virginia are not known. Their general distribution so far as known is given on the accompanying map. Description and analyses of the Greenbrier and Newman limestones are given on pages 157-158.

The distribution of the Greenbrier limestone in the State is limited to southwest Virginia, chiefly to those counties west of the Valley region proper, which in part border on the West Virginia line. These include, so far as known at present, Lee, Scott, Wise, Washington, Smyth, Bland, Tazewell, and Wythe counties. It has greater distribution in West Virginia where it roughly parallels the Virginia boundary.

In Virginia, one of the principal lines of outcrop of the Greenbrier limestone is along the border of the coal field. It generally consists of heavy blue limestone, cherty at some horizons, grading upward into thin beds of a light blue color, becoming decidedly shaly at its upper limits, and is abundantly fossiliferous. It varies in thickness, ranging according to Campbell, from 900 to 1,000 feet in the Tazewell quadrangle; from 1,200 to 1,700 feet in the Pocahontas quadrangle; and approximately 1,000 feet in the Bristol quadrangle. At Big Stone Gap, Wise county, the formation is 930 feet thick, composed in its upper part of calcareous shale, grading downward into shaly limestone and hard blue cherty limestone. In the Clinch syncline, Campbell estimates its thickness to be at least 1,500 feet. It is, so far as its composition is known, a non-magnesian limestone, a fact which renders it especially desirable for certain commercial purposes.

The Greenbrier limestone has only been utilized to a small extent in Virginia and strictly for local purposes. At Big Stone Gap, Wise county, the lower layers of the limestone are quarried and used for flux in the iron furnace at that point. Lime in abundance could be produced from many of the beds of limestone should the demand be sufficient to warrant the working of quarries. It will probably prove to be in the future an important source of material for cement manufacture in southwestern Virginia.

The following are analyses of the Newman (Greenbrier) limestone from near Cumberland Gap, quoted by E. C. Eckel in Bulletin No. 285 of the United States Geological Survey:

	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
SiO_2	1.40	1.86	5.05	4.20	2.00	2.80	1.32	4.12	0.74	5.78
Al_2O_3, Fe_2O_3	1.00	0.96	1.86	1.50	1.00	0.90	1.23	0.42	0.24	0.46
$CaCO_3$	94.57	94 85	90.05	89.54	94.57	91.72	95.62	87.10	95.50	90.90
$MgCO_3$	3.03	2.33	3.04	4.76	2.50	4.58	1.32	3.30	2.79	1.46

MARBLE.

Marble is partly described above under the different limestones with which it is associated west of the Blue Ridge. The localities are given above so far as they are known. Under the present heading is assembled in résumé form, with some description, the principal varieties of marble found west of the Blue Ridge, chiefly from color standpoint.

Bands occur in some of the limestones of this region, especially the Shenandoah and Chickamauga, of a color and texture adapted to ornamental purposes. There are according to Professor Rogers and other more recent geologists numerous varieties of these marbles which are distinguished chiefly by their color. The special varieties mentioned are:

(1) A dun-colored marble of homogeneous and coarse texture, and susceptible of fine polish. According to Professor Rogers, this is perhaps the most abundant marble of good quality found in the northern and middle counties of the Valley. It is met with near New Market and Woodstock, and on the opposite side of Massanutten Mountain, in Page county, and has been traced for some distance both north and south.

(2) A mottled bluish marble which occurs a short distance west of New Market and may be traced for many miles. It is described as being a somewhat coarser grained rock than the dun-colored marble.

(3) A gray marble occurring some three-quarters of a mile southeast of Buchanan near the contact of the Potsdam sandstone and the Valley limestone. It is of variable color, ranging from white to gray, and is a massive, compact, fine-grained rock. As exposed in Stone Run the bed is about 50 yards wide.

(4) A white marble of exquisite color and fine-texture occurs about 5 miles from Lexington, in Rockbridge county. Professor Rogers says that the marble of this particular locality can scarcely be excelled in susceptibility of polish, fineness and evenness of grain, and purity of color. Marble of similar color but not so abundantly nor of such excellent quality, occurs at other localities in the Valley.

(5) A red marble occurs in several of the southwestern counties. Professor Rogers described a red marble from near the base of Angel's Red Mountain, in Giles county, and one of the same here in the neighborhood of Chapman's ferry. In Scott county a mottled marble occurs in considerable quantity a short distance to the west of the Court-House. In the Valley portion of this region the dun-colored variety of marble and others are also found.

(6) A shaded marble is found in Rockingham county, which is said to

be compact, susceptible of a beautiful polish, and of a yellowish-gray and slate color. This variety is a compact, fine-textured rock, susceptible of a good polish, has been opened and to a small extent worked in Rockingham county.

(7) A black marble is found several miles northwest of Blacksburg in Montgomery county, which is a very compact, fine-textured, homogeneous rock and is susceptible of a good polish. It is found in considerable quantity outcropping on a number of adjoining farms and has been opened in a small way on Dr. Ribble's place, but systematic quarrying has not been attempted. The rock is beautifully homogeneous in color, and, unless the thin knife-edge seams of calcite do not prevent the quarrying of dimension stone, it should prove to be a most desirable ornamental stone.

Cave (onyx) marbles.—The stalactitic and stalagmitic deposits and crusts on the walls and floors of the limestone cave and caverns, so abundantly developed in places through the Valley region of Virginia, west of the Blue Ridge, furnish, when cut, occasional fine pieces of the so-called onyx marble. Of these, the Luray caverns, in Page county, are the largest and best example in the State. As Doctor Merrill remarks, the stone from this source is too easily fractured and too uneven in texture to be worked economically, even though the deposit were of sufficient extent to warrant the opening of quarries. Concerning the cave marbles in general, Doctor Merrill says: "But at best the cave marbles of America must rank as 'uniques' rather than objects of commercial value. They will never become regular sources of supply. There is too much waste and too much uncertainty regarding amount and quality."

Uses.

An examination of the table given below of production of limestone in Virginia, shows the varied uses made of the stone. All purposes for which limestone is used are shown. These include:

(1) Building stone. Limestone is one of the popular building stones where it is convenient to market and possesses the requisite quality and color. Marble, the crystalline variety of limestone, is the most valuable variety. The limestones found west of the Blue Ridge in Virginia have been used to a considerable extent locally for building purposes. Each of the principal limestone formations described above has been utilized to some extent for building.

(2) Road material and ballast. Nearly all varieties of limestone are used for road material and ballast, but those which combine good wearing qualities with cementing properties are the most desirable. Considerable

limestone has been used in places in the Valley region for this class of work. It is probable that a substantial increase in the quarrying and crushing of limestone for this grade of work will be shown in the future in the Mountain region of Virginia.

(3) Concrete. Limestone, crushed to gravel size or for special grades of work to flour, is used with cement for concrete. The utilization of limestone in the State for this purpose has only begun. Inexhaustible supplies of stone suited for this purpose are found west of the Blue Ridge.

(4) Lime and cement. Limestone of proper composition is used in the manufacture of lime for building and agricultural purposes and in the manufacture of both natural and Portland cement. Large quantities of limestone are quarried over portions of the Valley region and burned for lime. Natural cement is made from an impure argillaceous limestone, of which large supplies of this grade of rock occurs in Virginia and has been and is being quarried for the manufacture of natural cement. For the manufacture of Portland cement a pure limestone or one containing a minimum amount of magnesium carbonate is essential. A good grade of Portland cement should contain in the finished product not more than 3 per cent. of magnesia. Inexhaustible supplies of limestone of excellent grade for the manufacture of Portland cement are found in the region west of the Blue Ridge. Only one plant, however, has yet been established in Virginia for the manufacture of Portland cement, namely, the Fordwick Portland Cement Company at Craigsville, in Augusta county. The cement materials and cement industry in Virginia are discussed in full elsewhere on pages 86-167.

(5) Furnace flux. Limestone is extensively quarried west of the Blue Ridge and used for fluxing material in the iron furnaces over the region. Each of the principal limestone formations described above yields some material for this purpose.

Production.

Value of the production of limestone in Virginia by years from 1900 to 1905 inclusive.

Year	Building purposes	Paving, road-making, etc.	Made into lime	Stone sold to lime burners	Crushed stone, etc.	Flux	Total
1900	5 070	8,721	151,687	....	....	237,840	403,318
1901[1]	2,270	27,675[2]	230,810	8,758	77,985	595,929	986,177[3]
1902	41,355	....	241,984	....	19,455	220,001	634,113[4]
1903	5,325	....	336,461	1,665	25,743	199,989	569,205[5]
1904	9,160	....	277,519	....	38,249	65,085	390,118[6]
1905	6,090	....	396,434	....	25,774	180,676	608,974

[1] Includes West Virginia.
[2] Road-making included under crushed stone.
[3] Includes 42,750 for other purposes.
[4] Includes 11,318 for other purposes.
[5] Includes 22 for riprap.
[6] Includes 105 for other purposes.

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Of these, the limestones and shales of Ordovician age are the most promising on account of their abundance, widespread distribution, and usually favorable chemical composition. The Lewistown limestone is now used in the manufacture of Portland cement at Craigsville, Augusta county, and the Greenbrier limestone will probably become an important source of cement material in southwestern Virginia.

This article is based upon field work by the writer during the summers of 1905 and 1906, under the auspices of the U. S. Geological Survey and the Virginia Geological Survey. A more detailed report upon the same subject will shortly be published as a Bulletin of the Virginia Geological Survey.

Most of the analyses quoted in the following pages were made by Mr. J. H. Gibboney of the Virginia Polytechnic Institute, but a few were kindly furnished by Mr. Wirt Tassin of the U. S. National Museum, and by Mr. Charles Catlett of Staunton, Virginia. The writer is also indebted to Professor H. D. Campbell of Washington and Lee University for notes and photographs of localities in central western Virginia. The Virginia Portland Cement Company has also kindly furnished cuts and notes on the operation of their plant.

KINDS OF CEMENT.

Of the numerous kinds of cementing materials, only those which set under water, that is, hydraulic cements, are to be considered in the present connection. When comparatively pure limestone is heated, carbon dioxide is driven off and quick lime results. This, as is well known, will slake upon the addition of water. If, however, the original limestone contained silica, alumina, and iron oxide, in certain proportions, the resulting burned mass will be affected by water only when finely ground; and this powder will be a hydraulic cement.

Three classes or groups of hydraulic cement are recognized, and materials for their manufacture occur in Virginia. These three classes, in the order of their importance, are: (1) Portland cement, (2) natural cement, (3) Puzzolan cement.

In the manufacture of Portland cement, a finely ground mixture containing lime, silica, alumina, and iron oxide, in exactly determined proportions, is burnt at a temperature approaching 3000° F. This burning produces a semi-fused mass called "clinker," which, as a last step in the process of manufacture, must be finely ground. The theoretical mixture before burning consists of 75 per cent. of calcium carbonate, 20

II. CEMENT AND CEMENT MATERIALS.

By R. S. Bassler.*

The growth of the cement industry in the United States during the last ten years has been equalled by that of no other non-metallic structural material. This remarkable growth still persists and bids fair to continue because of the ever increasing building operations of the country. The recognition of cement as a most valuable structural material, and its advantages over many other building materials in the matter of cheapness and durability, will always cause it to be regarded as a staple article of manufacture. A region, therefore, containing the natural materials from which cement can be made, has economic resources which, sooner or later, will prove of great value. In this respect Virginia is pre-eminent. The Appalachian Valley and the various mountains and valleys westward, a tract 350 or more miles long, and averaging 50 miles in width, contains limestones and shales apparently equal in value and abundance to those of any other region.

Geographically the state of Virginia may be divided into three parts, the first being an eastern division commonly known as the Coastal Plain, the second, a large, plateau-like central area bounded on the west by the Blue Ridge Mountains, and the third, a western portion including the Valley of Virginia and the various valleys and ridges westward to the State line. Considered geologically, these same divisions may be maintained. Cenozoic and more recent rocks underlie the eastern portion of the State; the very ancient crystalline rocks, with a few comparatively small basins containing Mesozoic deposits, are exposed in the central area, or Piedmont plateau, while all the main divisions of Paleozoic strata are to be found in the western part. Raw material suitable for the manufacture of cement occurs in both the eastern and western divisions, but the nature of this material in the two areas is so different that it has been deemed best to consider them separately. The present report deals only with the limestones and shales of the larger western area.

Four prominent sources of cement material obtain in western Virginia. In geologic order these are:

4. Greenbrier (Mississippian) limestone.
3. Lewistown (Helderbergian) limestone.
2. Ordovician (Trenton, etc.) limestones and shales.
1. Cambrian—impure limestone and shale.

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Of these, the limestones and shales of Ordovician age are the most promising on account of their abundance, widespread distribution, and usually favorable chemical composition. The Lewistown limestone is now used in the manufacture of Portland cement at Craigsville, Augusta county, and the Greenbrier limestone will probably become an important source of cement material in southwestern Virginia.

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In the manufacture of Portland cement, a finely ground mixture containing lime, silica, alumina, and iron oxide, in exactly determined proportions, is burnt at a temperature approaching 3000° F. This burning produces a semi-fused mass called "clinker," which, as a last step in the process of manufacture, must be finely ground. The theoretical mixture employed for burning consists of 75 per cent. of calcium carbonate, 20-

per cent. of iron, alumina, and silica, and 5 per cent. allowed for magnesian carbonate and other substances. This ideal composition is seldom realized in nature, and, as a rule, an artificial combination is made by mixing limestone or marl with clay or shale. In this case, one part of the clayey materials is generally added to three parts of pure limestone.

The following are the more important particulars in which natural cements differ from Portland cements:

(1) Natural cements are made from the rock as it occurs in nature and not from a finely ground artificial mixture.

(2) The natural cement rock is burned at a considerably lower temperature.

(3) Natural cement is usually of a different color and of lighter weight than the Portland.

(4) The natural cements set more rapidly than the Portland but do not have so high a tensile strength.

Puzzolan cement is simply a mechanical mixture of powdered slaked lime with either a volcanic ash or a blast furnace slag. This mixture when finely ground will act like an ordinary hydraulic cement. In view of the materials in Virginia suitable for the manufacture of Portland and natural cements, Puzzolan cement is of slight consequence and is not discussed further. Again, Portland cement has become of so much greater importance than natural cement, that the few pages toward the close of this contribution devoted to the latter are deemed sufficient.

CEMENT MATERIALS.

It is the writer's intention to discuss only the more important cement materials of western Virginia and to indicate their distribution.

The most important materials in western Virginia for the manufacture of Portland cement are pure and argillaceous limestones, shales, slates, clays, and marls or calcareous tufa.

A theoretically pure limestone is composed entirely of calcium carbonate, but, as might be expected, limestones, as quarried, differ more or less widely from this composition. The principal impurities of limestone are magnesia, silica, iron, and alumina. Magnesium carbonate often occupies the place of part of the calcium carbonate and in that case a more or less magnesian limestone results. Should the magnesian carbonate be present in quantities over 5 or 6 per cent., the rock is of no value as a Portland cement material. The impurities silica, alumina, and iron, however, when combined in the form of clay, are often favorable components of a limestone to be used for making cement.

Shales, slates, and clays are essentially compounds of alumina and silica with iron oxide and other impurities. Shales are clays hardened by pressure while slates differ only in having an even, parallel cleavage developed by the same means. As cement materials, these are of value for mixture with the purer limestone in order to bring the rock to the proper composition for burning.

The marls or calcareous tufa of the Appalachian Valley are usually carbonate of lime deposits from spring water. Such material has been used in the manufacture of Portland cement, but in view of the more abundant limestones and shales, it can hardly be considered here as of economic importance.

DISTRIBUTION OF CEMENT MATERIALS.

The most important cement materials of western Virginia are found in the pure and argillaceous limestones of Cambrian and Ordovician age, and in the calcareous and argillaceous phases of the Ordovician shales. These shales and limestones have a wider distribution and are usually more accessible than such other cement rock horizons of the State as the Lewistown of Helderbergian age and the Mississippian or Subcarboniferous Greenbrier limestone. In general the entire Valley of Virginia is underlain by the Cambrian and Ordovician limestones, while the shales usually outcrop along the base of the mountains bounding it. In a similar manner, many of the valleys west of the Great Valley show these limestones and shales, higher formations occurring on the separating ridges.

A study of the Cambrian and Ordovician rocks of Virginia has shown that the State may be divided into three more or less well defined areas, in each of which the geologic sequence differs to some extent. Considering all of the State west of the Blue Ridge as western Virginia, these three areas may be designated as the northwestern, central western, and southwestern portions of Virginia. According to this somewhat arbitrary division, northwestern Virginia embraces that portion of the State north of the southern border of Rockingham county, while central western and southwestern Virginia are divided by the southern and southeastern borders of Roanoke and Craig counties.

The major portion of northwestern Virginia is included in the Valley of Virginia. Almost all the cement materials of the area are confined to outcrops in the Valley and to foothills of the mountains which bound it. The Blue Ridge on the east is made up of quartzites and other rocks un-suited for cement manufacture, while North and Shenandoah mountains, occupying the portion of the State west of the Valley, are composed of strata of sandstones, quartzites, and shales of Silurian and Devonian ages, also unsuitable for this purpose.

In a general way the geology of this portion of the State is quite simple. North of Strasburg the Valley is broad, rather level, and shows two belts of limestone separated by a belt of shale, which averages 4 miles in width, and occupies the central portion of the Valley, its western edge passing just east of Strasburg and Winchester. A structure section across the Valley from the Blue Ridge to Little North Mountain, about the latitude of Winchester (see page 106) illustrates the relation of the limestone and shales in this area. Massanutten Mountain occupies the central portion of the Valley south of Strasburg, extending southwest as far as the latitude of Harrisonburg. Here also the general geology is quite simple and is shown by the structure section on page 106.

The geologic feature of this area, most important from an economic standpoint, is the great downfold of strata occupying the central part of the Valley. North of Strasburg, the strata enclosed in this downfold or syncline have been worn down to the general level of the Valley, but south of this town, a deep sag in the syncline brings the more resistant Massanutten quartzites below the general level of erosion of the neighboring mountains. Thus when, as a result of subsequent erosion, the Great Valley was formed, Massanutten Mountain, on account of its hard quartzites, was left as a ridge dividing the Shenandoah Valley. On account of the relation of Massanutten Mountain to this downfold, this syncline has been called the Massanutten Mountain syncline.

Pure and argillaceous Ordovician limestones are brought to the surface along the eastern and western sides of the Massanutten Mountain syncline, hence its economic importance. Along the western side, the normal sequence of strata is usually exposed, but on the eastern side, overthrust faulting is not uncommon. This faulting is usually sufficient to cut out the limestones which are of economic importance, the dolomitic strata being thrust upon the Upper Ordovician shales.

The long narrow area lying between the Massanutten Mountain syncline and the Blue Ridge is occupied by dolomitic limestones and shales which are of no importance as a source of Portland cement rock. Just west of the great syncline, pure and argillaceous limestones occur in considerable

abundance, but the central portion of the western half of the Shenandoah Valley is again occupied mainly by the less valuable dolomitic limestone. The latter strata continue to the foothills of Little North Mountain, where, when faulting has occurred, they may be found resting upon the Ordovician shales or upon still higher formations.

When the structure is normal along the western edge of the Valley, essentially the same sequence of strata may be observed as farther east, with the exception that here the Trenton formation is composed mainly of limestone instead of shales, as in the more eastern localities. In addition to the Massanutten Mountain syncline, a few smaller synclines exposing the Ordovician shales and limestones have been noted in the Valley, but these are usually of slight consequence. The most important of these minor synclines lies just west of Harrisonburg.

In central western Virginia, the more important areas of outcrop of cement materials are: (1) a narrow strip following the Massanutten Mountain syncline which terminates in this area, (2) a considerable outcrop of argillaceous limestone in the vicinity of Lexington, and (3) a rather broad band of limestones and shales just east of Little North Mountain.

From a geological standpoint, southwestern Virginia may be considered as composed of elongated, narrow, northeast-southwest blocks, in each of which strips exposing favorable cement materials are found. The location of these strips and description of their contained cement materials are given later on.

CAMBRIAN AND ORDOVICIAN FORMATIONS OF NORTHWESTERN VIRGINIA.

Nearly all of the sedimentary rocks exposed in northwestern Virginia are of Cambrian and Ordovician age. The economic importance of the younger strata and of the area occupied by them is so small that they are not considered in the present description of the stratigraphy. Four well defined groups of these rocks have been recognized in this part of the State, namely, the sandstones, quartzites, and shales of Lower Cambrian age, the Shenandoah limestone belonging in part to the Cambrian and the Ordovician, the Martinsburg shales of the Middle and Upper Ordovician, and the Massanutten sandstones hitherto regarded as Silurian. Of these four main divisions the Shenandoah limestone and Martinsburg shales only are of economic interest in cement manufacture, and, therefore, their subdivisions will be considered more in detail. The relations and general character of these formations are expressed in the following table:

by Professor Campbell as the Sherwood limestone, consists of white cry line dolomites with heavily bedded light blue and gray magnesian l stone and occasionally more argillaceous limestones and shales. It i the latter occurrence that the formation may prove of some value. T argillaceous limestones and shales have a composition which will a of their use, particularly in the manufacture of natural cement. principal outcrops of the Sherwood limestone are to be found alo rather narrow strip just west of the Cambrian quartzites and shales.

The succeeding formation, the Buena Vista shales, is of econ interest because limestones suitable for the manufacture of natural ce alternate with the shales, especially in the lower part. This formati the source of the rock used by the natural cement plant near Bal Falls, Virginia.

The heavy-bedded gray and light blue limestones, distinguished Prof. Campbell as the Natural Bridge formation, compose the persistent formation of the Appalachian Valley. The strata are al invariably dolomitic and upon weathering leave a mantle of chert ments. This chert is especially abundant in the upper beds, wl geologically, are the equivalent of the Knox dolomite of Tennessee. S and shaly layers are often found in the lower third. Economically sidered, the Natural Bridge limestone is of little importance. Th especially true in regard to its use as a cement rock, the magnesian tent being too high, as the following analysis will show:

Analysis of Natural Bridge limestone, just west of Strasburg Junction, Virginia.

(J. H. Gibboney, Analyst)

	Per cent.
Insoluble	10.06
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	1.00
Lime (CaO)	28.60
Calcium carbonate ($CaCO_3$)	51.07
Magnesia (MgO)	18.00
Magnesium carbonate ($MgCO_3$)	37.80
Total	99.93

Following the Natural Bridge formation is a series of limest which, economically considered, are of greatest importance. These l stones are of Middle Ordovician age and are composed in large pa argillaceous and highly calcareous strata. The succession in this pa Virginia is most clearly shown in a section commencing west of Strasl Junction, Shenandoah county, and extending eastward to the vicinit

Natural Bridge, Virginia. View from southeast side. Type exposure of Natural Bridge limestone. (Photo. by C. D. Walcott.)

NATURAL BRIDGE, VIRGINIA.

Strasburg. Here the western side of the syncline forming Massanutten Mountain brings up the strata in regular order and excellent exposures may be found along the Southern railroad between the two places mentioned and in the neighboring quarries and creeks. This section is as follows:

Geologic section in the vicinity of Strasburg, Virginia.

	Feet
4. Martinsburg shales (Trenton, Utica, Eden). Gray and black shales, calcareous at the base, then more argillaceous, passing upward into sandy layers	2,000
3. Chambersburg (Black River) formation. About 400 feet of blue and argillaceous limestone arranged in the following order:	
(i) Earthy gray limestone and calcareous shales with numerous fossils, *Tretaspis*, *Christiania*, and several species of *Plectambonites* occurring most abundantly	40
(h) Light gray earthy limestone, no fossils observed	30
(g) Massive dove limestone holding numerous specimens of a large species of *Nidulites*	65
(f) Rather thin bedded dove limestone with *Nidulites* rare	60
(e) Thin bedded dark gray argillaceous limestone	52
(d) Thin bedded argillaceous black limestone	22
(c) Nodular argillaceous dark blue limestone with numerous fossils of which *Solenopora*, several species of *Phylloporina*, *Echinosphærites*, and *Christiania*, are especially abundant	30
(b) Crinoidal limestone	10
(a) Crystalline blue limestone, cherty in the upper part but pure in lower part, bryozoa abundant but a species of *Subulites* is especially characteristic of this bed	80
Total thickness of Chambersburg formation	398
2. Stones River formation. About 900 feet of more or less pure and magnesian limestones, the upper 100 feet consisting of heavily bedded, pure dove limestone (90 to 97 per cent. $CaCO_3$) with occasionally a black layer. In the vicinity of Strasburg Junction these beds are extensively quarried for lime. The remaining strata consist of heavily bedded, alternately arranged layers of pure and magnesian limestone. The presence of abundant gastropoda of Stones River types and the characteristic fossils *Tetradium cellulosum* and *Leperditia fabulites* in the uppermost layers determines the age of this formation.	
1. Typical Natural Bridge dolomitic limestone weathering into characteristic chert.	

Stones River formation.—The Stones River rocks in northwestern Virginia are, in general, heavy-bedded dolomitic layers alternating with purer limestone strata. In color and texture, the rock varies from fine-grained dove to a dense black with dove-colored rock predominating. Many of the layers run as high in magnesia as the underlying Natural Bridge limestone, but the Stones River formation differs in that at least a few pure limestone layers are found in almost every exposure. Another method of distinguishing the two formations lithologically lies in the character of the soil to which each gives rise on weathering. The soil resulting from the decomposition of the Natural Bridge limestone is of a deep red color and generally contains a considerable number of chert fragments scattered through it. Stones River rocks, on the other hand, give very little chert, on weathering, and areas underlain by them may often be distinguished further by the fact that the resulting soil seems to be particularly suited to the growth of cedar trees. Indeed, the presence of a considerable number of cedar trees in an area of Ordovician strata is quite a reliable sign that the underlying rocks are of Stones River age.

Although the analyses of the Stones River rocks show a considerable variation in lime and magnesia, still the strata can be divided chemically into two general classes, the purer and the dolomitic limestones. The purer limestones are generally of fine-grained texture and of a dove color, although darker strata are sometimes interpolated. These dove and dark layers occur most frequently near the top of the formation so that this portion may generally be depended upon to furnish the purer rock. Strings of calcite often penetrate this dove limestone and give the characteristic "birdseye" markings. With the exception of number II, all of the analyses in the table below are of samples from the upper portion. The lower strata of the Stones River formation often show a high percentage of magnesia and silica. Their value in the present connection is, therefore, correspondingly small.

Analyses of Stones River limestones in northwestern Virginia.
(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	I Per cent.	IV Per cent.	V Per cent.
SiO_2	0.36	56.26	3.11	9.10	8.06
Al_2O_3 and Fe_2O_3	0.08	4.82	0.64	1.32	1.14
$CaCO_3$	99.01	33.88	94.82	86.8	87.68
$MgCO_3$	0.45	1.91	1.53	.7	1.81
Total	99.90	96.87	100.10	99.95	98.69

I. Pure dove limestone, upper part of Stones River, Strasburg, Va.
II. Siliceous limestone, lower part of Stones River, Woodstock, Va.
III. Compact black layers in upper part of Stones River, Riverton, Va.
IV. Black limestone in upper part of Stones River, Riverton, Va.
V. Dark blue splintery limestone, Stones River, Mt. Horeb Church, Va.

Chambersburg formation.—About 400 feet of more or less pure and clayey limestones intervene between the top of the Stones River formation and the base of the Martinsburg shales in the vicinity of Strasburg. Although these strata correspond in position to the Black River formation of New York, their lithologic and faunal differences were found to be so great that the new name, Chambersburg, was proposed by Stose* for their reception. The rocks of this formation are well exposed in northwestern Virginia, particularly along the Massanutten Mountain syncline, but the most detailed section is to be had at Strasburg. By reference to the section on a preceding page, it will be noted that 9 beds are distinguished, these varying in lithology from siliceous blue limestone through purer blue and dove limestone to argillaceous strata, and finally, at the top, calcareous shales.

As stated before, the detailed section exposed so well at Strasburg cannot be made out in its entirety at many, if at any, other places, and therefore the following generalized section is introduced for the recognition of the rocks in any part of northwestern Virginia. The thicknesses given in this section are those observed at Strasburg where the rocks are believed to be well developed. Therefore it must be remembered that in other localities considerable departure from these figures may be observed.

Generalized section of the Chambersburg formation in northwestern Virginia.

(Martinsburg shales of Trenton, Utica, and Eden age at top)

	Feet
4. Gray earthy limestone with numerous fossils in upper part	70
3. Thin bedded and massive dove limestone holding *Nidulites* in more or less abundance	125
2. Nodular and thin bedded gray argillaceous limestone with numerous fossils in lower third	104
1. Pure limestone with cherty portions	90

The more persistent members of the Chambersburg formation are the massive dove and crystalline limestones holding *Nidulites* in abundance (bed 3), and the argillaceous limestones in which *Tretaspis* and *Christiania* are especially characteristic fossils (bed 4). These two divisions may be recognized in almost every section, but the other members are seldom so well shown as at Strasburg.

Bed 4 was recognized at practically every outcrop of the Chambersburg formation and was found as far south as Fort Defiance in Augusta county, where the thickness had apparently diminished greatly. Moreover, at this locality it rested upon the Murat limestone, which, in turn, overlapped upon a thin bed of Stones River rock, thus indicating the relations between the rocks of northwestern and central western Virginia as here subdivided.

*Journ. Geol., XIV, 1906, p. 211.

Portions of bed 4 approach a cement rock with an ideal chemical composition more nearly than any of the other divisions of the Ordovician limestone.

The southernmost exposure of bed 3 noted was at Harrisonburg, but more careful search will probably reveal its presence south of this city. The comparatively low dip of the rocks, forming the eastern limb of the syncline just west of Harrisonburg, causes the exposure of bed 3 in this region to be relatively wide. Along the western side of the Massanutten Mountain syncline the dip is steeper and the width of outcrop is therefore much less. From the viewpoint of cement manufacture, these dove limestones can be relied upon to furnish the purer rock for mixture.

A considerable variation in the composition of the various strata composing the Chambersburg formation is to be expected because of their diverse natures. Still these strata in general terms may be divided into (1) more or less pure, dark or dove-colored compact limestones, and (2) into dark, argillaceous limestone. Upon this classification, the analyses of these rocks in northwestern Virginia have been arranged and presented below:

Analyses of more or less pure, compact limestone, Chambersburg formation, northwestern Virginia.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
SiO_2	2.32	43.50	12.10	8.68	10.04	4.60	8.68	30.72	12.82	15.32	4.04
Al_2O_3 & Fe_2O_3	0.24	5.50	1.48	1.32	1.46	0.56	.94	3.52	1.84	1.34	1.80
$CaCO_3$	96.43	47.86	84.64	88.71	86.57	92.00	90.36	62.78	81.07	82.35	85.40
$MgCO_3$	1.09	2.18	1.68	1.34	1.54	2.79	.41	0.71	2.52	0.21	8.36
Total...	100.08	99.04	99.90	100.05	99.61	99.95	100.39	97.73	98.25	99.22	99.60

I. Unusually pure blue limestone, lower part of formation, Strasburg, Va.
II. Siliceous blue limestone, lower part of formation, Strasburg, Va.
III and IV. Dove limestone, middle part of formation, Strasburg, Va.
V. Dark blue limestone, lower part of formation, Woodstock, Va.
VI and VII. Dark blue compact limestone, Harrisonburg, Va.
VIII and IX. Semi-crystalline limestone, Harrisonburg, Va.
X and XI. Dark blue limestone, Mt. Horeb Church, Va.

These analyses and those following are here brought together for comparison of the chemical constituents of these and other strata.

Analyses of dark, argillaceous limestones, Chambersburg formation, northwestern Virginia.

(J. H. Gibboney, Analyst)

	I Per Ct.	II Per Ct.	III Per Ct.	IV Per Ct.	V Per Ct.	VI Per Ct.	VII Per Ct.	VIII Per Ct.	IX Per Ct.
SiO_2	19.78	12.00	14.88	18.20	15.88	16.34	23.24	37.06	14.68
Al_2O_3 and Fe_2O_3	1.88	2.26	2.38	8.00	0.92	7.49	3.22	3.60	1.88
$CaCO_3$	74.28	84.21	80.36	70.00	82.75	74.14	71.07	57.46	81.71
$MgCO_3$	0.82	1.13	2.18	2.00	0.44	1.00	1.72	1.47	0.05
Total	96.76	99.60	99.80	98.20	99.99	98.97	99.25	99.59	98.32

I and II. Gray, argillaceous limestone, middle and upper part of formation, Strasburg, Va.
III. Argillaceous limestone, upper part of formation, Woodstock, Va.
IV. Argillaceous limestone, Mt. Jackson, Va.
V. Argillaceous limestone, Riverton, Va.
VI. Argillaceous limestone, 5 miles east of Woodstock, Va.
VII. Argillaceous limestone, Harrisonburg, Va.
VIII. Argillaceous limestone, 3 miles west of Montevideo, Va.
IX. Knotty, argillaceous limestone, Mt. Horeb Church, Va.

Martinsburg Shale Group.

No sharp break occurs between the argillaceous limestones and calcareous shales forming the upper part of the Chambersburg formation and the overlying Martinsburg shales. From an economic standpoint, no arbitrary lines of separation need be given, since the lowest beds of the Martinsburg shales are as highly calcareous as the topmost part of the preceding formation. Paleontologically, however, the two divisions may be separated by the total absence of the characteristic Chambersburg fossils in the succeeding shales.

In general, it may be said that the lowest deposits of the Martinsburg shales are fine, calcareous to argillaceous shales, dark drab in color when fresh, and yellowish when weathered. Higher up in the series, brown or black micaceous shales are encountered, while toward the top, the rocks become more siliceous. The thickness varies considerably, but in this part of Virginia, 700 to 2,000 feet expresses their variation, although in other regions as much as 3,000 feet have been measured.

Three divisions of the geological time scale are represented in the Martinsburg shales. These are, in ascending order, (1) Trenton, (2) Utica, and (3) Eden. Although the actual lines delimiting these divisions are difficult if not almost impossible to determine, yet in a general way it may be stated that the lower calcareous portion is of Trenton age, the brown or black shales are Utica, and the upper gray and buff shales, or siliceous portion, belong to the Eden.

The Martinsburg shales weather into a yellow and brown clay soil which is in marked contrast to the red soil of the limestone areas.

Trenton shales.—That portion of the Martinsburg shale group, of Trenton age consists of calcareous and argillaceous strata of a dark drab color and with a thickness as yet undetermined. This thickness is probably over 100 feet and less than 300, but undoubtedly varies considerably in different areas. Considered from an economic standpoint, the Trenton phase of this shale group need not be distinguished from the underlying Chambersburg shales and argillaceous limestones, as both will prove of use in cement manufacture.

The main outcrops of the Trenton shale are parallel with and contiguous to the Chambersburg formation. The main exposures in northwestern Virginia are therefore along the flanks of the Massanutten Mountain syncline.

The following analyses of shales from the Trenton portion of the Martinsburg group show such a high percentage of lime that the rock, chemically at least, may be considered as an argillaceous limestone with a higher silica content than usual. These analyses also indicate a close similarity in composition to rock from the same geological horizon but from distant localities.

Analyses of calcareous shales, Trenton horizon of Martinsburg group.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	27.60	30.56
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	3.36	3.82
Calcium carbonate ($CaCO_3$)	66.97	61.07
Magnesium carbonate ($MgCO_3$)	1.22	3.44
Total	99.15	98.89

I. Strasburg, Va.
II. Harrisonburg, Va.

Trenton limestones.—Along the western side of the Appalachian Valley in northwestern Virginia, the Chambersburg formation is followed by thin-bedded limestones with interbedded dark shales instead of the dark calcareous or argillaceous shales just described. The surface of these limestones is often covered with fossils characteristic of the typical Trenton formation of New York. The rocks themselves, moreover, are very similar to the corresponding New York strata so that there is every reason to believe that they are identical.

The development of limestones and shales instead of shales alone, along this portion of the Valley, is of importance in that an additional cement rock is furnished. Unfortunately, the geologic structure and transportation facilities are such that at present little development of this rock could be expected. Moreover, the dolomitic limestones are generally thrust upon the Martinsburg shales or higher formations along the western side of the Valley, thus cutting out the strata of economic value. Still this limestone must be accounted as one of the cement resources, and analyses of the rock are therefore introduced below:

Analyses of Trenton limestone and shale, Mt. Horeb Church, Va.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	27.44	7.80
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	4.06	.90
Calcium carbonate ($CaCO_3$)	65.89	90.64
Magnesium carbonate ($MgCO_3$)	0.25	1.04
Total	97.64	100.38

I. Shale band.
II. Thin bedded, compact limestone.

Utica shale.—This and the succeeding Eden shale are two of the most constant divisions of the geologic succession of western Virginia and, with careful search, the characteristic fossils of both may be found in almost every section exposing the upper two-thirds of the Ordovician shales.

In comparison with the preceding shales, the amount of calcareous material in the Utica shale has been greatly diminished, so that, except for mixture, the rock will probably never prove of much use as a cement material. In view of the large amount of calcareous and argillaceous strata underlying the Utica shales, the necessity for the use of the latter need not arise, and there is no occasion for considering the formation as a source of cement rock. However, an analysis is introduced at this point for comparison with the associated strata.

Analysis of Utica shale, Mt. Horeb Church, Va.

(J. H. Gibboney, Analyst)

	Per cent.
Insoluble	43.94
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	5.18
Calcium carbonate ($CaCO_3$)	46.93
Magnesium carbonate ($MgCO_3$)	0.07
Total	96.12

Eden shales and sandstones.—Following the few feet of shale Cincinnati, Ohio, holding characteristic Utica fossils, are 250 feet of limestones and shales before strata of Lorraine age are reached. these the term Eden, defined by Orton in the first volume of the "Geol of Ohio," is used in the Cincinnati area. These beds contain great numl of bryozoa and brachiopods and are essentially thin blue limestones shales. Proceeding eastward, these beds become more arenaceous u in the Appalachian Valley sandy limestone and shales have taken the p of the purer limestones of the west. On account of the interven Appalachian coal field, this change cannot be traced continuously, but relations of the strata and their fossil contents prove the correctness of correlation beyond a doubt. Because of the high silica content, the E shales of the Appalachian Valley are of no value as a source of cem material.

Massanutten Sandstone Group.

At many places the crest of Massanutten Mountain is composed of yellow, and white sandstone and quartzite, which, on account of t conspicuous occurrence along this mountain, were named as above. Massanutten sandstone is divisible into two numbers, corresponding i general way to the Bays sandstone and Clinch sandstone of the south Appalachians. The lower member is 200 or more feet in thickness consists of micaceous sandy shales, coarse sandstone, and conglomer Portions of this division contain the characteristic Bays sandstone fo which indicate the Lorraine age in terms of the general time scale. lower division has been mapped in Virginia and Pennsylvania under name of Juniata sandstone. Fragments from the cliffs of the overl quartzite generally obscure this member so that good exposures are One of the localities where fossils may be found is at Buzzard's Roos the northeast end of Massanutten Mountain.

The upper or Tuscarora member of the Massanutten sandstone is m up of coarse conglomerates and quartzites, varying greatly in thick

Fold in Massanutten (Tuscarora) sandstone. Panther Gap, Virginia.
(Photo. by N. H. Darton.)

ANTICLINE IN MASSANUTTEN SANDSTONE.

but reaching a total of at least 500 feet. Fossils are scarce, although the characteristic *Arthrophycus alleghaniensis* may be found upon careful search.

GENERAL GEOLOGY AND STRATIGRAPHY OF CENTRAL WESTERN VIRGINIA.

The general geology of this division, although somewhat similar to that of northwestern Virginia, begins to assume the complexity of the area farther south. The great faults of southwestern Virginia are found in its southern part, while the Massanutten Mountain syncline and the structure along the western edge of the Valley in the northwestern part of the State may be traced through the northern part of the division. In the intermediate zone, namely, in Rockbridge county, the Ordovician limestones are so situated as a result of faulting, folding, and erosion, that a considerable area is underlain by them.

The principal features concerned in the exposure of the Ordovician strata are indicated on the accompanying structure sections. The Massanutten Mountain syncline enters the district from Rockingham county and occupies a portion of Augusta county, thus bringing these limestones and shales to the surface as far south as Greenville. The faulting along the western edge of the Valley becomes less and less in Augusta county until the structure becomes practically normal. As a result, the cement limestones are more abundant in this part of the Valley than northward along the same line. In the vicinity of Lexington, the argillaceous limestones are found over a considerable area, and on account of close folding, seem to be of great thickness.

South of Rockbridge county, the principal Ordovician outcrops follow the bases of the mountains and are thus exposed usually at some distance from railroads. Moreover, on account of the unusually steep dip of the strata, the outcrops are in long, narrow areas.

The regions of outcrop thus far noted are in the Appalachian Valley proper. West of this, namely in Alleghany, Bath, and Highland counties, anticlines are found, exposing these shales and limestones as their lowest strata. With the exception of the vicinity of Hot Springs, these anticlinal areas have no railroad facilities.

With a few exceptions, all of the geological divisions described previously for northwestern Virginia may be found well developed in the central western part of the State. These exceptions are the Stones River and the Chambersburg formations. The interval between the top of the Natural Bridge limestone and the base of the Martinsburg shale is here occupied almost invariably by the Murat and Liberty Hall limestones.

[illegible] western Virginia, the Stones River rocks are practically [illegible] areas show a slight development, but as a source of cement [illegible] formation may be neglected. The succeeding Murat and [illegible] limestones correspond in a general way to the Chambersburg [illegible] of the more northern parts of the Valley, although lithologi[illegible] trouble will be encountered in separating these different divisions. [illegible] heavy [illegible] beds of the Natural Bridge limestone are usually [illegible] a massive gray, coarsely crystalline pure limestone to which [illegible] Campbell has applied the name Murat from its occurrence along [illegible] at Murat, Virginia. The limestone, as a whole, runs very [illegible] calcium carbonate and, for this reason, it is the source of the lime [illegible] several points in central western Virginia. The lower portion [illegible] chert nodules upon weathering, and it was from this part that [illegible] the following table giving a high silica content were [illegible] About 125 feet of the Murat limestone are exposed at its type [illegible] frequently the thickness is not so great.

Analyses of Murat limestone.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.
[illegible]	1.80	5.92	11.72	1.58	1.62
[illegible] and Al_2O_3	0.22	.43	6.16	.34	0.72
[illegible]	54.50	52.00	44.14	54.40	54.18
[illegible]	97.32	92.85	78.82	97.14	96.71
[illegible]	0.07	.40	1.28	.91	0.42
[illegible]	0.15	.84	2.69	1.91	0.90
[illegible]	99.49	100.09	99.39	100.97	99.95

[illegible] Virginia.
[illegible] Baltimore and Ohio Railway, northeastern edge of Staunton, [illegible]
[illegible] Springs, Virginia.
[illegible] of Greenville, Virginia.
[illegible] Virginia.

[illegible] comparatively pure Murat limestone is a succession [illegible] strata possibly 1,000 feet in thickness. This is the [illegible] which was so named by Professor Campbell because [illegible] near Lexington constructed on and of this rock. [illegible] strata make up the lower third of the formation. [illegible] limestone occurs in the middle third, chang[illegible] in the topmost division. After long exposure [illegible] and upper divisions appear shaly at the surface.

Fig. 1.—House Mountains, Rockbridge county. View from Rich Hill, looking across valleys of Liberty Hall limestone and hills of Natural Bridge limestone. The mountains are capped by the Massanutten quartzite and the slopes show the Martinsburg shale.

Fig. 2.—Fold in Massanutten sandstone, C. & O. railroad, Eagle Mountain.

HOUSE MOUNTAINS AND FOLDED MASSANUTTEN SANDSTONE.

In central western Virginia, the Stones River rocks are practically absent. A few areas show a slight development, but as a source of cement material the formation may be neglected. The succeeding Murat and Liberty Hall limestones correspond in a general way to the Chambersburg formation of the more northern parts of the Valley, although lithologically, no trouble will be encountered in separating these different divisions.

The heavy cherty beds of the Natural Bridge limestone are usually followed by a massive gray, coarsely crystalline pure limestone to which Professor Campbell has applied the name Murat from its occurrence along Buffalo creek at Murat, Virginia. The limestone, as a whole, runs very high in calcium carbonate and, for this reason, it is the source of the lime burned at several points in central western Virginia. The lower portion often shows chert nodules upon weathering, and it was from this part that the samples in the following table giving a high silica content were obtained. About 125 feet of the Murat limestone are exposed at its type locality, but frequently the thickness is not so great.

Analyses of Murat limestone.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.
SiO_2	1.80	5.92	11.72	1.58	1.62
Fe_2O_3 and Al_2O_3	0.22	.43	6.16	.34	0.72
CaO	54.50	52.00	44.14	54.40	54.18
$CaCO_3$	97.32	92.85	78.82	97.14	96.71
MgO	0.07	.40	1.28	.91	0.42
$MgCO_3$	0.15	.84	2.69	1.91	0.90
Total	99.49	100.09	99.39	100.97	99.95

I. Eagle Mountain, Virginia.
II. Cut along Baltimore and Ohio Railway, northeastern edge of Staunton, Virginia.
III. Railroad cut, Mint Springs, Virginia.
IV. 4 miles northeast of Greenville, Virginia.
V. Near Lexington, Virginia.

Succeeding this comparatively pure Murat limestone is a succession of more argillaceous strata possibly 1,000 feet in thickness. This is the Liberty Hall limestone which was so named by Professor Campbell because of the old historic ruin near Lexington constructed on and of this rock. Fine-grained dark blue strata make up the lower third of the formation. Darker, more argillaceous limestone occurs in the middle third, changing into calcareous shales in the topmost division. After long exposure to the weather, the middle and upper divisions appear shaly at the surface.

Fig. 1.—House Mountains, Rockbridge county. View from Rich Hill, looking across valleys of Liberty Hall limestone and hills of Natural Bridge limestone. The mountains are capped by the Massanutten quartzite and the slopes show the Martinsburg shale.

Fig. 2.—Fold in Massanutten sandstone, C. & O. railroad. Eagle Mountain.

HOUSE MOUNTAINS AND FOLDED MASSANUTTEN SANDSTONE.

Numerous brachiopods, trilobites and ostracods occur in the lowest beds, but the higher divisions are seldom fossiliferous. The general distribution of both the Murat and Liberty Hall formations is indicated on the accompanying map, figure 17 (page 111). Analyses showing composition of the Liberty Hall formation are given below.

Analyses of Liberty Hall limestone.

(J. H. Gibboney, Analyst)

	I Per ct.	II Per ct.	III Per ct.	IV Per ct.	V Per ct.	VI Per ct.	VII Per ct.	VIII Per ct.
SiO_2	7.10	8.98	48.80	19.48	6.10	14.96	9.38	12.64
Al_2O_3 and Fe_2O_3	0.92	1.02	7.60	2.74	0.98	.94	1.02	1.82
CaO	51.10	47.12	22.46	42.16	51.02	46.54	49.56	46.86
$CaCO_3$	91.25	84.14	40.11	75.29	91.11	83.11	88.50	83.66
MgO	0.46	2.80	0.10	.81	0.08	.12	.57	.71
$MgCO_3$	0.96	5.88	0.21	1.70	0.17	.25	1.21	1.50
Total	100.23	100.02	96.72	99.21	98.36	99.26	100.11	99.62

I. Compact black argillaceous limestone, Eagle Mountain, Va.
II. Gray compact limestone, Eagle Mountain, Va.
III. Dark siliceous limestone, Eagle Mountain, Va.
IV. Shaly limestone, Mt. Sidney, Va.
V. Coarsely crystalline limestone, Mt. Sidney, Va.
VI and VII. Fine-grained, dark blue limestone, Staunton, Va.
VIII. Subcrystalline limestone, eastern foothills, Little North Mountain, Augusta Co., Va.

DETAILS OF LOCALITIES IN NORTHWESTERN AND CENTRAL WESTERN VIRGINIA.

Under this caption the writer wishes to discuss briefly only the more favorable localities in northwestern and central western Virginia showing good exposures of the pure and argillaceous limestones. It is to be understood, however, that unless otherwise stated, all discussion of these rocks refer to their use in the manufacture of Portland cement. Analyses of rock from other localities than those discussed are given, since a knowledge of the composition of the rock is most essential.

Winchester.—The geologic structure at Winchester and north to the state line is somewhat complicated by faulting, but two sources of cement material have been noted. These are: (1) a band of Stones River pure and dolomitic limestones passing through Winchester and thence northeast and southwest; (2) a strip of argillaceous limestone a short distance east

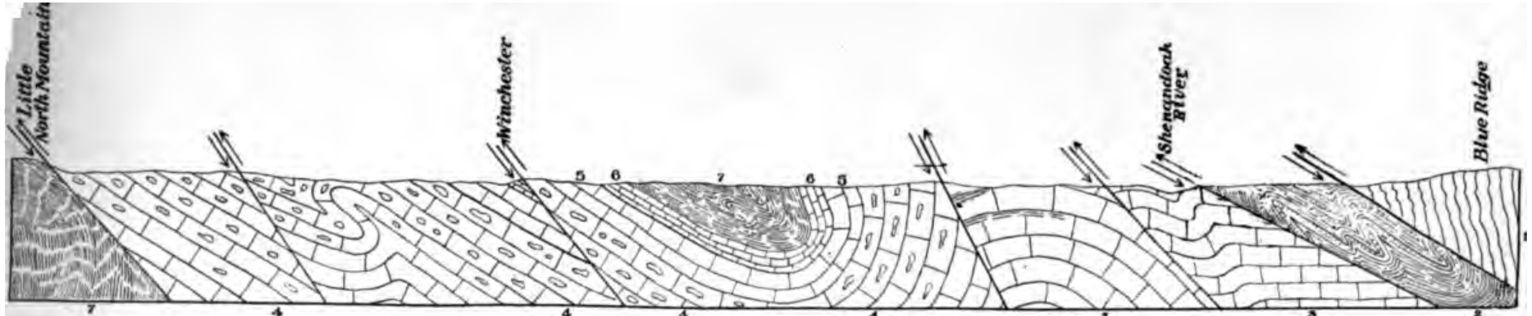


Fig. 13.—Structure section across the northern part of northwest Virginia from the Blue Ridge across the Shenandoah river to Little North Mountain. 1. Pre-Cambrian strata of the Blue Ridge; 2. Lower Cambrian shales; 3. Cambrian limestone; 4. Cherty Cambrian and Ordovician limestone (Natural Bridge); 5. Pure and magnesian dove Ordovician limestone (Stones River); 6. Dark, compact and argillaceous Ordovician limestone (Chambersburg); 7. Martinsburg shale series.

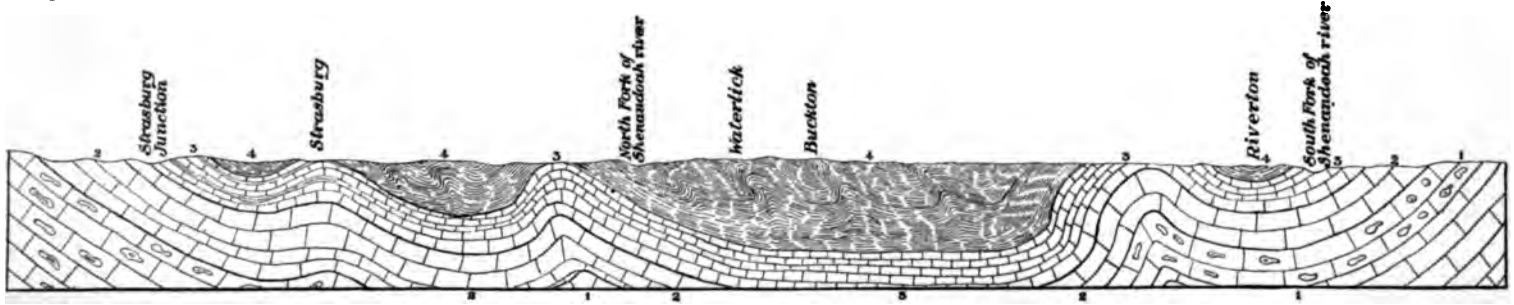


Fig 14.—Structure section across Massanutten Mountain Syncline, just north of Massanutten Mountain, from a point in the Valley east of Riverton to the vicinity of Strasburg Junction. 1. Cherty Natural Bridge limestone; 2. Pure and magnesian Stones River limestone; 3. Limestones of the Chambersburg formation; 4. Martinsburg shale series.

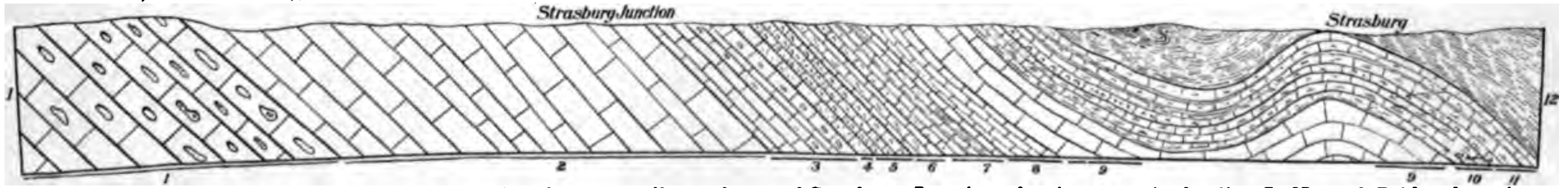


Fig. 15.—Structure section from Strasburg to a point about one mile northwest of Strasburg Junction, showing strata in detail: I. Natural Bridge dolomite; 2. Stones River limestone; 3-11. Chambersburg formation; 3. Silurian blue limestone, 80 ft.; 4. Crinoidal limestone, 10 ft.; 5. Nodular dark blue limestone, 30 ft.; 6. Argillaceous black limestone, 22 ft.; 7. Thin bedded gray argillaceous limestone, 52 ft.; 8. Thin bedded dove limestone, 60 ft.; 9. Massive [illegible] 65 ft; 10. Earthy limestone, 30 ft; 11. Earthy limestone and calcareous shale, 40 ft.; 12. Martinsburg shales.

of this band. The Stones River strata here are especially characterized by the growth of cedar trees along their outcrop. The purer portion of this formation is made up of dove or bluish limestones often showing outlines of small gastropods upon worn surfaces. The argillaceous materials are very similar to those described later in the Strasburg section, and, as the analysis shows, have a favorable composition:

Analysis of argillaceous limestone, just east of Winchester, Va.

(J. H. Gibboney, Analyst)

	Per cent.
Insoluble	14.78
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	2.72
Lime (CaO)	44.94
Calcium carbonate ($CaCO_3$)	80.25
Magnesia (MgO)	0.34
Magnesium carbonate ($MgCO_3$)	0.71
Total	98.46

Middletown.—This and the neighboring towns of Stephens City and Meadow Mills are favorably located so far as transportation facilities and abundance of cement materials are concerned. The following section taken along the street west from the depot at Middletown gives the sequence of rocks in the region.

Section of Ordovician rocks in the vicinity of Middletown, Virginia.

		Feet
9.	Mainly covered but apparently all calcareous shale	100
8.	Mainly covered but showing traces of earthy limestone	150
7.	Partially covered, with bluish limestone at the top and earthy or nodular limestone at intervals	100
6.	Nodular limestone with specimens of *Echinosphærites* near the base	20
5.	Arenaceous shale	20
4.	Unexposed	30
3.	Dark gray to black limestone with chert	38
2.	Massive dove limestone, apparently the same bed as that quarried for lime at Strasburg	40
1.	Mainly magnesian limestone but with a few layers of pure limestone	300

This section then continues westward, the magnesian and pure limestones of the Stones River formation being shown in a small anticline between Middletown and Meadow Mills, until in the vicinity of the latter place, the higher pure and argillaceous limestones are again exposed in a small syncline.

Strasburg.—The abundant pure and clayey limestones in the vicinity of Strasburg combined with the railroad facilities, makes this one of the most promising sites for cement manufacture. As shown on the map, figure 16 (this page), the line of outcrop of Martinsburg shales passes through Strasburg so that to the east of the town an abundance of shale may be found, while to the west occur the various limestones. The rocks of economic importance outcrop between the town and Strasburg Junction, a mile or more to the west, where the upper part of the Stones River

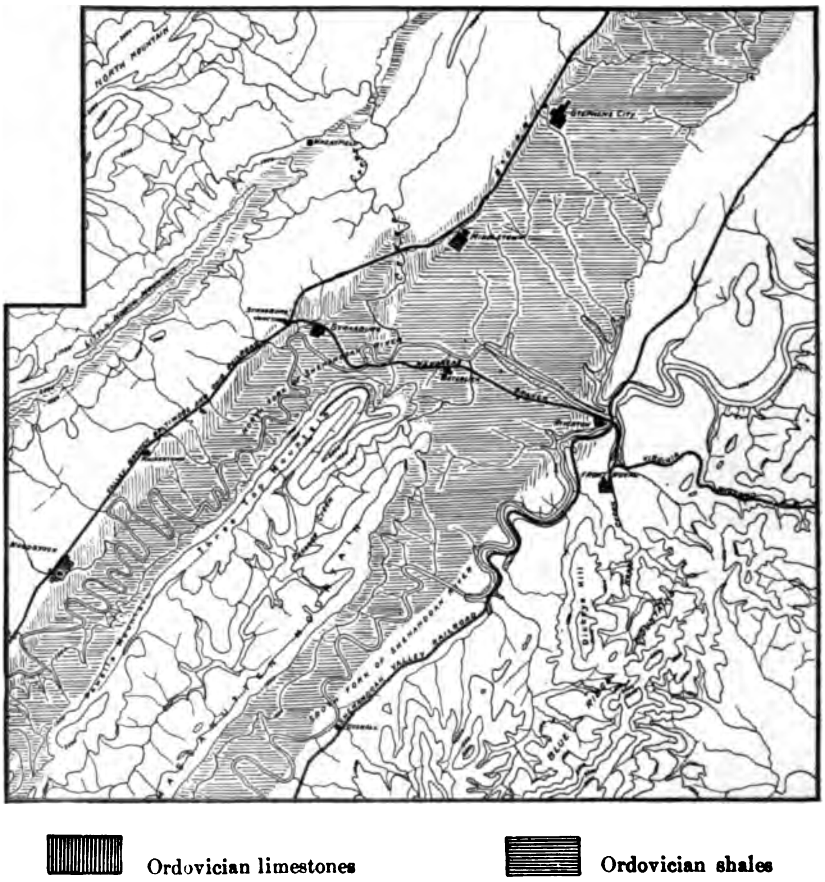


Fig. 16.—Map showing distribution of cement materials of northwestern Virginia.

formation is being quarried and burned into lime. The section printed on page 106 is found exposed mainly between the two localities mentioned, although the lower beds of the Stones River and the Natural Bridge dolomites outcrop west of Strasburg Junction. The rocks dip to the east and are encountered in ascending order as Strasburg is approached.

The Strasburg section is so complete that it has been employed as a type section for northwestern Virginia. For this reason, the various strata likely to be employed as cement materials were carefully sampled and analyzed. The results of these analyses are given in the following table:

Analyses of limestones and shales, vicinity of Strasburg, Virginia.

(J. H. Gibboney, Analyst)

	I Per ct.	II Per ct.	III Per ct.	IV Per ct.	V Per ct.	VI Per ct.	VII Per ct.
Insoluble	2.32	43.50	19.78	12.10	8.68	12.00	27.60
Iron oxide (Fe_2O_3)	0.24	} 5.50	1.88	1.48	1.32	2.26	3.36
Alumina (Al_2O_3)	....						
Lime (CaO)	54.04	26.80	41.60	47.40	49.68	47.16	37.40
Calcium carbonate ($CaCO_3$)	96.43	47.86	74.28	84.64	88.71	84.21	66.97
Magnesia (MgO)	0.52	1.04	0.39	0.80	0.64	0.54	0.58
Magnesium carbonate ($MgCO_3$)	1.09	2.18	0.82	1.68	1.34	1.13	1.22
Total	100.08	99.04	99.76	99.90	100.05	99.60	99.15

I. Blue limestone, lower part of bed 3a, Chambersburg formation.
II. Siliceous blue limestone, upper part of bed 3a, Chambersburg formation.
III. Dark gray, argillaceous limestone, bed 3e, Chambersburg formation.
IV. Thin bedded dove limestone, bed 3f, Chambersburg formation.
V. Massive dove limestone, bed 3g, Chambersburg formation.
VI. Gray earthy limestone, bed 3i, of Chambersburg formation.
VII. Calcareous shales at base of Martinsburg shales.

Woodstock and vicinity.—About 350 feet of argillaceous limestones of the Chambersburg formation may be found exposed just east of Woodstock before the Martinsburg shales are encountered. These limestones and the overlying shales dip at an angle of about 40° southeast. Practically the same thickness of cement rock is exposed to the northeast and southwest of Woodstock, but although the outcrops are not as good as those noted in the Strasburg area, essentially the same section may be found. As this line of outcrops is paralleled by the Southern Railroad, which is at no place more than 2 miles distant, favorable sites for cement plants are offered. The most promising location, however, is in the immediate vicinity of Woodstock, since here the cement rocks outcrop on the western side of the North Fork of the Shenandoah river. Farther south the river flows between the railroad and the cement rock outcrop, and the cost of a spur line would thus be greatly increased.

Pure limestones for mixture with the cement rock can be found in the immediate vicinity, west of the line of the outcrop of the argillaceous rock. Limestone strata, high in calcium carbonate and low in magnesia, were found interbedded with the dolomites west of Woodstock, and more extended search would no doubt reveal an ample supply. The following analyses are of the pure and argillaceous limestones in this vicinity:

Analyses of limestones, Woodstock, Virginia.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.
Insoluble	56.26	14.88	10.04
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	4.82	2.38	1.46
Lime (CaO)	18.96	45.00	48.48
Calcium carbonate ($CaCO_3$)	33.88	80.36	86.57
Magnesia (MgO)	.91	1.04	0.73
Magnesium carbonate ($MgCO_3$)	1.91	2.18	1.54
Total	96.87	99.80	99.61

I. Siliceous limestone, Stones River formation.
II. Argillaceous limestone, upper part of Chambersburg formation.
III. Dark blue limestone, lower part of Chambersburg formation.

Harrisonburg and vicinity.—A syncline showing the argillaceous limestones and Martinsburg shales occurs just west of Harrisonburg and extends northeast-southwest for a distance of some miles. The cement rock is especially well shown along the street just west of the Southern Railroad depot, but exposures of the shales and underlying argillaceous rocks may be seen along the country roads going northwest, west, and southwest from the town. The thickness of the argillaceous limestones in this vicinity could not be ascertained with certainty because of the lack of continuous exposures, but it probably does not fall short of 200 feet. Fossils indicating the Chambersburg age of the strata were not uncommon in the rocks shown along the western edge of the town.

Purer limestone deposits are found in considerable quantity east and southeast of Harrisonburg. Exposures of this rock may be seen in a cut on the Chesapeake and Western Railroad just east of the crossing with the Southern Railroad. Here a rather pure gray limestone occurs, having the composition shown in analysis No. I of the table on page 113.

From 75 to 100 feet of argillaceous limestones and calcareous slates are exposed in a cut on the Chesapeake and Western Railroad southwest of Harrisonburg and just west of the Southern crossing. Samples from this cut were analyzed by Charles Catlett with the result shown in analysis No. II.

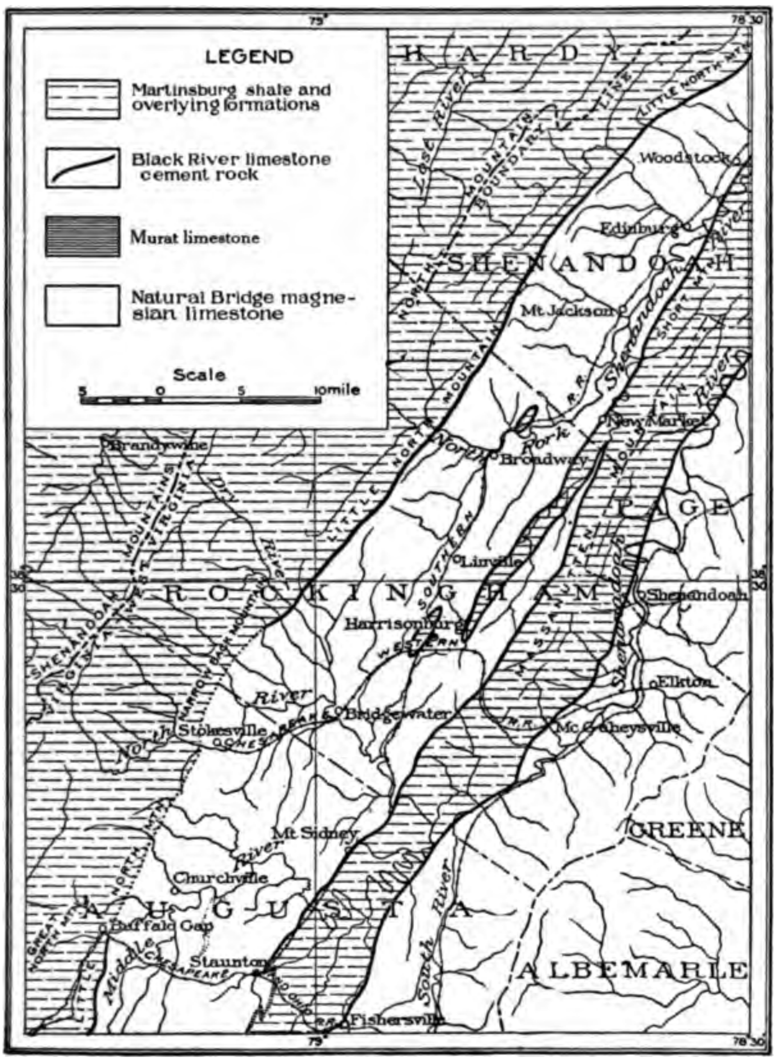


Fig. 17.—Map of the Valley of Virginia from Woodstock to Staunton. area includes Natural Bridge limestone and underlying formations.

About 1.5 miles north of Harrisonburg the Southern Railroad passes through a cut about 20 feet high and 400 to 600 feet in length, exposing comparatively horizontal slaty limestone with a composition shown in analysis No. IV.

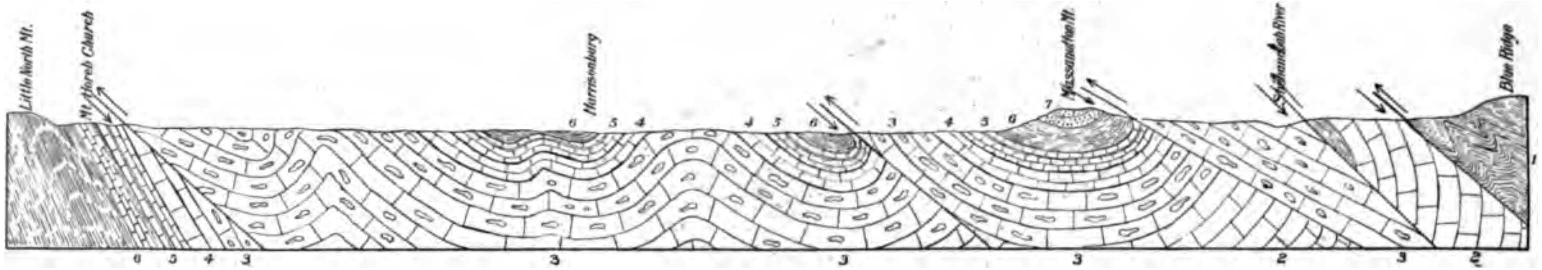


Fig. 18.—Structure section across Valley in the southern part of northwestern Virginia from the Blue Ridge to Little North Mountain, about the latitude of Harrisonburg. 1. Pre-Cambrian strata of the Blue Ridge; 2. Cambrian limestone; 3. Natural Bridge limestone; 4. Stones River limestone; 5. Chambersburg formation; 6. Martinsburg shale series; 7. Massanutten sandstone.

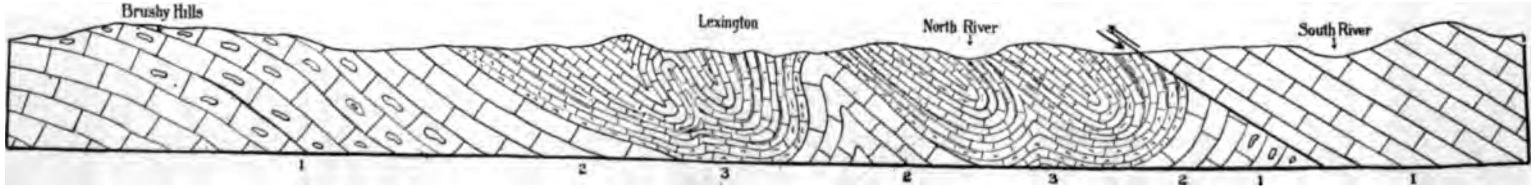


Fig. 19.—Structure section in the vicinity of Lexington, Virginia. 1. Natural Bridge limestone; 2. Murat limestone; 3. Liberty Hall limestone.

Partial analyses of cement material in the vicinity of Harrisonburg, Virginia.

(Charles Catlett, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Insoluble	2.08	27.06	7.00	25.24
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	.60	3.32	.70	1.58
Magnesia (MgO)	.60	1.42	2.36	1.67
Lime (CaO)	54.24	35.79	49.00	38.32

I. Pure gray limestone, cut on Chesapeake and Western Railroad just east of crossing with the Southern Railroad.

II. Calcareous slates, exposed in cut on Chesapeake and Western Railroad just west of crossing with the Southern Railroad.

III. Dark, friable limestones, exposed at crossing of railroads just south of Harrisonburg.

IV. Calcareous slates, cut along Southern Railroad 1.5 miles north of Harrisonburg.

All of the localities so far discussed are west of Massanutten Mountain and have good railroad facilities. East of this mountain the same limestone would normally occur, since the mountain itself is made up of a great downfold of strata or syncline. Here, however, the railroad facilities are not as good and moreover the pure and argillaceous limestones are often cut out by overthrust faulting. The best localities showing the complete geologic succession and with transportation facilities are at Wadesville and Riverton.

Wadesville.—The Middle Ordovician limestones exposed along the eastern edge of the Massanutten Mountain syncline are crossed by the railroad at Wadesville. For a short distance north of this place, the line of outcrop is not far from the railroad, and to the south and west for 1.5 miles the two parallel each other, so that this locality affords an abundance of suitable limestones within short distances of transportation facilities. The black argillaceous limestones are especially well shown along the road just east and west from the railroad station. The following section was observed along this road on the farm of John M. Lock, starting about half a mile east of Wadesville and ending at Opequon creek on the west. The strata dip at an angle of about 40° northwestwardly.

Geologic section, Wadesville, Virginia.

		Feet
5.	Martinsburg group, gray, black, and olive shales	——
4.	Dark blue and black, compact, argillaceous limestone	400
3.	Coarsely crystalline grayish blue limestone	70
2.	Stones River formation: Gray, dolomitic limestone with intercalated pure dove-colored layers, base not observed. These Stones River limestones have much the same character described for the formation in other sections of this part of Virginia. The only strata of economic importance are the intercalated dove-colored pure limestones. The rock may be identified by its numerous "birdseye" markings and by the presence of the ostracoda *Leperditia fabulites*.	
1.	Natural Bridge dolomite: Gray, dolomitic cherty limestone. These strata show comparatively few outcrops in this particular section but the presence of the rock can be detected by the more or less numerous chert fragments left upon weathering.	

Beds 3 and 4 of the above section form the Chambersburg formation and are of the most importance in the present consideration, as they will be the sources of whatever rock may be used for Portland cement. Bed 3 is a massive, rather pure limestone with some of the layers crowded with the peculiar organism *Strephochetus*. The same strata occur at the base of the Chambersburg formation in the Strasburg section, figure 15 (see page 106), and, as analyses of that rock indicate, the lime content is high. These particular strata therefore, together with the dove limestone of the underlying Stones River formation, can be relied on as a source of pure limestone for mixture with highly argillaceous rock. Bed 4 embraces the typical cement rock of Ordovician age and is a uniform, dark, compact argillaceous limestone. The lower portion is massive but the upper part is less so and weathers into a shaly rock. The latter may be distinguished from the succeeding Martinsburg shales, which it somewhat resembles when weathered, by the higher percentage of lime as well as by the fossil contents. As in other sections, the ball cystid *Echinosphærites* is the characteristic fossil of this bed. At Wadesville specimens occur sparingly throughout the bed but are most numerous in the upper part.

Riverton and vicinity.—Three distinct bands of cement rock outcrops are found at this place and in the immediate vicinity, on account of a fold in the Ordovician rocks east of the Massanutten Mountain syncline. As shown on the map, figure 16 (page 108), Riverton itself is built upon the Martinsburg shales which form the highest beds of this more eastern syncline, but just to the east and to the west of it, the strata of the Chambersburg and Stones River formations may be seen. The latter formation is being extensively quarried at a locality just northeast of Riverton.

Mount Sidney and vicinity.—From Staunton to Mount Sidney and thence for several miles northeast, the Valley Branch of the Baltimore and Ohio Railroad either closely parallels or cuts through the belt of argillaceous limestone brought up on the western flank of the Massanutten Mountain syncline. The same rocks reappear on the eastern flank, 3 to 4 miles distant. The intervening country is occupied by Martinsburg shales, all of the younger rocks found on Massanutten Mountain having been removed by erosion. The favorable composition of the rock and the proximity of these two belts to railroads—the western to the Baltimore and Ohio, and the eastern to the Norfolk and Western—cause them to be worthy of attention. The following analysis of specimens from the eastern belt in the vicinity of Weyers Cave shows more magnesia than the average.

Analysis of argillaceous limestones near Weyers Cave, Virginia.

(Wirt Tassin, Analyst)

	Per cent.
Silica (SiO_2)	14.62
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	6.90
Calcium carbonate ($CaCO_3$)	67.92
Magnesium carbonate ($MgCO_3$)	4.69
Water (H_2O)	3.94
Total	98.07

The section exposed along the railroad at Mount Sidney is as follows:

Geologic section, Mount Sidney, Virginia.

		Feet
6.	Typical Martinsburg shales	...
5.	Calcareous shales and shaly limestone with few fossils	200+
4.	Brown shales with graptolites	60
3.	Gray coarsely crystalline limestone yielding some chert upon weathering	70
2.	Heavily bedded dark blue limestone	100+
1.	Dolomitic limestone	...

Staunton.—East and northeast of this city the argillaceous limestones are well developed, and, together with the shales and pure limestones near by, offer abundant raw material for the manufacture of cement. The railroad facilities at Staunton are exceptionally good, for here a plant could obtain coal and ship its products over several lines. Ordinarily coal could be had on the most favorable terms over the Chesapeake and Ohio, but in times of labor disturbances in the New River field, the fuel supply could still be obtained from the Fairmont region. The purer limestones in the vicinity of Staunton, as a rule, run unusually high in lime, so that shales or clays for mixture with them will be necessary. Unlimited quantities of shale may be found in connection with the limestone, but deposits of good clays are not so common. In this region, the lower part of the shales are unusually calcareous, as the following analyses will show, but higher up in the series the percentage of lime is very small:

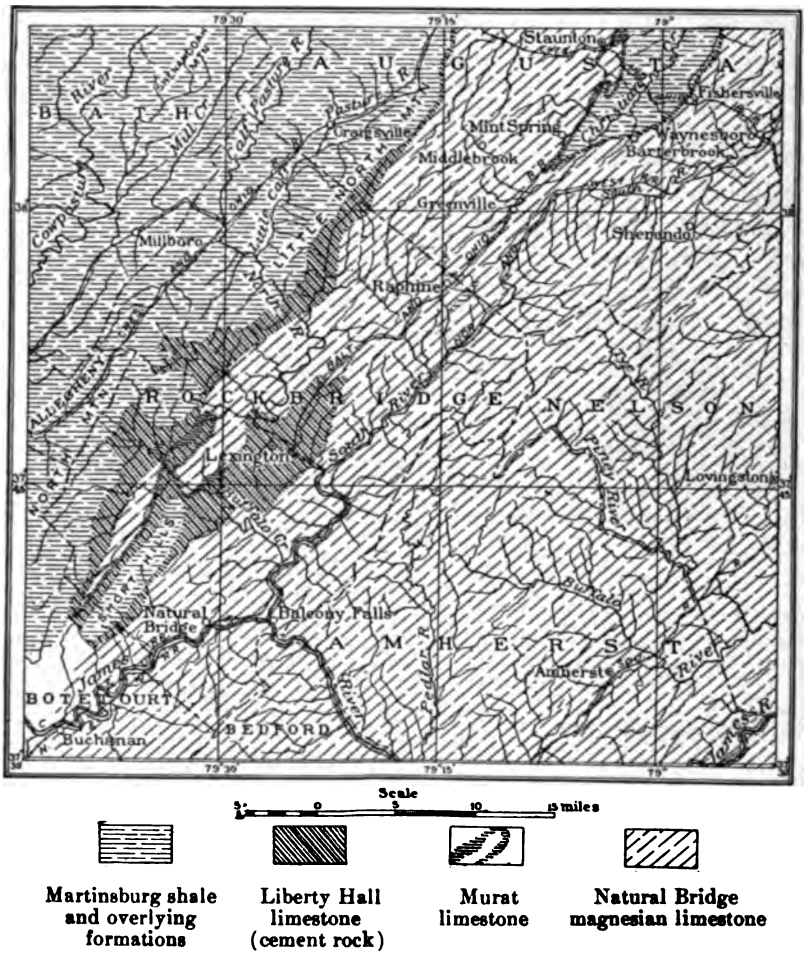


Fig. 20.—Map of the Valley of Virginia from Staunton to Natural Bridge. Area marked by diagonal broken lines includes Natural Bridge and underlying formations.

Analyses of Martinsburg shales and Liberty Hall limestone, vicinity of Staunton, Virginia.

(Charles Catlett, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Silica (SiO_2)	19.28	19.92	23.08	10.28
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	9.86	10.76	10.08	4.36
Lime (CaO)	36.42	37.05	35.89	45.79
Magnesia (MgO)	1.08	1.72	.94	.79
Carbon dioxide (CO_2)	31.70	——	——	32.80

I to III. Calcareous shales showing variation in composition.
IV. Liberty Hall limestone.

The Ordovician section in the vicinity of Staunton is best seen along the Baltimore and Ohio Railroad tracks and the road beyond the ice factory on the northeastern side of the city. Here it will be noted that the region is much folded and faulted but through the aid of several sections, the following succession can be determined:

Geologic section, Staunton, Virginia.

		Feet
4.	Martinsburg shale. Brown and yellow shales, calcareous at base	...
3.	Liberty Hall limestone. Fine-grained, argillaceous, unfossiliferous limestone	325+
2.	Murat limestone. Gray, coarsely crystalline limestone crowded with *Solenopora* and bryozoa	100
1.	Natural Bridge limestone. Gray dolomite strata with a few layers of purer limestones	...

All of the above formations of the Staunton section furnish cement materials but the most important and abundant rock is to be had from the Liberty Hall limestone. Analyses of the various divisions are given below.

The Cambrian dolomitic limestone forming the lower part of the Natural Bridge formation grade upward imperceptibly into another series of strata having essentially the same composition but differing in that extensive layers of chert are interbedded with the usual dolomites. The area occupied by this division may usually be recognized by their topographic features, for the chert gives rise to conspicuous hills or ridges. Chestnut Ridge, Sugar Loaf and Betsy Bell are examples of this topography in the vicinity of Staunton. The age of this portion, which is especially well exposed about Staunton, has been determined as Beekmantown from the gastropod and cephalopod remains found at various points in the Valley, but particularly in the vicinity of Lexington, Virginia.

Analyses of Liberty Hall limestone, vicinity of Staunton, Virginia.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	14.96	9.38
Organic matter	——	.24
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	.94	1.02
Lime (CaO)	46.54	49.56
Calcium carbonate ($CaCO_3$)	83.11	88.50
Magnesia (MgO)	.12	.57
Magnesium carbonate ($MgCO_3$)	.25	1.21
Total	92.26	100.35

Analyses prepared by Mr. Catlett from samples of the lower part of the Martinsburg shales have been given on a previous page. These indicate that this division of the shales in the vicinity of Staunton agrees with the same horizon elsewhere in chemical composition, the high amount of lime being the noteworthy feature. The higher members of the shales in the region east of Staunton show the same lithologic and other characters described for central western Virginia in general.

Western edge of Valley, north of Staunton.—The outcrops of the Ordovician limestone along the western edge of this part of the Valley are in general so remote from railroads that, in spite of the excellent rock shown at a few places, exploitation of this region is at present useless. Furthermore, throughout a considerable portion of this region the argillaceous limestones are cut out by overthrust faulting, the magnesian limestone resting upon the shales of still higher formations. But a single area can be mentioned in which the cement rocks are exposed within a reasonable distance of a railroad. Several miles north of Stokesville, the terminus of the Chesapeake and Western Railroad, and a few miles south of Little North Mountain, good outcrops of the rock are encountered. The quantity and quality of these limestones are such that, with the railroad facilities so near at hand, the rock will undoubtedly prove of economic importance. Shales are at hand for mixture with the cement rock when its percentage of lime is too high, while pure limestones, to increase the percentage when necessary, are found in sufficient quantity in the Valley just to the east. Indeed, even with the present facilities, this is one of the most promising cement localities in the Valley.

Fig. 1.—Overthrust fault in Tuscarora sandstone, near Panther Gap, Virginia.
Fig. 2.—Fields of residual decay in Shenandoah Valley, near Natural Bridge, Virginia.

Fig. 1.—View of the upper part of the Natural Bridge limestone, showing weathering into bands of chert nodules, 6 miles west of Lexington, Rockbridge county.

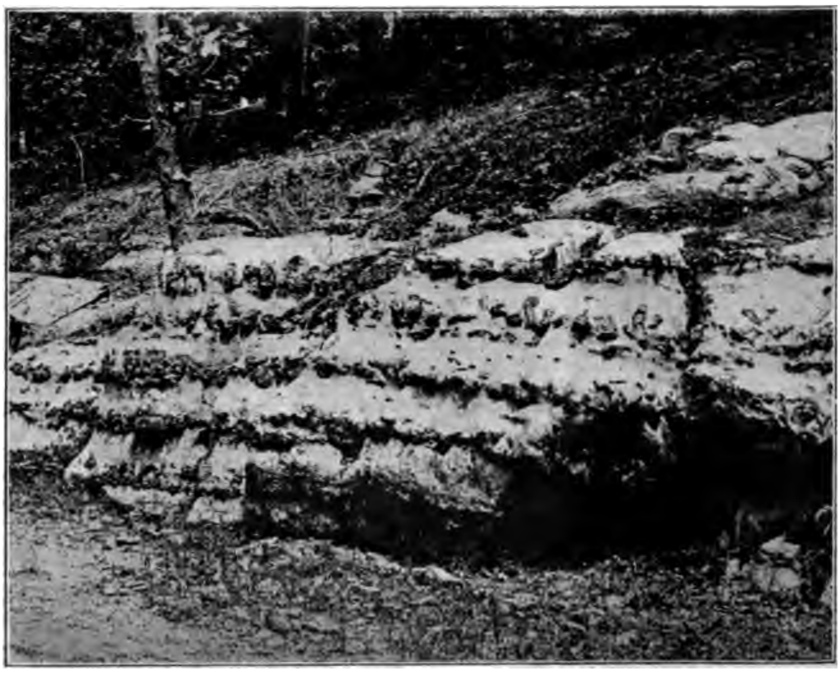


Fig. 2.—Same as Fig. 1.

NATURAL BRIDGE LIMESTONE, VIRGINIA.

limestone in this eastern area of outcrop, are overturned to the west so that the strata show a fairly uniform eastward dip. This folding likewise causes the rocks to have apparently a great thickness, but a careful examination will show the repetition of similar beds in regular order. In addition, the core of an anticline or syncline may be occasionally observed, and whenever it is possible to get a continuous section, a maximum thickness not exceeding that given by Professor Campbell is found. This close folding also involves the underlying Murat limestone, but because of the few and relatively unimportant exposures of this formation at the surface, it has been differentiated on the map only along the western border of the Lexington area where its outcrops are of most importance.

The general features of the geologic section at Lexington have been pointed out by Professor Campbell, but the following more detailed section is offered to show the variation in these strata:

Geologic section, Lexington, Virginia, and vicinity.

	Feet
III. Black River limestone including Liberty Hall, Murat, and underlying formations.	
3. Liberty Hall formation:	
(d) More or less thin bedded argillaceous limestone and calcareous shales	500±
(c) Fine-grained, dark, massive argillaceous limestone with an obscure conchoidal fracture	250±
(b) Argillaceous knotty limestone with many fossils, brachiopods and trilobites particularly numerous. *Ampyx* and *Agnostus* characteristic fossils	40
(a) Crystalline and subcrystalline limestone full of bryozoa, sponges, etc. Often absent from sections	10
2. Murat formation:	
Massive gray crystalline limestone weathering into a red, clayey soil comparatively free from chert	100
1. Massive, somewhat cherty limestone, seldom shown and of slight thickness. Fossils numerous	——
II. Stones River limestone.	
Massive dove limestone. Seldom present in the section and thickness slight when present	——
I. Natural Bridge limestone.	
Gray and light blue magnesian limestone weathering into chert. Conspicuous beds of chert near the top	——

Of the different divisions distinguished in the section, the Liberty Hall and Murat are the only formations worthy of consideration as a source of cement materials, the former as a cement rock itself, and the latter as a more or less pure limestone which could be used in mixture.

Mr. Charles Catlett has analyzed a series of samples from the Lexington strata, but the particular strata from which they were derived was not noted. In all probability, No. I of the subjoined table was from the Murat limestone, while Nos. II and VI represent various phases of the Liberty Hall beds.

Analyses of limestones from Lexington, Virginia.

(Charles Catlett Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.	VI Per cent.
Silica (SiO_2)	0.73	9.31	11.86	12.92	17.42	22.60
Alumina (Al_2O_3) and iron oxide (Fe_2O_3)	.79	3.47	1.76	3.88	4.70	7.06
Lime (CaO)	53.71	46.30	46.64	45.14	42.44	36.72
Magnesia (MgCO)	.83	.88	.74	1.37	1.68	1.69
Carbon dioxide (CO_2)	——	——	38.32	37.20	35.62	32.52

The analyses presented in the following table were made from samples selected by the writer:

Analyses of Murat and Liberty Hall limestones, vicinity of Lexington, Virginia.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Insoluble	1.62	4.32	10.24	1.30
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	0.72	.76	0.74	0.54
Lime (CaO)	54.18	52.06	48.16	54.28
Calcium carbonate ($CaCO_3$)	96.71	92.96	86.00	96.93
Magnesia (MgO)	0.42	.94	1.00	0.36
Magnesium carbonate ($MgCO_3$)	0.90	1.97	2.10	0.76
Total	99.95	100.01	99.08	99.53

I. Compact white limestone, Murat formation, Reservoir Hill, Lexington, Virginia.
II. Subcrystalline limestone, base of Liberty Hall beds, near Lexington, Virginia.
III. Dark argillaceous limestone, Liberty Hall formation, Spring Cave Hill, Lexington, Virginia.
IV. Compact gray limestone, Liberty Hall formation, Spring Cave Hill, Lexington, Virginia.

The analyses given below indicate the composition of the rocks in other parts of central western Virginia:

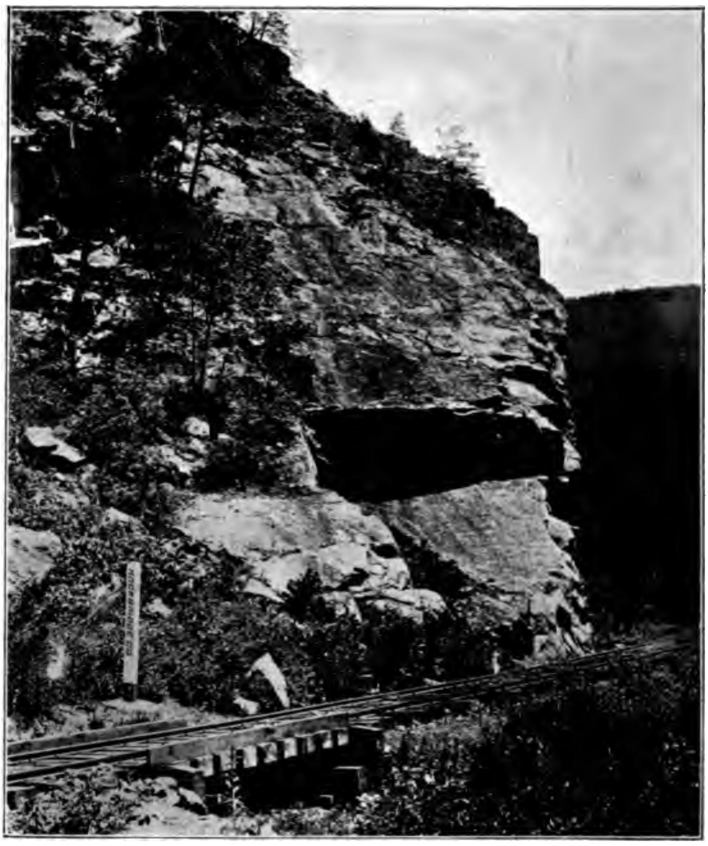


Fig. 1.—Balcony Rock composed of Lower Cambrian quartzite. Corner of Rockbridge and Amherst counties. Balcony Falls.

Fig. 2.—Cliff of Sherwood dolomite, near Sherwood. Natural Bridge station on **N. & W. and** C. & O. railroads.

LOWER CAMBRIAN QUARTZITE AND SHERWOOD **FORMATION.**

Analyses of limestones and shale, central western Virginia.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Insoluble	24.12	30.24	17.86	28.60
Organic matter	——	——	.14	1.32
Iron oxide (Fe_2O_3) / Alumina (Al_2O_3)	2.22	4.56	1.60	2.33 / 2.53
Lime (CaO)	40.24	33.00	41.34	35.08
Calcium carbonate ($CaCO_3$)	71.86	58.93	73.62	62.64
Magnesia (MgO)	.05	2.72	3.03	1.14
Magnesium carbonate ($MgCO_3$)	.10	5.81	6.38	2.39
Total	98.30	99.54	99.60	99.81

I. Murat formation, near Rockbridge Baths, Virginia.
II. Compact siliceous limestone, Liberty Hall formation, Kerrs creek, Virginia.
III. Argillaceous limestone, upper part of Liberty Hall formation, 5 miles west of Rockbridge Baths, Virginia.
IV. Highly calcareous shales, basal beds of Martinsburg group, 2 miles west of Rockbridge Baths, Virginia.

GEOLOGY OF SOUTHWESTERN VIRGINIA.

In the discussion of northwestern and of central western Virginia, the writer has indicated no great differences in the stratigraphic succession or the lithology of the Ordovician strata in various parts of the Valley. In southwestern Virginia, however, a new factor in the study of these same strata is introduced. Ordinarily rocks deposited synchronously in comparatively small areas show no great differences either in lithological aspect or in their fossil contents. In the division of the State now to be discussed the Ordovician strata, particularly, differ in various areas in both of these respects. For example, the eastern portion of the Great Valley shows a development of Ordovician limestones and shales totally different from that found in the westernmost part of the State. In the study of the various sections, these differences in strata of apparently the same age were encountered in traverses made across the Valley and ridges to the west, while little difficulty was experienced in correlating the rocks in directions paralleling the length of the Valley.

Major Faults.

When compared with the two divisions discussed previously, the geology of southwestern Virginia is complicated by great folds and overthrust faults. The region is traversed in a northeast-southwest direction by at least 7 major faults and a number of minor breaks. The easternmost of these major faults passes along the base of the Holston and Iron mountains, where a sandstone of Lower Cambrian age is faulted against the dolomitic limestones. Sandstone, shale, and impure limestone outcrop east of this fault, but on account of their unsuitable chemical composition are not considered here.

The 6 major faults west of this eastern break have been described and named by Professors Lesley and Stevenson in the articles mentioned in the bibliography (page 165). These are, in order going westward, (1) the Walker Mountain, (2) Saltville, (3) Copper Creek, (4) Hunter Valley, (5) Wallen Valley, and (6) Poor Valley faults. These 7 major faults divide southwestern Virginia into 6 rather narrow areas, in each of which a belt of Ordovician limestones and shales is usually exposed. The general distribution of the cement-making materials in these areas is indicated on the maps of southwestern Virginia (pages 143 and 147). The relation of these faults to one another and the arrangement of the strata in each of the areas is shown in the accompanying structure section, figure 23.

General Distribution of Cambrian and Ordovician Strata.

The study of numerous sections including the Ordovician rocks in this part of the State brought out the fact, as mentioned before, that similar successions of these strata are at present exposed in long narrow areas bounded by the major faults. The differences of sedimentation in these various areas may perhaps most readily be shown by an outline of the stratigraphic succession in each. In both cases the well known Knox dolomite serves as a basal datum line and the identification of the various formations rests upon their fossil contents as well as their lithologic characters.

In the easternmost area, namely the region between the Blue Ridge and the Walker Mountain fault, or the Bristol area of the accompanying table, the following succession of Ordovician rocks may be observed:

3. Thin bedded sandstones and sandy shales (Tellico).
2. Blue to black calcareous and sandy shales (Athens).
1. Knox dolomite.

Locally, a thin, somewhat magnesian, blue limestone, the equivalent of the Lenoir limestone of eastern Tennessee, occurs between the Knox and the Athens.

The narrow strip between the Walker Mountain fault and the Saltville fault, the Walker Mountain area of the table, shows an overlapping

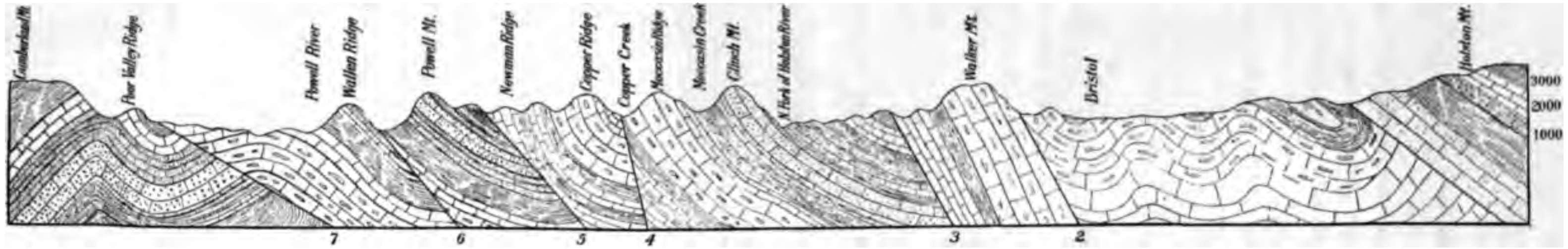


Fig. 23.—Structure section across southwest Virginia from Holston Mountain west to Cumberland Mountain. This section illustrates the blocks into which southwest Virginia is divided by the major faults of the region. The length of the section has been greatly lessened and the height exaggerated. As a result, only the general geologic structure of each block could be shown. 1. Fault along western edge of Holston Mountain; 2. Walker Mountain fault; 3. Saltville fault; 4. Copper Creek fault; 5. Hunter Valley fault; 6. Wallen Valley fault; 7. Poor Valley fault.

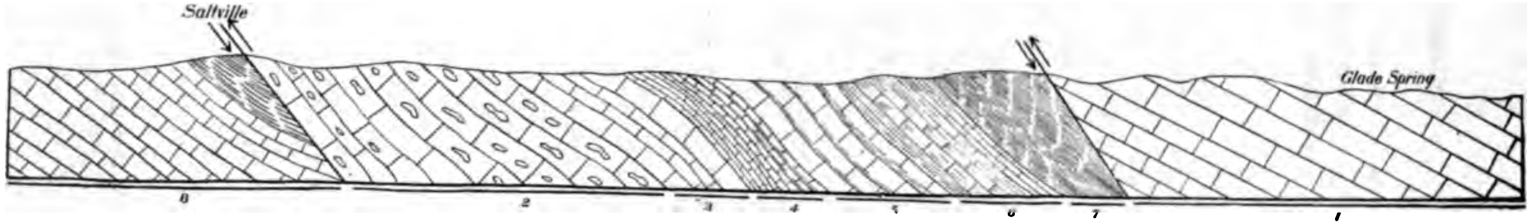


Fig. 24.—Structure section along railroad from Glade Spring to Saltville. 1. Cambrian limestone; 2. Knox dolomite; 3. Lenoir limestone; 4. Athens shales; 5. Holston formation; 6. Moccasin limestone; 7. Sevier shale; 8. Carboniferous limestone and shale.

of the formations of the next western band upon sediments of the one just described. This section, which is most clearly shown along the railroad from Glade Spring to Saltville, is as follows:

7. Red sandy shales and thin bedded sandstone (Bays).
6. Yellow and dark colored shales with thin bedded blue limestone at base (Sevier).
5. Red calcareous shales and impure red limestone (Moccasin).
4. Beds of marble with calcareous shales (Holston).
3. Blue and black calcareous shales (Athens).
2. Thick bedded, gray, slightly magnesian limestone (Lenoir).
1. Knox dolomite.

Beds of marble belonging to the Holston formation immediately follow the Knox dolomite in the Clinch Mountain area, namely the region between the Saltville and Copper Creek faults. Here, with the exception that the Lenoir limestone and Athens shale are wanting, the section, as shown below, is essentially the same as the preceding one:

6. Heavily bedded white quartzite and sandstone (Clinch).
5. Red sandy shales and thin bedded sandstone (Bays).
4. Yellow and dark colored shales with thin bedded blue limestone at the base (Sevier).
3. Red calcareous shales and impure red limestone (Moccasin).
2. Marble at base followed by thin bedded limestones and shales (Holston).
1. Knox dolomite.

The marbles of the Holston formation are particularly well developed in Tennessee. In Virginia, the northernmost occurrence of the fauna associated with these marbles was noted at the foot of Clinch mountain, south of Tazewell.

The strip bounded by the Copper Creek and Hunter Valley faults, here called the Copper Creek area, contains the Knox dolomite, the Moccasin, Sevier, Bays, and Clinch formations, but in place of the marbles and thin-bedded limestones of the Holston, heavily-bedded, gray and dark blue limestone is found. The difference between this and the Holston formation may be seen in cuts along the Virginia and Southwestern Railroad, near Speer Ferry and Clinchport. The exact equivalents of this massive limestone have not yet been determined, but, the new name, Pearisburg limestone, is here instituted.

The westernmost and most different sequence of the Ordovician in Virginia is found in the valley of Powell river, where the arrangement of the rocks, with the exception of the Clinch sandstone, is exactly the same as that obtaining in southwestern Ohio, central Kentucky, and central Tennessee. In Virginia, these rocks are known to occur throughout the Powell river valley eastward to the Wallen Valley fault, and in all probability the narrow strip between this fault and that of Hunter valley is also occupied by them. The formational names employed below for the rocks in this area are, with the exception noted before, those used in the Ohio Valley Ordovician:

10. Heavy bedded white quartzite or sandstone (Clinch).
9. Red and yellow limestones and shales (Lorraine).
8. Yellow arenaceous shales and limestones (Eden).
7. Olive and yellow shales (Utica).
6. Thin bedded blue limestones and blue or yellow shales (Trenton-Cathey).
5. Dark blue crystalline limestone (Trenton-Bigby).
4. Yellow and olive shales (Trenton-Hermitage).
3. Thin bedded dove limestones and yellow shales (Tyrone).
2. Massive dove limestone (Stones River).
1. Knox dolomite.

On account of the variation of the rocks in these different areas, the importance, from an economic standpoint, of delimiting their boundaries, is apparent. In the maps accompanying this article, it has been possible to show only the general areas of outcrop of the purer Ordovician limestones and of their associated strata.

The theories for this distribution of strata in separate areas need not be entered upon here more than to state that Ulrich and Schuchert, in their Paleozoic Seas and Barriers, have advanced the apparently well founded idea that the area of the Appalachian Valley during Ordovician times was divided longitudinally into several narrow troughs which were more or less effectively separated from each other; and that the observed differences in sedimentation and life characterizing the several troughs are attributable to this separation.

The general relation of the Cambrian and Ordovician formations and the more important cement rock horizons are indicated in the following correlation table:

Cambrian and Ordovician formations of southwest Virginia.

General time scale	Bristol area	Walker Mt. area	Clinch Mt. area	Copper Creek area	Powell Valley area
Cincinnatian (Upper Ordovician)		Clinch Bays Sevier*	Clinch Bays Sevier*	Clinch Bays Sevier*	Lorraine Eden Utica*
Mohawkian (Middle Ordovician)	Tellico Athens* Lenoir (often absent)*	Moccasin Holston* Athens* Lenoir*	Moccasin Holston*	Moccasin Pearisburg*	Trenton* Tyrone* Stones River*
Canadian (Lower Ordovician) Saratogan (Upper Cambrian)	Knox	Knox	Knox	Knox	Knox
Acadian (Middle Cambrian)	Nolichucky Honaker	Nolichucky Honaker	Nolichucky Maryville Rogersville Rutledge	Nolichucky Maryville Rogersville Rutledge	
Georgian (Middle Cambrian)	Russell	Russell	Russell	Russell	

*Horizons of cement materials.

Stratigraphy.

Instead of considering each of these areas of deposition separately, it seems best in the present connection, because of lack of space, to give a short description of the various formations, and to present the analyses in tabular form. The geographic distribution of the formations and the assignment of each analysis to its proper place in the section, must, therefore, be left to the reader.

Cambrian Formations.

Russell shales.—The oldest strata outcropping in southwestern Virginia northwest of Holston Mountain, are sandy shales, thin-bedded sandstones, and brown argillaceous shales, found in the valleys of Copper creek and Clinch river. The sandy beds make up the greater part of this formation, and therefore, as a whole, the Russell shales are of little value from an economic standpoint. Argillaceous shales occur somewhat sparingly in the upper third and might prove of value for a mixture with pure limestones in the manufacture of cement. The great range in the chemical composition of these shales is indicated in the following analyses:

Analyses of Russell shales, vicinity of Clinchport, Virginia.
(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	41.72	89.52
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	5.68	7.22
Lime (CaO)	17.32	0.40
Calcium carbonate ($CaCO_3$)	30.93	0.72
Magnesia (MgO)	9.17	1.05
Magnesium carbonate ($MgCO_3$)	19.29	2.21
Total	97.62	99.67

I. Brown argillaceous shales, upper part of formation.
II. Sandy shales, several hundred feet from top of formation.

Rutledge limestone.—Impure magnesian limestones 200 to 300 feet in thickness follow the Russell shales. Their composition varies considerably but the magnesia content appears too high in all the samples examined to make the rocks of use.

Analyses of Rutledge limestones, vicinity of Clinchport, Virginia.
(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	3.88	2.58
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	1.36	1.12
Lime (CaO)	46.22	30.80
Calcium carbonate ($CaCO_3$)	82.53	55.00
Magnesia (MgO)	5.62	19.70
Magnesium carbonate ($MgCO_3$)	11.80	41.37
Total	99.57	100.07

I. Gray limestone near base of formation.
II. Dark limestone near top of formation.

Rogersville shale.—Separating the impure Rutledge limestone from the purer limestone of the succeeding formation—the Maryville limestone—is a blue calcareous shale named from Rogersville, Tennessee. This shale is abundantly fossiliferous and contains a fauna of Middle Cambrian age. The shale persists as such over a large area in northeastern Tennessee, but in southwestern Virginia it disappears from a shale formation toward the east. Along the western side of the Valley the formation often changes to a dark, siliceous limestone which cannot be separated from the underlying Rutledge limestone.

Analyses of Rogersville shale, vicinity of Clinchport, Virginia.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	31.22	87.48
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	6.20	1.32
Lime (CaO)	21.41	3.60
Calcium carbonate ($CaCO_3$)	38.23	6.42
Magnesia (MgO)	10.90	1.76
Magnesium carbonate ($MgCO_3$)	22.89	3.70
Total	98.54	98.92

I. Calcareous shales, upper part of formation.
II. Sandy shales, lower part of formation.

Maryville limestone.—Of all the Cambrian formations, this is the most promising from an economic standpoint, because it is a comparatively pure limestone which, in a combination with associated shales, might make a good cement rock mixture. Wherever these strata occur as a well defined formation, they are heavily bedded, blue limestones, varying in thickness from 500 to 650 feet. The type locality is at Maryville, Blount county, Tennessee, but typical exposures are found in southwestern Virginia northwest of a line following Moccasin Ridge.

Analyses of Maryville limestone, vicinity of Clinchport, Virginia.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Insoluble	35.06	31.78	10.54	2.16
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	1.90	1.84	0.64	0.54
Lime (CaO)	29.16	35.78	46.74	50.80
Calcium carbonate ($CaCO_3$)	52.07	63.89	83.43	89.43
Magnesia (MgO)	5.33	0.93	1.82	3.79
Magnesium carbonate ($MgCO_3$)	11.20	1.96	3.82	7.95
Total	100.23	99.47	98.43	100.08

I and II. Cherty black limestone.
III. Blue crystalline limestone.
IV. Grayish, subcrystalline limestone.

Honaker limestone.—Southeast of a line paralleling Moccasin Ridge, the Maryville limestone, the Rogersville shale, and the Rutledge limestone, cannot be distinguished as separate formations but form a lithological unit for which the name Honaker limestone is employed, because of good exposures at Honaker, Russell county, Virginia. This formation is of blue and gray limestone with a maximum thickness of 1,400 feet. It seems worthy of exploration only as a source of natural cement rock.

Nolichucky shale.—This formation, the second shale horizon of economic importance, overlies the Honaker limestone in the Valley proper but follows the Maryville limestone west of Moccasin Ridge. The shale derives its name from the Nolichucky river in Tennessee and carries a fauna of Middle Cambrian age. As a whole, the formation is composed of calcareous shale and shaly limestone reaching a maximum of 400 feet in thickness. West of Copper Ridge the Nolichucky shale is greatest in thickness, but eastward it diminishes until just east of Bristol it disappears altogether. At a few localities in this portion of Virginia, the Nolichucky shales contain limestone lentils of considerable thickness, which, with the associated shales, furnish the necessary raw material for cement manufacture. The most important of such occurrences is in Carter Valley, where a lentil of blue limestone with a maximum thickness of 550 feet is found.

Analysis of Nolichucky shale, vicinity of Clinchport, Virginia.

(J. H. Gibboney, Analyst)

	Per cent.
Insoluble	38.68
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	5.28
Lime (CaO)	29.46
Calcium carbonate ($CaCO_3$)	52.61
Magnesia (MgO)	0.80
Magnesium carbonate ($MgCO_3$)	1.69
Total	98.26

Cambro-Ordovician.

Knox dolomite.—Succeeding the Nolichucky shale is the great limestone formation of the Valley—the Knox dolomite. In southwest Virginia this formation varies from 2,000 to 3,000 feet in thickness, a considerable diminution from the 4,000 feet exposed in the typical localities in Knox county, Tennessee. The Knox is generally a heavily-bedded gray magnesian limestone or dolomite with comparatively few natural outcrops. The line of outcrop is usually indicated by the heavy mantle of residual chert. These cherts occur in the limestone as nodular, dense masses of a white color, although often they appear as a porous sandstone. At some places the top of the formation is marked by a white argillaceous limestone which, if developed in sufficient quantity, and easily accessible, would prove of value economically. The reference of this limestone to the Knox is doubtful and the exact position of these strata cannot be determined until more paleontological evidence is at hand.

The Knox dolomite is one of the sources of the ridges of southwestern Virginia, but only when its strata are inclined at a considerable angle. In the process of weathering, the soluble dolomite is washed away, leaving the insoluble chert to maintain the ridge. In this area the most prominent of such ridges are Copper and Moccasin Ridges, Walker Mountain, and Chestnut Ridge.

The lower part of the formation is generally unfossiliferous, but from evidence found elsewhere in the Valley, this portion is of Upper Cambrian age. The cherts in the upper part of the Knox dolomite are sometimes fossiliferous and contain a fauna of Beekmantown age. As this fauna has been found 1,000 feet below the top of the Knox, the Beekmantown portion has a thickness of at least that amount.

Considered as a source of cement material, the Knox is of little, if any, importance.

Analyses of Knox dolomite.

(J. H. Gibboney, Analyst)

	I Pr. cent.	II Pr. cent.	III Pr. cent.	IV Pr. cent.	V Pr. cent.	VI Pr. cent.
Insoluble	2.54	3.98	3.62	1.40	40.44	1.38
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	0.78	1.12	0.48	0.08	4.00	2.88
Lime (CaO)	53.90	44.88	37.90	31.48	16.90	52.48
Calcium carbonate ($CaCO_3$)	96.25	80.14	67.68	56.22	30.18	93.71
Magnesia (MgO)	0.41	6.43	13.50	20.29	11.42	0.67
Magnesium carbonate ($MgCO_3$)	0.87	13.52	28.35	42.61	23.98	1.41
Total	100.44	98.76	100.13	100.31	98.60	99.38

	VII Pr. cent.	VIII Pr. cent.	IX Pr. cent.	X Pr. cent.	XI Pr. cent.	XII Pr. cent.
Insoluble	24.54	9.60	7.56	8.09	34.62	12.34
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	3.66	0.40	0.98	1.52	4.72	2.34
Lime (CaO)	39.20	50.60	30.10	46.64	31.72	39.60
Calcium carbonate ($CaCO_3$)	70.00	90.35	58.75	83.28	56.64	70.72
Magnesia (MgO)	0.62	4.29	18.00	3.18	1.26	6.22
Magnesium carbonate ($MgCO_3$)	1.31	9.00	37.80	6.68	2.64	13.06
Total	99.51	110.35	105.09	99.57	98.62	98.46

I. Purer limestone seam from thick bedded strata (Upper Cambrian), lower portion of formation, 2 miles south of Saltville, Virginia.
II. Dolomitic limestone (Beekmantown), middle portion of formation, 4 miles south of Saltville, Virginia.
III. Dolomitic limestone (Beekmantown), upper part of formation, 4 miles south of Saltville, Virginia.
IV. Knox dolomite, Lyon Gap section (Bed 1), Smyth county.
V. Knox dolomite, Lyon Gap section (Bed 2), Smyth county.
VI. Dove-colored purer limestone, near Goodwin Ferry, Giles county.
VII. Arenaceous limestone, 800 feet below top of formation, near Goodwin Ferry, Giles county.
VIII. Bluish-gray limestone, lower part of formation, vicinity of Clinchport, Virginia.
IX. Gray dolomite limestone, upper part of formation, vicinity of Clinchport, Virginia.
X. Less dolomitic layer in upper part of formation, vicinity of Clinchport, Virginia.
XI and XII. White argillaceous limestone, top of formation, Speer Ferry, Virginia.

Ordovician Formations.

The most promising sources of supply for cement materials in this part of Virginia, as elsewhere in the Appalachian Valley, are of Middle Ordovician age. On account of the variation in the Ordovician formations noted before, various names have been applied to the several lithologic units. These names, as well as the sequence of formations in the different areas of outcrop, have been indicated in the table on page 128, where a name hitherto most commonly applied to the purer Ordovician limestones of the southern Appalachians has been omitted. Explanations regarding this formation, the Chickamauga limestone, are therefore in order.

Chickamauga limestone.—The Ordovician limestone exposed in the westernmost outcrops of the Appalachians show a considerable thickness when compared with limestones of the same age farther east. To this thick limestone formation the name Chickamauga was applied and has been employed on the maps of many of the Valley folios. The separation and delimitation of this purer limestone from the great underlying dolomitic series was a distinct advance in mapping, and the name was subsequently employed for any or all of the purer Ordovician limestones following the Knox dolomite. As mapping proceeded, eastward and northward from the typical area, other Ordovician formations were distinguished. In these cases the term Chickamauga was restricted to the pure limestone immediately following the Knox dolomite. Thus while its lower boundary was thought to be constant, the upper was regarded as variable.

At the typical Chickamauga outcrops along Chickamauga creek, in Georgia, and east of Chattanooga, Tennessee, this limestone appears to contain representatives of most of the geological formations of the general time scale between the top of the Knox dolomite and the base of the Silurian. With this explanation in mind, a glance at the table of geologic formations will indicate that in the type locality the Chickamauga includes representatives of not only the Ordovician limestone, but also of the succeeding shales and sandstones of Virginia localities. In the eastern part of the Appalachian Valley the term was applied to the strata to which Safford long before gave the name Lenoir limestone; farther west, the Holston marbles and limestones have been mapped as the Chickamauga, while in Powell River Valley, the generally quite distinct or different Stones River, Black River, and Trenton strata have been grouped under the same name.

Lenoir limestone.—A gray, slightly magnesian limestone usually mapped as the Chickamauga succeeds the Knox dolomite in the more eastern portions of the Valley in Virginia and Tennessee. To this, Safford and Killebrew applied the above name from its occurrence at Lenoir, Tennessee. In Virginia a maximum of 200 feet is reached in the Glade Spring region, but the usual thickness is much less than this amount. The Lenoir limestone is of particular interest paleontologically on account of its typical Chazy fauna.

Analyses of Lenoir limestone.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.
Insoluble	4.60	7.34	16.12
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	.24	0.88	3.20
Lime (CaO)	51.90	48.04	42.74
Calcium carbonate ($CaCO_3$)	92.68	85.78	76.32
Magnesia (MgO)	1.06	3.07	1.34
Magnesium carbonate ($MgCO_3$)	2.32	6.45	2.82
Total	99.84	100.45	98.46

I and II. Slightly magnesian limestones, 4 miles south of Saltville, Virginia.
III. Argillaceous limestone, Lyon Gap section. (Bed 3), Smyth county.

Athens shale.—Resting either upon the Lenoir limestone, or, when this is absent, upon the Knox dolomite, are dark and blue calcareous shales named from Athens, McMinn county, Tennessee, where they are well developed. In Virginia, these shales attain a maximum thickness of 1,000 or 1,200 feet. The lower strata are black carbonaceous shales passing into blue calcareous shales, which, as the top of the formation is approached, become more and more sandy. In folio No. 59 of the U. S. Geological Survey, the more important Athens shale areas of Virginia are shown. The composition of all the samples selected for analysis is given below. These analyses, which are of only the lower and middle divisions, indicate the value of this shale as a cement material.

Analyses of Athens shale.

(J. H. Gibboney, Analyst)

	I Per ct.	II Per ct.	III Per ct.	IV Per ct.	V Per ct.	VI Per ct.	VII Per ct.
Insoluble	19.48	11.24	5.82	17.64	11.40	25.80	17.58
Organic matter	1.28	.60	——	.08	.82	——	——
Iron oxide (Fe_2O_3) alumina (Al_2O_3)	1.28	.96	0.54	1.40	1.38	3.74	2.44
Lime (CaO)	42.20	48.62	47.32	43.84	47.14	37.96	43.44
Calcium carbonate ($CaCO_3$)	75.36	86.82	84.50	78.28	84.18	67.36	77.59
Magnesia (MgO)	1.16	Trace	4.16	1.26	.95	0.12	0.04
Magnesium carbonate ($MgCO_3$)	2.45	Trace	8.74	2.64	2.00	0.24	0.08
Total	99.85	99.62	99.60	100.04	99.78	97.14	97.69

I. Calcareous shale, 2 miles south of Abingdon, Virginia.
II. Shaly limestone, 3 miles east of Bristol, Virginia.
III. Limestone band, 4 miles east of Bristol, Virginia.
IV and V. Dark shales about 5 miles south of Saltville, Virginia.
VI. Dark shales (Bed 4), Lyon Gap section, Smyth county.
VII. Dark blue shales (Bed 4), Lyon Gap section, Smyth county.

Holston formation.—The Ordovician limestone mapped by the U. S. Geological Survey in the vicinity of Knoxville, Tennessee, as the Chickamauga, contains beds of marble in its upper part, distinguished as the Holston marble. These marbles and thin shale beds accompanying them, hold a fauna of bryozoa, crinoids, cystids, and sponges so different from other Ordovician formations that this Holston division or its equivalent can easily be recognized elsewhere. In some parts of Virginia and Tennessee, these shales and marbles immediately follow the Knox dolomite; elsewhere they rest upon the Lenoir limestone or its equivalent, as at Knoxville, Tennessee; again, in more eastern belts where the marble is comparatively thin, either the Athens shales or both the Athens and Lenoir may intervene. Therefore in view of the characteristic lithology, the peculiar fauna, and the fact that it occupies a definite position in the stratigraphic column, the name Holston is herein accorded the rank of a formational name.

The Holston formation is probably best developed along the nortl ern edge of Clinch Mountain in both Tennessee and Virginia. At ' Hill, west of Morristown, Tennessee, the various strata making u formation are well exposed, and this section as well as any other aloı same line of outcrop, may be taken as typical for the Holston. In ı west Virginia, a good section may be observed at almost any point be Speer Ferry and Gate City. The railroad cuttings and the naturı posures about Speer Ferry show the following succession of rocks:

Geologic section, Speer Ferry, Virginia.

6. Clinch sandstone. Coarse, white, massive quartzite and sandstone, outcropping at crest of Clinch Mountain..............................
5. Bays sandstone. Red sandy shales and sandstone containing numerous Lorraine fossils..
4. Sevier shales. Yellow or blue shales, calcareous in lower part especially
3. Moccasin limestone. Red argillaceous limestone with a few drab-colored layers ....
2. Holston formation. Marble, limestone and shales in the following order:
   (d) Yellow shales with thin argillaceous blue or dove limestone breaking up into nodular masses upon weathering..................
   (c) Blue and gray coarsely crystalline limestone, massive when unweathered but splitting up into layers 2 to 4 inches in thickness when exposed...
   (b) Blue, drab, and yellow shales with numerous fossils.............
   (a) Pink and gray marbles with coarsely crystalline limestone.......
1. Knox dolomite:
   (b) White, fine-grained argillaceous limestone (Knox?)...........
   (a) Gray, magnesian, cherty limestone.........................

Although the Holston formation contains a variety of diverse ε still all of them are low enough in magnesia to be considered as cı materials.

Analyses of Holston marble and shale.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V	VI
	Per ct.	Per ct.	Pr. ct	Pr. ct.	Pr. ct.	Pr. ct.
Insoluble	23.54	0.86	39.52	33.80	10.56	10.10
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	3.52	1.10	5.64	4.36	2.24	2.36
Lime (CaO)	39.86	55.00	28.44	35.14	48.06	49.70
Calcium carbonate ($CaCO_3$)	71.18	98.21	50.70	59.18	85.82	85.72
Magnesia (MgO)	0.88	0.08	0.88	0.66	0.70	0.21
Magnesium carbonate ($MgCO_3$)	1.78	0.17	1.85	1.38	1.43	0.44
Total	100.02	100.34	97.71	98.72	100.05	98.62

	VIII Per ct.	IX Per ct.	X Pr. ct.	XI Pr. ct.	XII Pr. ct.	XIII Pr. ct.
Insoluble	8.16	4.66	12.18	14.96	8.26	8.42
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	1.24	1.46	0.98	1.70	1.82	3.66
Lime (CaO)	49.76	51.50	47.56	45.08	50.40	47.12
Calcium carbonate ($CaCO_3$)	88.86	91.96	84.93	80.50	90.89	84.14
Magnesia (MgO)	0.75	0.51	0.75	0.38	0.12	0.67
Magnesium carbonate ($MgCO_3$)	1.58	1.06	1.58	0.81	0.26	1.41
Total	99.84	99.14	99.67	97.97	101.23	97.63

I. Calcareous shale interbedded with Holston marble, 5 miles south of Saltville, Virginia.
II. Light-colored, coarsely crystalline marble, base of formation, Speer Ferry, Virginia.
III. Blue shale, succeeding marble, in lower part of formation, Speer Ferry, Virginia.
IV. Drab shales, middle portion of formation, Speer Ferry, Virginia.
V. Bluish argillaceous limestone, upper part of formation, Speer Ferry, Virginia.
VI. Dark argillaceous limestone, upper part of formation, Speer Ferry, Virginia.
VII. Heavily bedded argillaceous limestone, 3 miles north of Mendota, Virginia.
VIII. Dove limestone, 3 miles north of Mendota, Virginia.
IX. Thin bedded argillaceous and crystalline limestone (Bed 5), Lyon Gap section, Smyth county, Virginia.
X. Blue argillaceous limestone (Bed 6), Lyon Gap section, Smyth county, Virginia.
XI. Gray argillaceous limestone (Bed 6), Lyon Gap section, Smyth county, Virginia.
XII. Dark argillaceous limestone, Gate City, Virginia.
XIII. Blue argillaceous limestone, Gate City, Virginia.

Pearisburg limestone.—In the table of formations on page 128, the Pearisburg has been indicated as a formation between the Knox dolomite and the Moccasin limestone in the Copper creek area of southwestern Virginia. This is a new formational name introduced for the limestones occupying this interval, and particularly for the rocks at Pearisburg, Giles county, where the following type section for the formation is exposed.

Geologic section, Pearisburg, Virginia.

	Feet
4. Sevier shales	——
3. Moccasin limestone. Purple calcareous shales and argillaceous limestones with seams of impure dove limestone	200
2. Pearisburg limestone:	
(f) Light gray compact limestone with gastropods abundant in the lower beds and numerous ostracoda in the upper part	60
(e) Fine-grained dove limestone	20
(d) Imbedded magnesian limestone	25
(c) Light to dark gray moderately fine-grained limestone in lower part and massive cherty beds in upper division	65

(b) Dark bluish-gray limestone, subcrystalline or earthy in the upper part and slightly cherty in the lower beds. A *Girvanella* less than 0.5 inch in diameter very abundant 50
(a) Dark gray mottled massive limestone leaving a deep red chert upon weathering. Fossils numerous, bryozoa, brachiopods, and *Solenopora* being particularly abundant 250
1. Knox dolomite. Magnesian limestone weathering into reddish chert ...... ——

Analyses of Pearisburg limestone, vicinity of Pearisburg, Virginia.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V	VI	VII
	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.
Insoluble	6.14	7.86	5.02	3.88	3.14	2.16	0.52
Organic matter	.26	——	.43	——	——	——	——
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	.94	.90	1.00	.50	1.58	0.66	0.38
Lime (CaO)	50.30	48.00	51.36	52.00	51.60	50.30	51.24
Calcium carbonate ($CaCO_3$)	89.82	85.72	91.71	92.84	92.14	89.82	91.50
Magnesia (MgO)	1.57	2.85	1.24	1.43	1.54	3.62	3.66
Magnesium carbonate ($MgCO_3$)	3.30	6.00	2.60	3.00	3.23	7.60	7.68
Total	100.44	100.48	100.76	100.22	100.09	100.24	100.08

	VIII	IX	X	XI	XII	XIII	XIV
	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.
Insoluble	2.24	6.56	0.98	6.64	6.04	1.00	1.42
Organic matter	——	——	——	——	——	——	——
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	0.46	.64	0.68	0.80	0.84	0.10	0.26
Lime (CaO)	53.80	50.28	54.88	50.80	51.20	54.83	54.84
Calcium carbonate ($CaCO_3$)	96.07	89.78	98.00	90.71	91.43	98.00	97.98
Magnesia (MgO)	0.48	1.66	0.20	1.04	0.80	0.18	0.11
Magnesium carbonate ($MgCO_3$)	1.00	3.48	0.43	2.18	1.67	0.38	0.23
Total	99.77	100.46	100.09	100.33	99.98	99.48	99.84

	XV	XVI	XVII	XVIII	XIX	XX	XXI
	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct.	Pr. ct	Pr. ct.
Insoluble	3.26	1.17	2.12	1.35	5.60	1.50	2.30
Organic matter	——	0.25	.18	.40	——	——	——
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	0.34	1.20	.25	.43	0.78	0.58	0.60
Lime (CaO)	52.90	——	——	——	51.40	54.76	54.06
Calcium carbonate ($CaCo_3$)	94.46	91.85	95.03	96.04	91.80	97.78	96.54
Magnesia (MgO)	0.98	——	——	——	0.72	0.15	0.30
Magnesium carbonate ($MgCO_3$)	2.05	5.52	2.40	1.75	1.52	0.31	0.64
Total	100.11	99.99	99.98	99.97	99.70	100.17	100.08

I. Dark gray limestone (Bed 2a), Pearisburg, Virginia.
II. Dark blue limestone weathering into chert (Bed 2a), Pearisburg, Virginia.
III. Subcrystalline limestone (Bed 2b), Pearisburg, Virginia.
IV. Light gray, massive limestone (Bed 2c), Pearisburg, Virginia.
V. Dark, massive limestone (Bed 2c), Pearisburg, Virginia.
VI and VII. Laminar, unfossiliferous limestone (Bed 2d), Pearisburg, Virginia.
VIII. Fine-grained dove limestone (Bed 2e), Pearisburg, Virginia.
IX. Semi-mottled limestone (Bed 2f), Pearisburg, Virginia.
X. Coarsely crystalline gray limestone, near Goodwin Ferry, Virginia.
XI. Compact, dark argillaceous limestone, near Goodwin Ferry, Virginia.
XII. Dark, argillaceous limestone, near Goodwin Ferry, Virginia.
XIII. Dark, compact limestone, near Goodwin Ferry, Virginia.
XIV. Crystalline limestone, near Goodwin Ferry, Virginia.
XV. Dove limestone, near Goodwin Ferry, Virginia.
XVI, XVII, XVIII. Massive limestone from lower part of formation, Ripplemead, Virginia. Dr. Henry Froehling, analyst.
XIX. Compact, massive limestone, lower part of formation, vicinity of Narrows, Virginia.
XX. Thin bedded blue limestone, middle portion of formation, vicinity of Narrows, Virginia.
XXI. Dove-colored compact limestone, upper part of formation, vicinity of Narrows, Virginia.

Analyses of Pearisburg limestone, vicinity of Tazewell, Virginia.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V	VI	VII
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Insoluble	2.04	1.80	5.36	2.82	5.94	6.04	4.56
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	0.50	1.00	0.72	0.78	1.46	1.14	1.84
Lime (CaO)	53.80	53.24	51.32	53.90	51.34	51.20	49.14
Calcium carbonate ($CaCO_3$)	96.07	95.42	91.64	96.25	91.68	91.42	87.75
Magnesia (MgO)	1.33	0.43	0.67	0.51	0.33	0.43	2.09
Magnesium carbonate ($MgCO_3$)	2.78	0.91	1.40	1.06	0.70	0.91	4.40
Total	101.39	99.13	99.12	100.91	99.78	99.51	98.55

I. Massive, finely crystalline limestone, base of formation, Tazewell, Virginia.
II. Blue, coarsely crystalline limestone. base of formation, Tazewell, Virginia.
III. Thin bedded dove limestone, middle portion of formation, Tazewell, Virginia.
IV. Massive dove limestone, top of formation, Tazewell, Virginia.
V. Granular blue limestone, Five Oaks, Virginia.
VI. Thin bedded shaly limestone, Five Oaks, Virginia.
VII. Dove limestone, Five Oaks, Virginia.

Moccasin limestone.—East of the Powell river valley the various Middle Ordovician limestones are followed by an argillaceous red limestone named as above from its occurrence along Moccasin creek in Scott county. Along Clinch Mountain in both Virginia and Tennessee, the best development of this impure limestone occurs, with an average thickness of 500 feet. The following table gives analyses of samples from various points in southwestern Virginia, which indicate a rather uniform composition for the rock.

Analyses of Moccasin limestone.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V	VI	VII	VIII	IX	X
	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct
Insoluble	23.58	8.28	24.72	13.20	11.73	7.66	6.90	34.28	32.24	28.86
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	1.18	1.72	3.94	2.66	1.48	.82	1.24	4.96	4.50	4.40
Lime (CaO)	40.34	49.30	38.48	45.40	47.78	50.38	50.10	31.88	33.96	35.96
Calcium carbonate ($CaCO_3$)	72.04	88.23	68.71	81.07	85.32	89.96	89.48	56.92	60.64	64.26
Magnesia (MgO)	0.83	0.96	0.64	0.87	.24	.35	0.75	0.68	0.25	0.55
Magnesium carbonate ($MgCO_3$)	1.74	2.02	1.35	1.83	.58	.76	1.57	1.44	0.53	1.17
Total	98.54	100.25	98.72	98.76	99.11	99.20	99.19	97.60	97.91	98.69

I. Argillaceous limestone about 5 miles south of Saltville, Virginia.
II. Impure drab limestone, Tazewell county, Virginia.
III. Impure red limestone, Five Oaks, Virginia.
IV. Dove-colored, argillaceous limestone, Five Oaks, Virginia.
V. Granular blue limestone, Five Oaks, Virginia.
VI. Red clayey limestone, Pearisburg, Virginia.
VII. Red limestone, near Goodwin Ferry, Virginia.
VIII. Red shales, vicinity of Speer Ferry, Virginia.
IX. Red shaly limestone, Gate City, Virginia.
X. Red shaly limestone, 3 miles north of Mendota, Virginia.

Sevier shales.—In Sevier county, Tennessee, the Tellico sandstone is followed by a great shale formation of Middle and Upper Ordovician age. Although fossils are rare in these shales, sufficient evidence has been found to indicate that the strata are of Trenton, Utica, and Eden age. The Sevier shales are, therefore, apparently only a southern extension of the Martinsburg shales of more northern localities. The lithological features of the Sevier are also quite similar to the Martinsburg, so that a detailed description is unnecessary. The lower strata are of calcareous shale and interbedded limestone, the middle portion is more argillaceous, while the upper beds are quite sandy. The lower and middle portions, therefore, are of value as a source of cement rock. All the various horizons of the Sevier are represented in the table of analyses below, but most of the samples were obtained from the more important lower portion.

Analyses of Sevier limestones and shales.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V	VI
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Insoluble	4.74	29.90	11.68	20.48	22.50	8.14
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	1.72	{ 2.02 1.30	1.52	2.04	2.34	1.24
Lime (CaO)	51.92	36.80	48.08	42.76	41.34	50.54
Calcium carbonate ($CaCO_3$)	92.71	65.72	85.86	76.36	73.82	90.25
Magnesia (MgO)	0.13	.58	0.45	0.51	0.05	0.28
Magnesium carbonate ($MgCO_3$)	0.27	1.23	0.94	1.06	0.11	0.58
Total	99.44	100.17	100.00	99.94	98.77	100.21

	VII Per ct.	VIII Per ct.	IX Per ct.	X Per ct.	XI Per ct.	XII Per ct.
Insoluble	28.62	73.00	29.70	5.12	41.48	71.88
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	3.76	11.28	3.18	2.92	6.04	8.56
Lime (CaO)	36.42	6.76	36.16	51.16	28.00	8.54
Calcium carbonate ($CaCO_3$)	65.03	12.07	64.57	91.39	50.00	15.25
Magnesia (MgO)	0.99	0.04	0.60	0.25	0.30	1.27
Magnesium carbonate ($MgCO_3$)	2.08	0.09	1.26	0.53	0.64	2.68
Total	99.49	96.44	98.71	99.96	98.16	98.37

	XIII Per ct.	XIV Per ct.	XV Per ct.	XVI Per ct.	XVII Per ct.	XVIII Per ct.
Insoluble	7.08	33.40	55.60	23.48	55.55	39.20
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	1.88	4.92	7.60	3.86	8.37	5.80
Lime (CaO)	50.60	32.86	18.20	39.44	18.41	29.20
Calcium carbonate ($CaCO_3$)	90.36	58.68	32.50	70.53	32.88	52.16
Magnesia (MgO)	0.41	0.18	0.61	0.09	0.72	0.07
Magnesium carbonate ($MgCO_3$)	0.87	0.38	1.29	0.18	1.51	0.15
Total	100.19	97.38	96.99	98.05	98.31	97.31

I. Limestone band, lower part of formation, about 6 miles south of Saltville, Virginia.
II. Calcareous shales, lower part of formation, about 6 miles south of Saltville, Virginia.
III. Compact, black limestone, Trenton horizon, Tazewell, Virginia.
IV. Calcareous shales, Trenton horizon, Tazewell, Virginia.
V. Compact argillaceous layers, lower part of formation, Five Oaks, Virginia.
VI. Limestone bands, lower part of formation, Five Oaks, Virginia.
VII. Calcareous shales at base of formation, Five Oaks, Virginia.
VIII. Sandy shales, upper part of formation, Five Oaks, Virginia.
IX. Calcareous shales, northern part of Wythe county, Virginia.
X. Thin bedded blue limestone, lower part of formation (Trenton), near Goodwin Ferry, Virginia.
XI. Calcareous shales, near Goodwin Ferry, Virginia.
XII. Sandy shales from Eden horizon, near Goodwin Ferry, Virginia.
XIII. Thin bedded black limestone, Trenton horizon, Speer Ferry, Virginia.
XIV. Calcareous shales, Trenton horizon, Speer Ferry, Virginia.
XV. Sandy shales, Eden horizon, Speer Ferry, Virginia.
XVI. Calcareous shales, basal portion of formation, Gate City, Virginia.
XVII. Upper part of formation, Gate City, Virginia.
XVIII. Calcareous shale, 3 miles north of Mendota, Virginia.

Bays sandstone.—In the Bays mountains of Tennessee, the Sevier shales are overlain by red sandy shales grading upward into red sandstones which have been mapped as a separate formation. This, the Bays sandstone, contains fossils of Lorraine age and is one of the more widespread formations in both Tennessee and Virginia. Its outcrops are generally near the summits of the Valley ridges, but the strata are usually concealed by debris from the formations above.

Analysis of Bays sandstone, near Glade Spring, Virginia.

(J. H. Gibboney, Analyst)

	Per cent.
Insoluble	90.18
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	5.72
Lime (CaO)	0.64
Calcium carbonate ($CaCO_3$)	1.14
Magnesia (MgO)	0.03
Magnesium carbonate ($MgCO_3$)	0.07
Total	97.11

Clinch sandstone.—All the more prominent Valley ridges owe their existence to this heavy sandstone. The Clinch is a massive, coarse, white sandstone or quartzite 200 to 300 feet thick, and is prominently displayed along Clinch Mountain, the most conspicuous of the Valley ridges. The sandy nature of both the Clinch and the underlying Bays prevent their use as cement materials.

Details of Localities.

Although a variety of cement rocks outcrop in southwestern Virginia, the railroad facilities are such that the strata are accessible at comparatively few points. In the present article, only the more important areas in counties with transportation facilities, are mentioned, leaving a detailed account to a more extended work upon the subject.

Giles County.—The portion of Giles county occupied by Ordovician strata is so large when compared with most other counties of southwestern Virginia, that a special map based upon a manuscript map by Mr. M. R. Campbell, is introduced. As indicated on this map, there are four important areas of these limestones and shales, and, further, each area is either crossed by or is within short distance of a railroad. The cement materials occur in the Pearisburg limestone and the lower portion of the Sevier shales. Analyses and a detailed section of the Pearisburg limestone in this area are given on pages 137-138.

Tazewell County.—This county has the advantage over many others in Virginia in having large outcrops of cement-making materials in close proximity to a railroad. Between the stations of Cedar Bluff and Tiptop, through the valley of Clinch river, the Norfolk and Western Railroad passes over Pearisburg limestone for almost the entire distance. A second line of outcrop of the same rock is found southeast of Paint Mountain, a third occurs about Morris Knob and extends northeastward, while a fourth may be found along the foothills of Clinch Mountain. Of these, the first is of most importance on account of railroad facilities, and the analyses

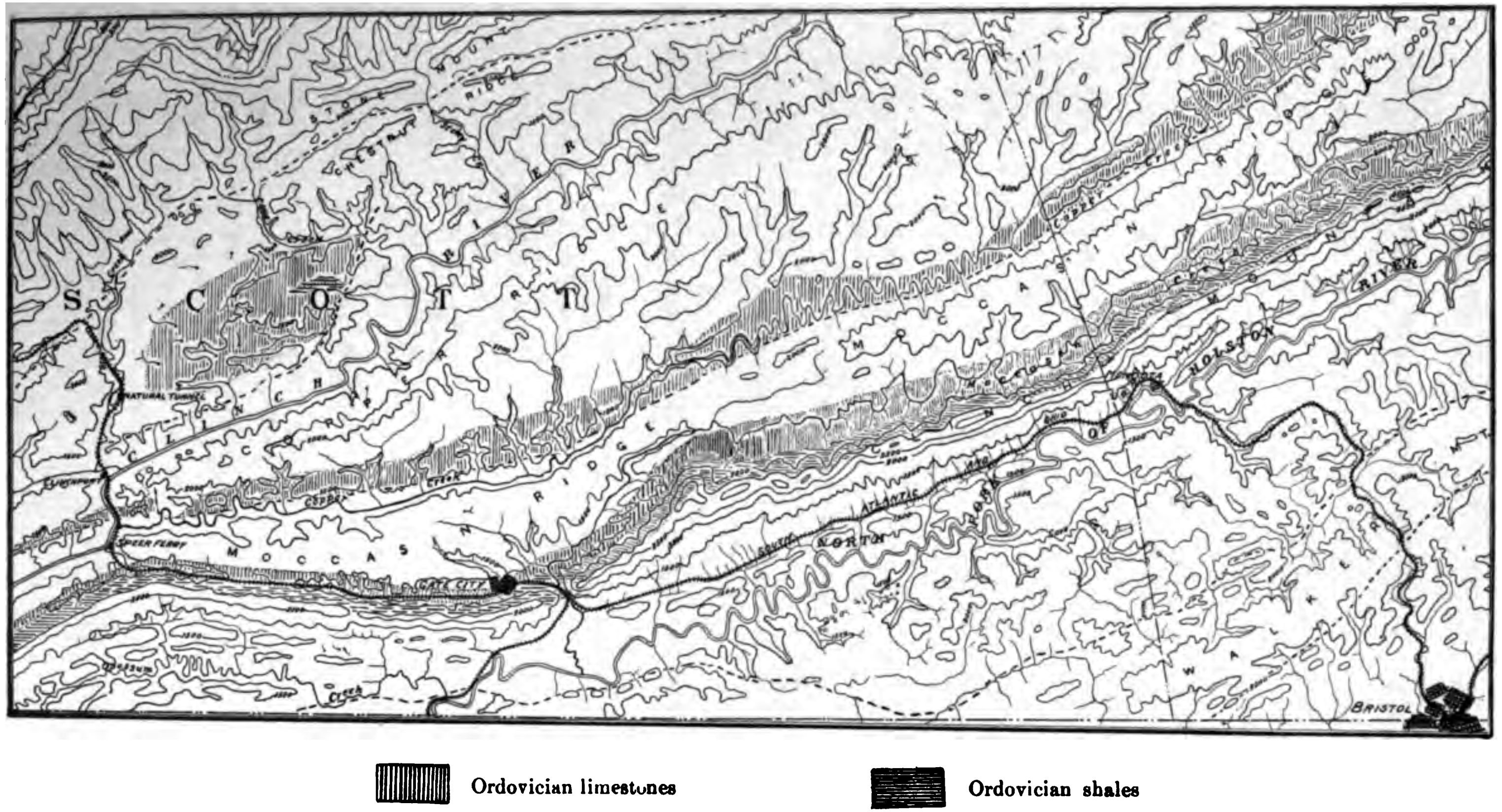


Fig. 25.—Map showing distribution of cement materials of southwestern Virginia.

are mainly from samples collected along this strip. All the analyses of Pearisburg limestone from Tazewell county are assembled in the table on page 139.

Sections showing the structural geology and a detailed map of the general geology of the greater part of the county are given in the Tazewell folio of the U. S. Geological Survey. The succession and average thickness of the Ordovician rocks in this county are, in ascending order, as follows:

	Average thickness in feet
6. Clinch sandstone	200
5. Bays sandstone	300
4. Sevier shale	1,200
3. Moccasin limestone	300
2. Pearisburg limestone	900
1. Knox dolomite (upper part)	1,200+

Numerous exposures showing the purer and argillaceous limestones may be found in the vicinity of Tazewell, but continuous sections exhibiting all the subdivisions are not so common. The following detailed section of the Pearisburg limestone may be observed along the road following Plum creek, just north of Thompson valley, about 4 miles southwest of Tazewell, Virginia.

Geologic section, just north of Thompson Valley, Virginia.

	Feet
III. Moccasin limestone:	
Red and drab impure argillaceous limestone	—
II. Pearisburg limestone:	
6. Thin bedded, mottled, dove limestone with red and drab shales in the lower part. Fossils numerous	130
5. Drab shales with bands of thin blue limestone crowded with crinoid stems	30
4. Thin bedded dove limestone with rather numerous fossils	60
3. Heavy bedded dark blue impure and argillaceous limestone	120
2. Shaly mottled limestone with few fossils	150
1. Coarsely crystalline crinoidal limestone, yielding some chert upon weathering	180
I. Knox dolomite:	
Heavily bedded magnesian limestone	—

Washington County.—In this county, the outcrops of Ordovician limestones and calcareous shales are found in two areas separated in a general way by Walker Mountain. In each of these areas the geological succession is somewhat different. East of Walker Mountain the dolomitic limestones of Cambrian and Ordovician age are succeeded usually by a blue to black calcareous and sandy shale formation, which, in the Bristol folio of the U. S. Geological Survey, has been mapped as the Athens shale. The main

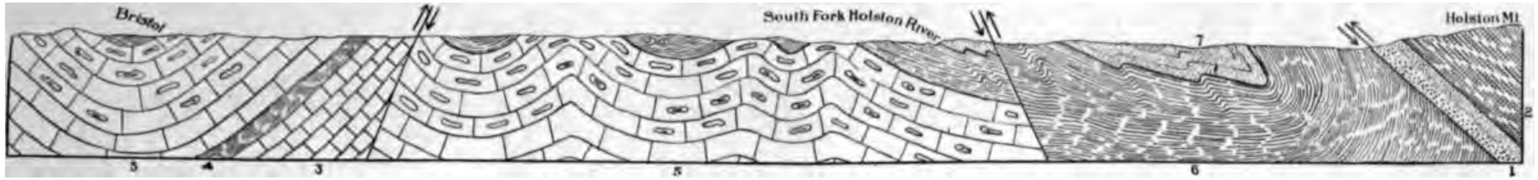


Fig. 26.—Structure section from Bristol east to Holston Mountain. 1. Unicoi sandstone; 2. Hampton shale; 3. Honaker limestone; 4. Nolichucky shale; 5. Knox dolomite; 6. Athens shale; 7. Tellico sandstone.

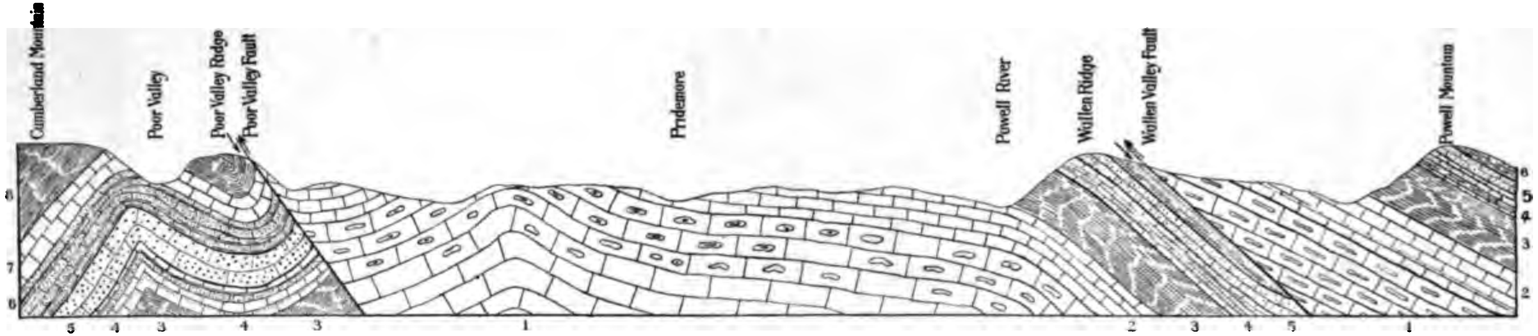


Fig. 27.—Structure section across Lee county, from Powell Mountain north to Pridemore; thence northeast to Cumberland Mountain. 1. Knox dolomite; 2. Middle Ordovician limestone (Stones River—Trenton); 3. Sevier shales (Utica and Eden;); 4. Lorraine (Bays) limestone and sandstone; 5. Clinch sandstone; 6. Rockwood shale and sandstone.

outcrops of these shales, which here are from 1,000 to 1,200 feet in thickness, occur east of Bristol and Abingdon. As the more eastern parts of the Valley are approached, the Athens shales become more sandy and cannot be regarded as a possible source of cement material.

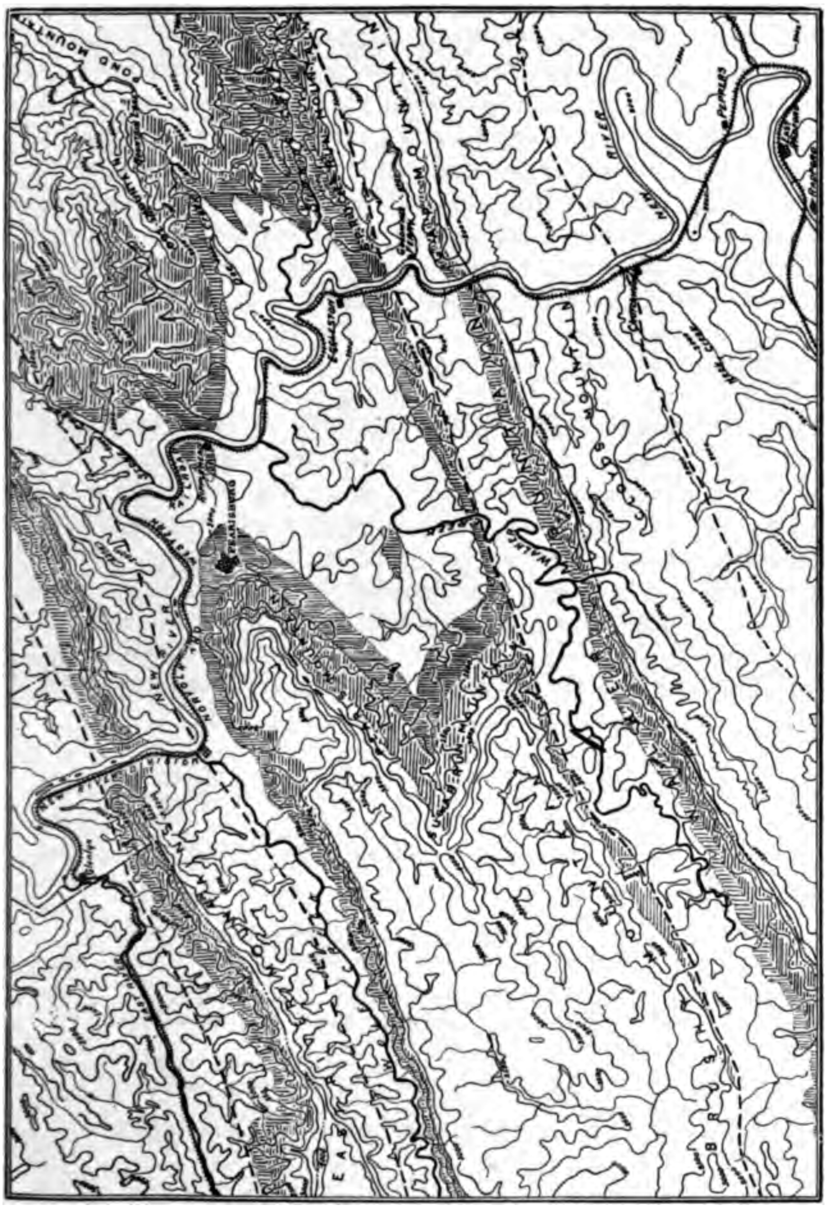
West of Walker Mountain only a few and generally unimportant areas are occupied by Ordovician rocks. This region is also without railroad facilities.

Smyth County.—The Walker Mountain fault passes through Smyth county along a southwest-northeast line, dividing it into southeastern and northwestern portions of nearly equal dimensions. This fault traverses the western part of the Valley of Virginia and brings the Knox dolomite or older limestones in contact with the Carboniferous gypsiferous shales. East of this fault line, the strata are limestones or shales generally unsuited for cement material. The important cement rocks are Ordovician limestones and shales outcropping along the western foothills of Walker Mountain. With the exception of the vicinity of Saltville, this strip is everywhere at such distance from railroads that the material cannot at present be considered of much value other than for local use. In the valley west of Walker Mountain the Knox dolomite and underlying Cambrian limestone are exposed, but proceeding westward, these strata are found to be faulted against the Carboniferous gypsiferous shales similar to the faulting east of the mountain. This second fault is well shown at Saltville and has received its name from that town. The Cambro-Ordovician section exposed between these two faults is essentially the same throughout the county and therefore only a single section is given.

The following section is exposed along the road through Lyon Gap, northeast of Glade Spring, Virginia, starting at the cross roads near McHenry creek, west of the Gap. The section concludes with the Clinch sandstone forming the crest of Walker Mountain.

Geologic section, Lyon Gap, Virginia.

		Feet
11.	**Clinch sandstone.** White quartzite and sandstone	——
10.	**Bays sandstone.** Yellow and red sandy shales and sandstones with arenaceous limestone in lower portion	300
9.	**Sevier (Eden) shale.** Yellow shales with thin arenaceous limestone layers	1,000
8.	**Sevier (Trenton and Utica) shale.** Brown to yellow shales	600
7.	**Moccasin limestone.** Purplish shales and impure reddish limestone	400
6.	**Holston limestone.** Blue and gray argillaceous limestone	500
5.	**Holston limestone.** Thin bedded argillaceous and crystalline limestones	100
4.	**Athens shale.** Dark blue calcareous shales	400
3.	**Lenoir limestone.** Compact dark argillaceous and magnesian limestone	200
2.	**Knox dolomite.** Compact gray clayey limestone weathering into shales	30
1.	**Knox dolomite.** Magnesian limestone weathering into chert	——



Ordovician limestones — Ordovician shales

Fig. 28.—Map showing distribution of cement materials of the New River district, southwestern Virginia.

Scott and Russell Counties.—Geologically, these two counties are so similar that in order to save repetition, they are treated together.

On account of faulting, two strips of Ordovician strata traverse both counties. The first line of outcrops is along the western slope of Clinch Mountain, and the second occurs similarly just west of Moccasin Ridge. The eastern line of outcrops forms a portion of the section bounded on the east by the Saltville fault traversing the western part of Washington county. The geologic section commences on the east with Carboniferous rocks and continues westward exposing the various formations in descending order until in the vicinity of Copper creek, the Cambrian limestones are found thrust upon Ordovician rocks.

The geologic structure and character of the limestone of economic importance in these counties are well shown along the Virginia and Southwestern Railroad between Clinchport and Gate City. As this railroad cuts across both of the strips of Ordovician strata mentioned above, the section of the rocks along this line is given below. Starting with the Russell shales exposed just north of Clinchport, and proceeding south, the succeeding Cambrian and Ordovician strata are seen until the Copper Creek fault is encountered, with the Pearisburg limestone and the Russell shales in contact. The sections then continue southward without interruption to Clinch Mountain, capped by the Clinch sandstone. As this section illustrates the general structure and sequence of rocks in both Scott and Russell counties, samples for analysis were taken from most of the formations.

Geologic section, exposed along the railroad, Clinchport, Virginia, south to Clinch Mountain.

(Thickness approximate)	Feet
1. Russell shales (exposed just south of Clinchport). Sandy shales and sandstones with brown shales at top	——
2. Rutledge limestone (exposed at Clinchport). Impure mottled limestones; thin streaks of dove limestone alternating with impure black bands	200
3. Rogersville shales. Blue to brown calcareous shale	100
4. Maryville limestone. Massive gray limestone, lower part crystalline, upper part dove with bands of dolomite	600
5. Nolichucky shale. Brown to yellow calcareous and arenaceous shale	500
6. Knox dolomite. Gray magnesian limestone, sandy in the middle part and cherty toward the top	2,100
7. Pearisburg limestone. Heavily bedded crystalline and argillaceous dark blue limestone. Fault	——
8. Russell shales.	
9. Rutledge limestone.	
10. Rogersville shale.	
11. Maryville limestone.	
12. Nolichucky shale.	

Fig. 1.—Buena Vista, Virginia. Type locality of Buena Vista shales. Blue Ridge composed of Cambrian quartzites in the distance.

Fig. 2.—Quarry in Lewistown limestone, Longdale, Virgi

BUENA VISTA SHALES AND LEWISTOWN LIM

13.	**Knox dolomite.** Beds 8 to 13 have essentially the same lithology and thickness as beds 1 to 6 respectively.	
14.	**Holston formation.** Thin bedded blue limestone and yellow shales with lenses of red marble toward the base	1,000
15.	**Moccasin limestone.** Red argillaceous limestone	500
16.	**Sevier shale.** Yellow and blue calcareous shales	1,500
17.	**Bays sandstone**	— —
18.	**Clinch sandstone**	— —

Lee County.—Two horizons in Lee county furnish raw material suitable for cement manufacture. The first and more important of these occupies the interval between the Knox dolomite and the Clinch sandstone, the second is the Hancock limestone of Silurian age. On account of greater extent and more accessibility, the Ordovician limestones are by far of greater importance and are therefore discussed more in detail. The Hancock limestone outcrops generally in small patches along the fault lines and is often cut out altogether. When well exposed it is seen to be a blue limestone high in lime but becoming cherty toward the top. The maximum thickness in the Powell Valley region was found to be 275 feet.

In this county, the Ordovician rocks of value for cement purposes occur in two well defined areas. The less important of these is a strip brought up by the Wallen Valley fault and following the western slope of Powell Mountain along which these limestones and shales outcrop at a number of places. Although these rocks occur in quantity and usually have the proper chemical constitution of cement material, the distance of their outcrops from the railroad and their otherwise general inaccessibility, cause them to be, at present, of little economic importance.

The second and more important area is bounded in a general way by Wallen Ridge and Cumberland Mountain, thus embracing the valley of Powell river. This valley in Lee county shows numerous outcrops of shales and pure and argillaceous limestones of Ordovician age along its edges, the central portion being occupied mainly by the Knox dolomite. Along the northern edge of the eastern half of the Valley, the dove limestones immediately succeeding the Knox dolomite are faulted against Devonian black shale, all the intervening formations being thus cut out. In the western half along the same side, faulting becomes less and less until finally the full sequence of strata may be observed. All along the southern edge, however, the succession of rocks seems to be normal so that the full development of Ordovician limestones and shales may be found. The central portion of the valley occupied by the Knox dolomite averages several miles in width, but between this strip and Wallen Ridge is an area of Ordovician shales and limestones of equal width.

In Powell valley, the strata are of such composition that cement materials of some nature may be obtained from almost any part of the rocks occurring between the top of the Knox and the base of the Bays sandstone, a thickness of at least 2,500 feet. The general geologic section of the Ordovician rocks of Powell valley is therefore quite different in the nature of its sediments from the rest of southwestern Virginia. The following section exposed along the railroad, at Ben Hur and vicinity, is typical for the region.

Geologic section, vicinity of Ben Hur, Virginia.

	Feet
Rockwood.	
17. Dark red shales with thin sandstone beds toward the top	100
16. Red sandstones and shales with beds of fossiliferous iron ore	90
15. Red and greenish shales and sandstones	100
14. Thin bedded sandstone with some red shale	50
Clinch (?).	
13. Heavy bedded quartzite	10
Lorraine (Bays).	
12. Green and red shales with occasional thin beds of sandstone	17
11. Dark blue nodular shales crowded with *Hebertella sinuata*. Other fossils are *Pterinea demissa* and other pelecypods	30
10. Red to yellow and dark blue arenaceous limestone and shale with *Modiolopsis modiolaris*, *Bellerophon capax*, *Platystrophia lynx*, and *Orthorhyncula linneyi*	200+
Eden (Sevier in part).	
9. Dark blue to yellow shales passing upward into impure arenaceous limestone; holds numerous bryozoa and *Zygospira modesta*	300
Utica (Sevier in part).	
8. Olive to yellow shales partly covered	300+
Trenton (Chickamauga in part—Cathey of Tennessee).	
7. Thin bedded yellowish and blue argillaceous limestone and yellow shales with numerous fossils, *Rafinesquina alternata* and *Constellaria teres* being particularly abundant	50
Trenton (Chickamauga in part—Bigby of Tennessee).	
6. Thin bedded dark blue to black crystalline and argillaceous limestone with numerous bryozoa large crinoid columns, *Plectambonites sericeus* and other fossils	300
Trenton (Hermitage shales of Tennessee).	
5. Shales mainly covered	300
Black River, Tyrone of Kentucky and Stones River (Chickamauga in part).	
4. Heavy bedded limestone below, passing upward into light blue and dove limestone with yellow shales. Numerous bryozoa in upper part	230
3. Hard calcareous shales and dove or argillaceous limestones	130
2. Thin bedded dove limestones and yellow shales. Surface of limestone bands often crowded with small ramose and bifoliate bryozoa	35
1. Heavy bedded dove to light blue limestone weathering into beds two to four inches thick and filled with a species of *Camarocladia*	50+

Lack of space prevents a consideration of the various limestones and shales of this area at the present time. Lithologically and paleontologically the Ordovician portion of the section with the exception of the Clinch sandstone is so similar to that of central Kentucky and central Tennessee that little doubt is entertained in regard to the correctness of correlation in the foregoing section. Samples of some of the limestones were analyzed with the following results:

Analyses of Ordovician limestones, Ben Hur, Virginia.
(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.
Insoluble.	8.56	14.00	7.22	17.80	3.34
Iron oxide (Fe_2O_3), alumina (Al_2O_3)	1.68	2.36	2.68	1.16	1.12
Lime (CaO)	50.28	36.40	49.26	43.66	53.08
Calcium carbonate ($CaCO_3$)	89.48	82.86	87.96	77.57	95.50
Magnesia (MgO)	0.08	0.05	0.68	1.11	0.33
Magnesium carbonate ($MgCO_3$)	0.17	0.11	1.43	2.33	0.69
Total	99.89	99.33	99.29	98.86	100.65

I. Black crystalline limestone, Bed 6 (Trenton).
II. Blue argillaceous limestone, Bed 7 (Trenton).
III. Dove limestone, Bed 1 (Stones River).
IV. Dove limestone, Bed 2 (Stones River).
V. Heavy bedded limestone, Bed 4 (Tyrone formation).

Post-Ordovician Cement Materials.

In consideration of the Portland cement materials of western Virginia, the Ordovician limestones and shales are of prime importance on account of their abundance and, usually, more favorable location and composition. Two other limestone formations suitable chemically for cement manufacture obtain in this part of the State, namely, the Lewistown limestone of Helderbergian age, and the Greenbrier limestone of the Mississippian series. However, their areas of outcrop are comparatively few, of little extent, and are generally situated so far from transportation facilities that, with the exception of a few localities, the rock at present has little economic value.

Lewistown Limestone.

Immediately overlying the Silurian sandstones and shales, and preceding the Devonian shales in this part of the Appalachian district, may sometimes be found limestones varying in thickness up to 1,000 feet. These limestones are of Helderbergian age but have been mapped under several names. In northwestern and central western Virginia, these strata have been designated the Lewistown limestone, while limestones occupying the same position in the southwestern part of the State have been called the Hancock limestone. In Giles and neighboring counties of southwestern Virginia, these limestones form a part of the Giles formation. The Lewistown limestone is well known as a source of cement material, and therefore all of these Helderbergian limestones are here considered under that name.

The lithology and thickness of the Lewistown formation varies considerably even in small areas. In general, these limestones are thin bedded below, massive in the middle portion, and cherty above; consequently the lower and middle portions are of most importance as a cement rock. The cherty upper beds are massive and give rise to ridges, but the lower members are sometimes more favorably located, although much of the Lewistown area lies upon steep mountain slopes. This occurrence is illustrated in the accompanying photograph, plate XIX. The middle beds are made up of light-colored, coarsely crystalline, fossiliferous strata and a few shaly limestones, while the lower beds contain, for the most part, flaggy limestone, the individual layers of which readily separate with smooth surfaces. The formation as a whole, therefore, is seen to be composed of argillaceous and calcareous strata, of which nearly all might be employed in the manufacture of cement. The basal flaggy limestone is usually of greater thickness than the other members combined, and this fact, together with its favorable composition, causes it to be of most importance as a cement rock.

General distribution.—The more extensive areas of Lewistown limestone are located in the western part of central western Virginia. A portion of this area is mapped in detail in the Monterey, Staunton, and Franklin folios (numbers 61, 14, and 32, respectively) of the U. S. Geological Survey.

In northwestern Virginia, two occurrences of these strata may be noted. The easternmost is a narrow strip brought up by the Massanutten Mountain syncline. This has been mapped in detail by A. C. Spencer. The western area occupies portions of Shenandoah and Frederick counties in the vicinity of North and Little North mountains.

Narrow strips of the Giles and Hancock formations are found west of the Appalachian Valley in southwestern Virginia. These outcrops generally follow the mountains or are brought up along the great faults. In either case the outcrops, almost without exception, are so far from transportation facilities, or the rock is of such poor quality, that the Helderbergian limestone in southwestern Virginia cannot be regarded as a very promising future source of cement rock. The Giles and Hancock forma-

Anticline in Lewistown limestone with capping of Monterey sandstone, showing occurrence along mountain slope. North Fork of the Potomac river, 2 miles south of Hopeville, West Virginia. (*Photo. by N. H. Darton.*)

ANTICLINE IN LEWISTOWN LIMESTONE.

the usual lithology of the Lewistown limestone in this part of the State. The lower sandy strata of this section, however, belong to the Salina formation, which, at the time of publication of the folio, was not differentiated in Virginia.

Section on road from Warm Springs to Mountain Grove, Virginia, west of Jackson River.

	Feet
At top, alternations of impure and shaly limestone, fossiliferous	460
Wavy-bedded, massive limestone with coralline bed at base	?
Slabby limestone	400
Calcareous shale	25
Massive fine-grained sandstone, weathering light buff; probably cement rock	15
Sandstone	4
Shaly material	20
Sandstone and sandy beds	20
At bottom, buff shales and thin, dark, semi-crystalline limestone layers	100

Reference to the two folios mentioned will show the distribution of these limestones so that detailed descriptions of these areas need not be given. Samples from the upper beds of this formation were collected for analysis.

Analyses of Lewistown limestone, Warm Springs, Mountain Grove section.

(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	14.68	19.12
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	1.26	2.70
Lime (CaO)	43.96	42.12
Calcium carbonate ($CaCO_3$)	78.50	75.21
Magnesia (MgO)	2.09	1.09
Magnesium carbonate ($MgCO_3$)	4.40	2.30
Total	98.84	99.33

I. Impure fossiliferous limestone.
II. Shaly limestone.

Details of Localities.

Craigsville.—Commencing at Pond Gap and continuing for some miles southwest, the Lewistown limestone outcrops either very close to the Chesapeake and Ohio Railroad or is crossed by it. This region therefore is of particular importance, and the favorable location of good cement rock and railroad facilities have been taken advantage of in the establishment of a Portland cement factory at Craigsville. This plant, the property of the Virginia Portland Cement Company, is of note in that it is the only well established Portland cement manufactory in the State. The following section and analysis of the limestone and shale at this place have been published by Catlett in bulletin No. 225, of the U. S. Geological Survey, pages 460, 461.

Section near Craigsville.

		Feet
1.	Layer heavy fossiliferous limestone passing into sandstone..........	—
2.	Very dark slaty siliceous limestone..................................	10
3.	Gray fossiliferous limestone..	10
4.	Dark, irregular siliceous magnesian limestone.........................	2 to 20
5.	Gray, soft, highly fossiliferous limestone............................	30 to 50
6.	Dark, close-grained limestone of varying thickness and carrying varying quantities of flint..	—

The most important beds of this series and the ones which would be used in the manufacture of Portland cement are (3) and (5). The principal facts to be determined are the extent and composition of the superimposed layers, and therefore the ease and cheapness with which (3) and (5) can be secured. The black slates of the Devonian everywhere fill the valleys in this section and afford very excellent material to combine with the limestone. The following analyses are of the limestones and shales taken from the property adjoining that of the Virginia Portland Cement Company:

Analyses of limestone and shale from near Craigsville.

(Charles Catlett, Analyst)

	Limestone Per cent.	Shale Per cent.
Silica	0.43	58.07
Alumina	.21	19.08
Iron oxide.........................	.55	6.16
Lime	54.55	none
Magnesia	.63	.64
Volatile matter....................	43.70	11.17

Other analyses of the limestones and shales at Craigsville, quoted from the Cement Industry, are as follows:

Analyses of cement materials used at Craigsville, Virginia.

	Limestone Per cent.	Shale Per cent.
Silica (SiO_2).....................	n. d.	53.63
Iron oxide (Fe_2O_3) } Alumina (Al_2O_3) }	n. d.	24.47
Lime (CaO)........................	54.30	5.94
Magnesia (MgO)...................	.66	1.79
Carbon dioxide (CO_2) } Water }	43.63	10.03

Covington.—The more sandy portions, particularly of the Lewistown limestone, are exposed at a number of places along the Chesapeake and Ohio Railroad and vicinity between Covington and Clifton Forge. Some of these strata show a fair composition according to the first analysis quoted below, but others again contain too much arenaceous material to be of use. The rock in this vicinity would therefore require careful selection. Shales for mixing are abundant throughout the area.

Analyses of Lewistown limestone, Covington, Virginia.
(J. H. Gibboney, Analyst)

	I Per cent.	II Per cent.
Insoluble	19.32	48.20
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	1.00	3.80
Lime (CaO)	44.50	18.00
Calcium carbonate ($CaCO_3$)	79.45	32.14
Magnesia (MgO)	0.05	6.89
Magnesium carbonate ($MgCO_3$)	0.12	14.46
Total	99.89	98.60

I. Blue crinoidal limestone.
II. Arenaceous gray limestone.

Mississippian Limestones.

The particular portions of Virginia occupied by Mississippian (Subcarboniferous) limestones are small when compared with the outcrops of the strata previously discussed. They consist of rather narrow strips occurring mainly in the southwestern part of the State. The longest and also widest of these strips lies just southeast of Clinch Mountain and extends from the State line on the south, northeastward to the vicinity of Bland court-house. Throughout the greater part of its length this strip is either closely paralleled or traversed by the North Fork of the Holston river. The second important area is somewhat less than the preceding in length and follows the western slope of Stone Mountain from the southern boundary of the State northward to Little Stone Gap, where it bends and circles a portion of Powell Mountain. This area has railroad facilities close at hand since Stone Mountain is paralleled by the Louisville and Nashville Railroad, while the Virginia and Southwestern Railroad closely approaches, and at one point crosses the Powell Mountain line of outcrop. The other occurrences in southwestern Virginia are small and otherwise unimportant. The Estillville, Pocahontas, Tazewell, and Bristol folios of the U. S. Geological Survey (Nos. 12, 26, 44, and 59, respectively), contain maps showing the larger portion of these areas in detail. On account of the unequal development of Subcarboniferous formations in the northwestern and southwestern halves of this general region, the limestones of this age in the former portion have been mapped as the Greenbrier, and in the latter as the Newman limestone.

Greenbrier limestone.—This well known limestone formation is best developed in Greenbrier county, West Virginia. In general, the Greenbrier consists of massive dark blue limestone, often cherty in the lower part, purer in the middle, and becoming shaly toward the top. The shales of the upper portion are quite calcareous and pass without any noticeable break into the less calcareous shales of the succeeding formation.

Probably the best and most detailed section of the Greenbrier limestone in Virginia may be seen along the Norfolk and Western Railroad near Lurich, in Giles county. Here, all of the beds are fairly well exposed and the section may be considered as typical for the region. For this reason all of the variations in the strata at this point were noted and samples taken for analysis. The section observed here is, in ascending order, as follows:

Geologic section, Greenbrier limestone, vicinity of Lurich, Virginia.

1. Dark blue to black heavily bedded limestone with many small chert nodules. *Productus*, *Zaphrentis*, and *Fenestella* observed............. 175
2. Drab and yellow calcareous shales with occasional bands of compact blue limestone 180
3. Massive blue and argillaceous limestone with a few shaly beds in the upper part 90
4. Drab and blue shales.. 80
5. Compact blue-black, fine-grained limestone alternating with coarsely crystalline fossiliferous strata, with blue limestone and yellow shales in upper part... 150
6. Compact blue to black argillaceous limestone in thin flaggy layers, much fractured 179
7. Thin bedded blue limestone with beds of blue and yellow shale............ 400

Analyses of Greenbrier limestones and shales, Lurich, Virginia, section.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct	Pr. ct
Insoluble	8.38	31.82	48.80	63.40	3.80	8.24	41.36	8.42	4.46	15.10	23.06
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	1.20	1.80	4.52	4.52	0.68	1.04	4.26	1.00	1.56	1.46	2.74
Lime (CaO)	49.24	34.90	23.80	16.54	52.74	48.52	28.80	48.56	51.22	43.84	39.62
Calcium carbonate ($CaCO_3$)	87.93	62.32	42.86	29.53	94.18	86.64	51.43	86.71	91.46	78.28	70.75
Magnesia (MgO)	0.80	1.43	1.10	0.83	0.40	1.87	1.04	1.32	0.51	2.07	0.78
Magnesium carbonate ($MgCO_3$)	1.67	2.99	2.31	1.75	0.84	3.92	2.19	2.77	1.08	4.34	1.64
Total	99.18	98.93	98.49	99.20	99.50	99.84	99.24	98.90	98.56	99.18	98.19

I. Dark blue limestone from strata free from chert nodules. Bed 1.
II. Dark limestone from usual cherty layers. Bed 1.
III. Drab calcareous shales. Bed 2.
IV. Yellow shales. Bed 2.
V. Blue fossiliferous limestone. Bed 2.
VI. Bluish-black compact limestone. Bed 3.
VII. Drab shale. Bed 4.
VIII. Compact, bluish-black limestone. Bed 5.
IX. Coarsely crystalline crinoidal limestone. Bed 5.
X. Flaggy black limestone. Bed 6.
XI. Thin bedded blue limestone. Bed 7.

Newman limestone.—Following the sandy Devonian and Mississippian shales in southwest Virginia, is a limestone formation varying from 1,000 to 2,600 feet, to which the name Newman limestone has been applied from its outcrop on Newman Ridge in Tennessee. The principal areas of outcrop in Virginia have been indicated under the discussion of the Mississippian limestones of the southwestern part of Virginia. The more massive strata of the Newman limestone are characteristic of its lower part, while higher in the formation considerable calcareous shale deposits are found. Chert, likewise, is most abundant in the lower strata, although a considerable portion of the limestone layers are free from it. Several miles southeast of Mendota, Virginia, the area of outcrop south of Clinch Mountain is traversed by the Virginia and Southwestern Railroad, and here for a distance of 3 or 4 miles, exposures of this limestone may be seen.

Analyses of Newman limestone.

(J. H. Gibboney, Analyst)

	I	II	III	IV	V
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Insoluble	7.72	10.40	8.56	7.22	15.82
Iron oxide (Fe_2O_3) alumina (Al_2O_3)	0.68	0.72	1.00	0.41	3.40
Lime (CaO)	50.20	48.64	49.24	50.96	43.98
Calcium carbonate ($CaCO_3$)	89.64	86.85	87.92	91.00	78.54
Magnesia (MgO)	0.89	0.86	0.88	0.65	0.47
Magnesium carbonate ($MgCO_3$)	1.87	1.71	1.85	1.37	0.99
	99.91	99.68	99.33	100.00	98.75

I. Massive blue limestone, 2 miles southeast of Mendota, Virginia.
II. Dove-colored limestone, 2 miles southeast of Mendota, Virginia.
III. Dark blue limestone, vicinity of Horton Summit, Scott county, Virginia,
IV. Dark blue limestone, 1 mile north of Big Stone Gap, Lee county, Virginia,
V. Massive blue limestone, Ollinger Gap, Lee county, Virginia.

Pennington shale.—Succeeding the Mississippian limestones of southwestern Virginia is a shale formation which, in the event of the use of the limestone as a cement material, would be found of importance for mixture. This shale, which in one part of this region has been mapped as the Pennington shale, and in another as the Bluefield shale, is, in general, calcareous at the bottom and sandy in its upper part. The lower portions only, therefore, are of importance in the present connection.

The Pennington shale, named from Pennington Gap in Lee county, is about 1,000 feet thick in its typical area of outcrop. It is made up of calcareous and argillaceous shales with beds of heavy sandstone. The calcareous portions are limited mainly to the base, while the top of the formation is composed of red and purple shales. The formation is well exposed at Big Stone Gap as well as at Pennington Gap.

In the typical areas of Greenbrier limestone, the upper or shaly member of this formation passes gradually into a shale formation named from Bluefield, Mercer county, West Virginia. Like the Pennington, the Bluefield shale is composed of calcareous and argillaceous shales with sandstone beds; similarly, the more calcareous beds are at the base and the sandy layers are most abundant at the top. Between these extremes is found every variation in composition. The thickness of the Bluefield shale is usually about 1,300 feet.

Travertine Deposits.

Many of the numerous springs of western Virginia contain carbonate of lime in solution. These have been and are still depositing considerable quantities of calcareous tufa or travertine. Small deposits of such material have been noticed in various parts of this region, and these, if favorably located and in sufficient quantity, would undoubtedly be of value in cement manufacture. Such materials have been used in the making of Portland cement, although with the abundant limestone of western Virginia, their use is less likely. A noteworthy example of the use of such material in cement manufacture is at the plant of the Pacific Portland Cement Company in Selano county, California, where travertine and clay are the ingredients mixed. In certain portions of Staunton. Virginia, as noted by Mr. Catlett, the foundations of the houses have been cut in a calcareous marl or travertine 10 or 12 feet deep. An analysis of this deposit is presented below. The surface indications of these travertine deposits are usually not sufficient to estimate the quantity or extent of the rock, and drilling would be necessary to determine these points.

Analysis of travertine deposit, Staunton, Virginia.

(Charles Catlett, Analyst)

	Per cent.
Insoluble	5.92
Iron oxide (Fe_2O_3) and alumina (Al_2O_3)	.62
Lime (CaO)	50.62
Calcium carbonate ($CaCO_3$)	90.40
Magnesia (MgO)	30
Magnesium carbonate ($MgCO_3$)	.63
Total	97.57

NATURAL CEMENT.

The relation of natural cements to other cements has been briefly noted on a previous page. An extended and valuable treatise on this subject is presented by Mr. Eckel in his "Cements, Limes and Plasters." In the present article, the writer wishes to point out briefly the distribution of the limestones suitable for this kind of cement, to give analyses, and to indicate the present status of the natural cement industry in Virginia.

Under ordinary circumstances the value of natural cement is too small to allow it to be shipped any distance with profit. Therefore. the manufacturer must have a home market and little competition. The raw material is an argillaceous limestone carrying from 13 to 35 per cent. of clayey material, of which about 10 to 22 per cent. is silica, while alumina and iron oxide together may vary from 4 to 16 per cent. Unlike Portland cement rock, the percentage of magnesium carbonate may run high, the reason for this being, that in natural cements the magnesium and lime are regarded as interchangeable. The hydraulic properties do not depend upon the percentage of lime but upon the clayey materials, which therefore are the important factors to consider in the rock analysis. Limestones having a composition within the limits just indicated are more or less abundant at several horizons in western Virginia, but probably the only one which will meet all the requirements and prove of economic importance is the argillaceous magnesian limestone of the lower part of the Shenandoah group. This rock, although often very similar in lithologic characters to the dolomitic limestone found higher in the Shenandoah, can be recognized as containing argillaceous matter by the clayey odor given forth when breathed upon.

These limestones (Sherwood) and shales (Buena Vista) have been described on page 94, where their use in the making of natural cement was noted. These strata may be found at various points along the eastern side of the Appalachian Valley so that a considerable supply of the necessary materials should be available.

The clayey magnesian Cambrian limestone used by the James River Cement Company at Balcony Falls, Rockbridge county, Virginia, in making natural cement, gave the following results upon analyses:

Analyses of natural cement rock, Balcony Falls, Virginia.

	I Per cent.	II Per cent.	III Per cent.
Silica (SiO_2)	17.38	17.21	17.30
Alumina (Al_2O_3)	7.80	tr.	6.18
Iron oxide (Fe_2O_3)		1.62	1.62
Lime (CaO)	34.23	24.85	29.54
Magnesia (MgO)	9.51	16.58	13.05
Carbon dioxide (CO_2)	30.40	37.95	34.17

I. E. C. Boynton, analyst. Gillmore, "Limes, Cements, and Mortars," p. 125.
II. C. L. Allen, analyst. "The Virginias," vol. 3, p. 88.
III. Average of preceding two analyses.

This same belt of magnesian limestones and shales of Cambrian age crosses Virginia into West Virginia and Maryland. Several small natural cement plants have been established in this district at various times, particularly near Antietam, Maryland, and Shepherdstown, West Virginia.

Analyses of natural cements, Shepherdstown-Antietam District, West Virginia-Maryland.

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Silica (SiO_2)	33.42	36.51	33.50	15.97
Alumina (Al_2O_3)	10.04	9.36	10.44	7.59
Iron oxide (Fe_2O_3)	6.00		3.25	
Lime (CaO)	32.79	34.83	29.38	23.72
Magnesia (MgO)	9.59	11.33	13.37	15.60
Alkalies (K_2O, Na_2O)	0.50	1.25	n. d.	n. d.
Sulphur trioxide (SO_3)	n. d.	1.49	1.15	0.71
Carbon dioxide Water	7.66	5.13	7.15	34.82

I. Shepherdstown, W. Va. Quoted by Cummings. "American Cements," p 35.
II. Shepherdstown, W. Va. C. Richardson, analyst. Brickbuilder, vol. 6, p. 229.
III. Antietam, Md. C. Richardson, analyst. Brickbuilder, vol. 6, p. 229.
IV. Antietam, Md. C. Richardson, analyst. Brickbuilder, vol. 6, p. 151.

Limestones suitable for the manufacture of natural cement occur in southwestern Virginia, particularly along the eastern half of the Appalachian Valley. Geologically, these succeed the siliceous deposits of Lower Cambrian age and form the base of the great Shenandoah limestone group. Geographically, however, these particular areas cannot be indicated without detailed mapping, requiring long field work. During the progress of his work on the lead and zinc deposits of Virginia, Dr. T. L. Watson collected samples of these limestones for analysis. The results were published in Bulletin No. 1 of the Virginia Geological Survey, and analyses selected from this publication are quoted below.

Analyses of Shenandoah limestone.

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.
Insoluble residue	2.90	0.594	0.45	0.20
SiO_2	trace	.073	trace	trace
TiO_2	none	none	none	none
Al_2O_3	0.43	0.344	0.24	0.37
Fe_2O_3	0.94	0.19	0.17	0.22
MnO	none	0.193	0.37	trace
CaO	30.06	29.085	29.50	30.71
MgO	18.41	20.54	19.93	21.56
BaO	none	none	trace	none
K_2O	0.24	0.22	0.56	0.12
Na_2O	0.21	0.38	1.03	0.10
H_2O 100°C− / H_2O 100°C+	3.30	2.58	3.73	3.92
CO_2	43.98	45.40	44.01	43.88
P_2O_5	none	none	none	none
SO_3	none	none	none	none
Total	100.47	99.599	99.99	101.08

I. Limestone. Massive grayish black fine granular, crushed and recemented with stringers of pure white calcite. Martin property, two and three-quarter miles southwest of Roanoke City, Roanoke county, Virginia. Dr. W. E. Barlow, analyst.

II. Limestone. Grayish white and moderately coarse crystalline. Specimens taken from the 100-foot level in the Austinville zinc and lead mines, Wythe county, Virginia. Dr. W. E. Barlow, analyst.

III. Limestone. White, coarsely crystalline, and crushed. Specimens taken from the 80-foot level at bottom of open cut, in the Austinville zinc and lead mines, Wythe county, Virginia. Dr. W. E. Barlow, analyst.

IV. Limestone. White and medium crystalline. Specimens taken from the 80-foot level at bottom of open cut, in the Austinville zinc and lead mines, Wythe county, Virginia. Dr. W. E. Barlow, analyst.

CEMENT INDUSTRY IN VIRGINIA.

Although the cement industry may be said to be in its infancy in western Virginia, yet the manufacture of this important economic pro-

Old Dominion Portland Cement Mill, Craigsville.

duct has been carried on for many years at one locality, and for a less time at another. Natural cement has been burned near Balcony Falls, Rockbridge county, for over half a century. The demand for a cheap and trustworthy cement for use in the construction of masonry, locks, and walls on the James River Canal, led to the discovery of the hydraulic properties of the rock used at this plant. Since that time a natural cement has been manufactured at this locality almost continuously, the James River Cement Company operating the plant at the present time. The rock used is a steel blue, argillaceous limestone of Lower Cambrian age, with an average thickness of twelve feet. For a description and history of this cement plant, the reader is referred to an anonymous article published in the *Engineer*, September 29, 1899.

But a single plant for the manufacture of Portland cement is in operation in Virginia, namely, that of the Virginia Portland Cement Company at Craigsville, Augusta county. The geologic section at Craigsville and analyses of the rock employed have been given on a previous page. As the methods employed by the Virginia Portland Cement Company are those of a large, modern plant, a description of the process of manufacture is here introduced.

The materials used in the manufacture of the Old Dominion cement are Lewistown limestone and shale. The principal limestone quarry is located a mile and one-eighth from the plant, and the shale quarry three-quarters of a mile.

The shale is crushed at the quarry and brought down on a standard gauge track to the scale house, where it is elevated into bins over the scales.

The limestone is brought to the scale house on a narrow gauge track in cars containing about 3,000 pounds of limestone. The limestone cars are weighed and the proper percentage of shale is dropped from the bins onto the limestone, and the narrow gauge car is then picked up by a cable and carried to a 7-½ Gates crusher, through which the limestone and shale pass together.

The output of the crusher goes through a revolving screen and the rejections from the screen are passed through a No. 3 crusher. From the crushers, the raw material is elevated on a belt conveyer to 12 tanks containing about 70 tons each. The material is drawn from the bottom of these tanks into a belt conveyer, which carries it to the rotary dryers, 3 in number. From the dryers, the material is carried on a belt conveyer to [illegible] material mill, where it receives its preliminary grinding in ball mills, and its fine grinding in pebble mills. The outfit of this raw material mill consists of 3 Krupp ball mills, 2 Smidth kominuters, 3 Krupp pebble mills and 3 Smidth pebble mills.

The ground material is conveyed by means of belt conveyers, elevators and screw conveyers to tanks over the kilns, and is fed into the kilns by conveyers in the bottom of tanks. The rotary kilns are 10 in number, 60 feet long, 6 feet in diameter, slightly inclined from the feed end to the discharge end. Powdered coal is used as fuel for burning the raw material. It is blown in by a low pressure blast of air and ignites instantly. The heat generated is about 2,600°. The coal is first dried in rotary dryers and passed through pebble mills similar to those used for grinding the raw material.

The material passes from the kilns in the form of clinker and is elevated into coolers through which a blast of air is forced. From the bottom of the coolers, it is drawn by means of a belt conveyer to the clinker storage, where it is allowed to age for about three weeks. Underneath the floor of the clinker storage are belt conveyers, which convey the clinker to the cement mill.

The process in the cement mill is a repetition of that in the raw material mill. The cement grinding machinery consists of 2 Krupp ball mills, 3 Smidth kominuters, 2 Krupp pebble mills, and 4 Smidth pebble mills. From the cement mill, the finished cement is conveyed by belt conveyers to the 2 stockhouses, where it is stored in bins until such time as it is shipped out. The cement is drawn from the bins into screw conveyers, elevated into bins over the bag packers and barrel packers. The bag packers are operated by hand and the barrels are packed by power.

The storage capacity is 100,000 barrels. The present output of the plant is between 1,800 and 1,900 barrels per day. Construction work is at present under way to increase the capacity of the plant to 3,000 barrels per day.

The power equipment of the plant includes 8 Sterling water tube boilers, 1 Hamilton Corlis engine of 750 H. P., 1 Cooper Corlis engine of 1,100 H. P., and 1 Westinghouse engine of 250 H. P. Electric generators located in the power house furnish current to motors which operate the kilns and a large part of the conveying machinery. The grinding machinery is belted to shafting.

As the mill is located so far away from any city, it was necessary for the company to provide homes for its employees. The company has accommodations for some 200 families, runs a commissary store, village water works, etc. The company employs a physician, maintains a hospital, and close attention is paid to sanitary inspection. The number of employees is about 425.

References.

Reports treating of the limestones and shales of Virginia with reference to their use as cement materials have been few. Numerous papers treating of the geology of Appalachian Virginia, particularly of the southwestern part, have been published, but few of these have direct bearing on, or are of use in, the location of cement rock. Those which may be found of value in this respect are noted in the following bibliographic list.

The U. S. Geological Survey has mapped all of western Virginia geographically, this area being included in 27 quadrangles. However, only 8 folios of the Geologic Atlas of the United States touching this region have been published. These are the Harper's Ferry folio for northwestern Virginia; the Staunton, Franklin, and Monterey folios for central western Virginia; and the Pocahontas, Tazewell, Bristol, and Estillville folios for southwestern Virginia. These folios contain topographic sheets, areal and economic geologic sheets, and structure sections of the areas studied, with text descriptions of the geology and mineral resources. However, only the 4 last mentioned give maps in which the argillaceous and pure limestones of Ordovician age are separated from the impure Cambro-Ordovician series.

Natural Cement.

Anonymous. James River, Virginia, Cement Co. Engineer (London), September 29, 1899.

Eckel. E. C. Natural cement resources of Virginia. U. S. Geological Survey, Bulletin No. 225, 1904, 457-461.

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III. CLAYS.

BY HEINRICH RIES.

DEFINITION AND PROPERTIES OF CLAY.

Clay is one of the most curious and least understood of our common mineral products, and various investigators have spent much time in attempts to discover the causes of its peculiar properties. In some cases they have partially succeeded; in others it must be admitted that while they have partly solved the problem, they are nevertheless still very far from a complete and satisfactory interpretation of the phenomena discussed.

Man at a very early period in the earth's history discovered the peculiar qualities of the common substance known as clay. That its usefulness has steadily increased is evidenced by the fact that in 1904, the value of clay products made in the United States alone exceeded $130,000,000, which was greater than the value of other important products such as gold, silver, copper, and petroleum, and was only outranked by iron and coal. This being the case, we can justly regard clay as one of our most important mineral resources, although up to a few years ago it was quite neglected by both government and state surveys.

To the unaided eye, clay usually appears so fine-grained that most of its component grains cannot be identified, although some particles of quartz, or small scales of mica are not infrequently recognizable. Microscopic examination, however, reveals the presence of a number of small mineral grains, many of which are under one one-thousandth of an inch in diameter. In addition to these there are particles of organic matter as well as other small bodies of non-crystalline character, which are classed as colloids, and may be of either organic or inorganic origin. The mineral fragments making up the bulk of the clay represent a variety of compounds in all stages of decomposition, but their properties and effect on the clay will be left until a later page.

ORIGIN OF CLAY.

So far as we know clay results primarily from the decomposition of other rocks, and very often from rocks containing an appreciable amount of the mineral, feldspar. There are some rocks, however, that contain practically no feldspar which, on weathering, yield a most plastic clay. In all of these clays there is found a variable amount of the mineral kaolinite, which is of secondary origin, *i. e.*, it is derived from other minerals by decomposition. This is termed the *clay base.*

In order to trace the process of clay formation, let us take the case of granite, a rock which is commonly composed of three minerals, namely, quartz, feldspar, and mica. When such a mass of rock is exposed to the weather, minute cracks are formed in it, due to the rock expanding when heated by the sun and contracting when cooled at night; or there may be joint-planes formed by the contraction of the rock as it is cooled from a molten condition. Into these cracks the rain water percolates and, when it freezes in cold weather, it expands, thereby exerting a prying action, which further opens the fissures, or may even wedge off fragments of the stone. Plant roots force their way into these cracks and as they expand in growth, supplement the action of the frost, thus further aiding in the breaking up of the mass. This process alone, if kept up, may reduce the rock to a mass of small angular fragments.

CLASSIFICATION OF CLAYS.

The state of Virginia contains a variety of clays, which are adapted no doubt to a wide variety of uses, but many of the deposits have remained undeveloped, because little is known regarding them, the only ones which have been systematically studied being those of the Coastal Plain or the Tidewater belt.

In discussing the clays of Virginia it might perhaps seem more practical to group them according to kinds, but since one type of clay may be often used for the manufacture of several types of clay-products, such a mode of treatment does not form a satisfactory basis and therefore a grouping by formations is adopted.

Fig. 1.—General view in railroad cut near Christiansburg, Virginia, showing weathering of limestone.

Fig. 2.—General view of Oldfield Brick Company's plant, Oldfield, on James River. Clay pit at rear of yard.

LIMESTONE WEATHERING, BRICK PLANT AND CLAY PIT.

The clays of Virginia can be divided into two groups, namely, *residual* and *sedimentary*. The residual clays have been formed by the weathering of rocks, involving processes of disintegration and decomposition. As a result of this we find the residual clay overlying the parent rock from which it was derived, plate XXI, figure 1. These deposits are of variable thickness depending partly on the depth to which the rock has been changed, and partly on the amount of erosion which they have suffered since their formation. Knowing this we should expect to find heavier deposits on a flat surface, than on a sloping one where the rain-wash is more active.

The sedimentary clays represent deposits which have been laid down under water, one layer on another, the materials composing them consisting of the products of rock decay, which have been removed by erosion from the land surface, and washed down into the lakes, or seas, where they have finally settled.

Residual Clays.

These predominate in the belt underlain by the crystalline rocks. The crystalline rocks, consisting of granite, gneisses, and schists, with some intrusives, extend across the State from north to south in a belt of increasing width, whose western boundary follows approximately a line running from Harper's Ferry, southwestward. The eastern edge coincides somewhat closely with the "fall-line." Residual clays are not uncommon throughout this area, but they are usually quite ferruginous and therefore red-burning. Their main use is for the manufacture of brick and drain tile, and some of the smoother deposits have been employed for making smoking pipes.

Here and there the decomposition of pegmatite veins has yielded clays of high grade, free from iron, and sometimes sufficiently white to be used for the manufacture of white-ware products. Deposits of this type known as *kaolins* have been found in Henry, Nelson, Patrick, and other counties in the Piedmont region. In the former county, Henry, a kaolin deposit is being worked near Oak Level station, by John Sant and Company of East Liverpool, Ohio. (Plate XXII.) The clay occurs as a series of veins, cutting across the schists of that region. It is mined by circular pits and, before shipment to market, it is put through a washing process in order to free it from grains of sand, mica, and other mineral impurities, which are present in small quantities.

The following analyses give the composition of the crude (I) and washed (II) kaolin from this locality:

	I Per cent.	II Per cent.
Silica (SiO_2)	66.82	45.70
Alumina (Al_2O_3)	24.00	39.18
Ferric oxide (Fe_2O_3)	.94	.78
Lime (CaO)	.28	.44
Magnesia (MgO)	.11	.05
Potash (K_2O)	2.59	1.78
Soda (Na_2O)	.16	.20
Titanic oxide (TiO_2)	.12	.28
Water (H_2O)	5.52[2]	12.09[1]
Total	100.54	100.50

([1]) Includes 1.98 per cent. of moisture.
([2]) Includes 2.00 per cent. of moisture.

A deposit of refractory residual clay is said to occur at Bon Air, 9 miles west of Richmond, and is well exposed in the cut of the Southern Railway. The following analysis of a washed sample is given by Dr. Froehling:

	Per cent.
Silica (SiO_2)	46.71
Alumina (Al_2O_3)	37.62
Ferric oxide (Fe_2O_3)	1.10
Lime (CaO)	.25
Magnesia (MgO)	.14
Alkalies (Na_2O, K_2O)	trace
Loss on ignition	14.10
Total	99.92

This deposit is said to have been worked for several years.

A bed of refractory clay has also been exploited near Clayville, but the deposit is now exhausted.

A second deposit reported by Dr. Froehling occurs on the land of F. B. Deitrick, at Lorraine, in Henrico county. This clay is said to be quite free from grit, very plastic, and to have an air and fire shrinkage of 12 and 7 per cent., respectively. It burns to a dense hard brick of bright red color at 1750° Fahr. The same analyst gives its chemical composition as follows:

	Per cent.
Silica (SiO_2)	62.80
Alumina (Al_2O_3)	21.30
Ferric oxide (Fe_2O_3)	4.80
Lime (CaO)	.54
Magnesia (MgO)	.57
Potash (K_2O)	2.35
Soda (Na_2O)	.83
Loss on ignition	7.00
Total	100.19

Fig. 1.—View of kaolin-pit near Oak Level, Henry county. The ferruginous clay walls are clearly contrasted to the white kaolin.

Fig. 2.—General view of kaolin washing plant near Oak Level, Henry county. The crude clay is washed down the trough from the mine.

KAOLIN PIT AND WASHING PLANT, HENRY COUNTY, VIRGINIA.

Additional localities are given by the same analyst as follows: A deposit of crude kaolin occurs on the property of the Kaolin Mining and Manufacturing Company near Abbeyville, Mecklenburg county. The deposit is said to be of considerable size, and is in 3 layers, separated by thin bands of ocher. The following analyses give the composition of the individual layers:

	1st layer 4 feet thick.	2nd layer 2 feet thick.	3rd layer 30 feet thick.
	Per cent.	Per cent.	Per cent.
Silica (SiO_2)	69.40	69.01	60.36
Alumina (Al_2O_3)	20.85	20.97	24.82
Ferric oxide (Fe_2O_3)	1.40	1.36	1.60
Lime (CaO)	.14	.11	.40
Magnesia (MgO)	trace	trace	.43
Potash (K_2O)	2.03	2.01	2.60
Soda (Na_2O)	.79	1.19	4.72
Titanic oxide (TiO_2)	.65	.65	1.01
Loss on ignition	4.70	4.62	3.93
Total	99.96	99.92	99.87

The clay is stated to be of low plasticity, with 2.5 per cent. air shrinkage, and 2.5 per cent. fire shrinkage at 2250° F. It burns to a cream color.

Another deposit of kaolin is reported on the land of Carroll Brothers, near Lynchburg, in Campbell county. The analysis given shows:

	Per cent.
Silica (SiO_2)	45.13
Alumina (Al_2O_3)	37.96
Ferric oxide (Fe_2O_3)	.24
Lime (CaO)	.85
Magnesia (MgO)	.23
Soda (Na_2O)	.52
Potash (K_2O)	.31
Water and loss	14.59
Sulphuric oxide (SO_3)	.01
Phosphoric oxide (P_2O_5)	.06
Total	99.90

At the same locality there is said to be found a yellow clay used for bright red brick and a blue clay adapted to pottery manufacture. The composition of the two is given as follows:

	Yellow clay. Per cent.	Blue clay. Per cent.
Silica (SiO_2)	61.75	44.70
Alumina (Al_2O_3)	21.46	35.59
Ferric oxide (Fe_2O_3)	6.76	3.46
Lime (CaO)	.65	1.76
Magnesia (MgO)	.33	.12
Soda (Na_2O)	.87	.16
Potash (K_2O)	.73	.37
Water and loss	7.22	13.55
Sulphuric oxide (SO_3)	.02	.08
Phosphoric oxide (P_2O_5)	.06	——
Total	99.85	99.79

About a half mile north of Roseland, Nelson county, the Pittsburg Kaolin Company mined kaolin on a very extensive scale for many years, from altered pegmatite dikes. An extensive plant was erected at the mines at a reported cost of $50,000, for preparing the product for market. It was used in paper making. The mill was elaborately equipped with machinery for crushing, screening, and drying the kaolin by steam. Mining is said to have commenced in 1890 and was suspended about 10 years ago.

A deposit of residual clay, 7 miles southwest of Sherando at Waynesboro, was analyzed by Dr. Froehling with the following result:

	Per cent.
Silica (SiO_2)	47.90
Alumina (Al_2O_3)	39.86
Ferric oxide (Fe_2O_3)	.24
Lime (CaO)	.23
Magnesia (MgO)	.19
Alkalies (Na_2O, K_2O)	1.55
Loss on ignition	9.85
Total	99.82

The Cambro-Silurian shales and limestones yield an abundance of impure residual clay, which clay is well adapted to brick manufacture. These clays, which are likely to be used throughout the Great Valley region, are chiefly red-burning, so far as known. In addition to being adapted to brick manufacture they can also be employed for mixing with limestone to make Portland cement.

Sedimentary Clays.

These are abundant in both the Coastal Plain area, where they are usually of unconsolidated character, and west of the Blue Ridge, in which region they are mostly of a hard and shaly nature. They are widely distributed geologically, and the geological distribution agrees also somewhat closely with the geographical range.

THE COASTAL PLAIN CLAYS.

The deposits of the Coastal Plain consist of a series of unconsolidated beds of sand, gravel, clay, and marl, which may be locally indurated by the presence of a cement of iron oxide or lime carbonate. The strata have in general an easterly dip, which varies from 30 feet per mile in the lowest formations to less than 5 feet per mile in the highest ones. The effect of such a low dip is to make the beds appear almost horizontal. Good sections, such as are usually afforded along the valleys and hill sides, are scarce, because the Coastal Plain is an area of low relief that slopes gradually from the Piedmont hill country to the ocean border. The few good sections that exist are to be found in the low bluffs bordering some of the more important rivers, such as the James.

Since the formations dip southeastward the oldest ones will outcrop at the western edge, and any bed outcropping at this point will be found at a much greater depth near the sea coast. Or again, if a formation were found at sea-level at a point midway between the coast-line and the "fall-line," its dip would carry it higher up if it were followed inland, or lower down if followed toward the coast.

The Coastal Plain formations range in geologic age from Jurassic (?) to Quarternary, but of these only the Eocene and Miocene beds of the Tertiary, and the Pleistocene of the Quaternary, have thus far proved to be of marked value to the clay-worker. The others contain scattered beds of clay, but sands are the predominating materials in most of them.

The Eocene clays are best developed in the region south of Stafford court-house, where they form rather promising outcrops, but have not yet been developed.

The Miocene clays are best known south of Richmond, in the vicinity of Curle's Neck, and Bermuda Hundred. This same formation also carries extensive beds of diatomaceous earth or clay, which is well exposed at Richmond and along the Rappahannock river.

The Pleistocene clays occur as more or less basin-shaped deposits, which are widely scattered over the surface of the Coastal Plain region, and rest on top of the other formations.

Economic value of the Coastal Plain clays.—Nearly all the clay deposits noted in the Coastal Plain area, whatever their geological age, are of lenticular or lens-shaped character. The majority are red-burning, while only a few are buff-burning. No white-burning clays have thus far been found; but even though they lack in variety, so far as their color-burning qualities are concerned, it is probable that their possible uses are more numerous than is now supposed.

The localities from which samples of the Coastal Plain clays were collected by the writer and subjected to laboratory study, the results of which are given in the table opposite page 175, are shown on the accompanying map, plate XXIII. The characters of the clays in the more important areas are separately discussed below.

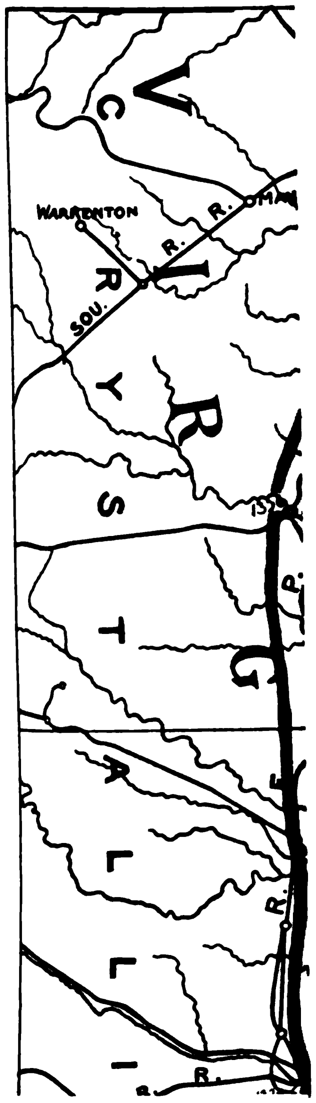
DESCRIPTION OF CLAY AREAS.

The Alexandria Area and Vicinity.

This area is the most important brick-making district in the Virginia Coastal Plain region. It cannot be said that this marked local expansion of the clay-working industry is due to the more abundant occurrence of clay at this point, but rather to the fact of its nearness to an active and important market, namely, the city of Washington. Nearly all the brick yards of the area here described are situated so close to the city, that the product is hauled across the river by teams, and the daily continuous procession of wagons loaded with brick indicates the demand for the Virginia product.

The clays used in the Alexandria district are the Columbian loams, which underlie the low hills around Alexandria, Arlington, Addison, Riverside, etc. They are all sandy loams of variable color, yellow, red, brown, and bluish-gray, and are frequently of a mottled character. Most of the clays burn to a red brick, but certain ones show a tendency to fire buff, and since these lighter burning parts are oftentimes tougher, they do not mix readily with the red-burning clay when the run of the bank is used, so that the buff spots show in the brick after burning. At the yard of the Washington Hydraulic Pressed Brick Company, the several clays are carefully separated and burned alone, thus giving several different shades of product.

The firms in operation in this region are: Washington Hydraulic Pressed Brick Company—a view of the company's plant is given in plate XXVI; Jackson-Phillips Company; Potomac Brick Company; Virginia Brick Company; Estate of Charles Ford; Walter Brick Company; West Brothers; Alexandria Brick Company; Washington Brick and Terra Cotta Company; and American Hygienic Brick and Tile Company. The last is located near Riverside.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The Fredericksburg Area.

The most prominent clays in the region around Fredericksburg are those belonging to the Eocene formation. While these no doubt underlie a considerable area between Fredericksburg and Stafford to the north, still prominent outcrops of them are not very abundant.

The nearest of these to Fredericksburg is located along the road from Fredericksburg to the Davis granite quarry on the hill leading up from the canal. This material, which is of a bright red color, is known, locally, as paint clay, and is said to have been used by the Indians for that purpose. How extensive the bed is can only be determined by boring, for no outcrops of it are seen, except along the road, but there it is exposed in the ditch at the roadside for several hundred feet at least. Tests of this clay (No. 1356) are given in the appended table, facing this page.

Following the road from Fredericksburg to Stafford, there are a number of indications of bluish-white Eocene clay in the ditches along the roadside but most of these are topped by a heavy bed of sand. About 6 miles east of north from Fredericksburg, a heavy bed of the clay is found on top of a ridge.

The section here involves:

	Feet.
Surface sand and soil	1-2
Pink clay, laminated	12
Whitish clay	4

The pink clay (Lab. No. 1350) is distinctly stratified and in its upper part contains some scattered crusts of limonite. The physical and chemical properties of this clay are given in the table opposite this page.

The clay, although burning to a good color, is not a dense-burning one; in fact, it does not yield as tight a body as some of the Pleistocene clays. Its main use should be for common brick, pressed brick, or drain tile. The outcrop mentioned is somewhat distant from the railroad for cheap exploitation, but the extension of this bed should be found to the westward, nearer lines of transportation.

The whitish clay (Lab. No. 1352), which underlies the pink clay, is of buff-burning character and burns to a good body. It would no doubt make a good light-colored pressed brick by either the wet method repressed, or the dry-press process. Its analyses and physical tests are given in the table opposite this page.

The Wilmont Area.

This is practically the only locality along the Rappahannock river where the Pleistocene clays are worked, and the quality of those developed at this point would make it seem desirable to prospect further for other deposits.

At the brick works at Wilmont the following section is exposed:

	Feet.
Soil	1
Blue clay (so-called)	5-6
Gravelly sand (variable thickness)	6-15
Diatomaceous earth	10
Green sand clay	4

The blue clay, which is of Pleistocene age, is mixed with either the diatomaceous clay, or with clay from another surface deposit not far distant. The green sandy clay, which is the same as that tested from Layton, lies below the level of the yard. Plate XXXV, figure 1, shows the Pleistocene clay overlying the diatomaceous earth.

Another deposit of Pleistocene clay, known as the House clay, is dug about one-fourth mile northeast of the brick works. Here the clay runs from 9 to 13 feet in thickness and is underlain by sand. Still another deposit has been located one-half mile northwest of the brick yard. Only the House clay (Lab. No. 1365) and that at the brick yard (Lab. No. 1362) were tested. Their properties are given in the table opposite page 175.

Although these clays are both surface clays, and occur in the same formation at no great distance from each other, still they are quite dissimilar in many respects.

No. 1362 is a red-burning clay which burns to a good bright color. Its air shrinkage is not excessive and its fire shrinkage is low. It contains some coarse grit which shows up clearly on the fractured surface of the burned bricklet. At cone *8* portions of the clay become viscous. This is not a fire clay, but it works well for brick and fireproofing.

No. 1365 is a gritty, light-burning clay which does not burn steel-hard until cone *5*, and even at *8* still shows a rather high absorption. Its low air shrinkage and low tensile strength are characteristic of sandy clays. The material can be classed as a low-grade fire clay, such as is used in terra-cotta manufacture, or for boiler-setting brick. It is the most refractory of the series tested from the Coastal Plain area.

The brick works at Wilmont produce fireproofing, boiler-setting brick, and some front brick. In each case a mixture of the Pleistocene clays, or of these with diatomaceous earth, is used.

The Layton Area.

Along the shore of the Rappahannock river, about 1 mile south of Layton, there is a long outcrop of gritty greenish clay, of Miocene age, which is evidently part of a rather extensive deposit. The material is well shown in the river bluff, and its smooth vertical surface stands out in marked contrast to the overlying sand. The bed as here exposed is not less than 9 feet thick, and is overlain by 6 to 8 feet of sand, which may be adapted to molding purposes. The clay (Lab. No. 1354) in table opposite page 175, evidently underlies the diatomaceous earth which crops out farther down the river, and both are overlain by the sand referred to above. This same clay is seen inland from the river, behind the mill at Occupacia post-office; it also underlies the diatomaceous earth at Wilmont, and is seen at several other points along the river bank.

It is exceedingly sandy, as can be told by the feel, and seen from the analysis (silica, 85.72 per cent.). Its shrinkage is very low and it burns to a very porous body, so that it would seem undesirable to use it for even common brick.

Overlying this at Occupacia post-office is a whitish sandy clay (No. 1367) of table opposite page 175, which, although quite different in appearance from the green clay, resembles it closely in both physical and chemical properties. One might suppose, judging from its color, that it was a fire clay, or at least semi-refractory in its character, but it is not.

The Milford Area.

Along the road from Milford to Bowling Green, and about three-quarters of a mile from the former locality, there is a promising deposit of yellowish brown Pleistocene clay, 10 to 12 feet thick. The bed is underlain by sand, but has very little overburden. Its characters are given in the table opposite page 175. (No. 1353.)

This is a red-burning surface clay, which becomes steel-hard at *03*, but is too gritty to use for any purpose except common-brick manufacture. It would probably work on a dry-press machine.

The Richmond Area.

Richmond, next to Alexandria, is the most important clay-working center in the Coastal Plain region of Virginia, there being a number of yards engaged in the manufacture of common and in some cases pressed brick. Most of these are located on the edge of Richmond and in the suburbs of Manchester and Fulton, while a few are located near the reservoir and race track.

The output of these is not sufficient to supply the demand, and some outlying towns are also drawn upon. The better grades of pressed brick in Richmond are not made in the Coastal Plain area. Some are obtained from Clayville, Powhatan county, Virginia, but most of them come from points outside of the State.

There are four yards in operation in Manchester, all of them being located in the vicinity of Knight and Maury streets. All of these are engaged in the manufacture of soft-mud brick and a few of them also produce a small quantity of pressed brick. The clay used is a more or less mottled, gritty, yellow or reddish clay, which is covered by a thin layer of sandy soil and commonly underlain by a bed of sand. At only one point, namely, the yard of Green and Harrison, is an underlying crystalline rock encountered. The clays in general are very tough and plastic, sometimes quite sandy, and they contain a variable quantity of stony material which ranges in size from small pebbles up to large boulders, most of these being of crystalline character. This stony material is not found to be uniformly distributed through all the beds, but seems to run rather in streaks, the greatest quantity of it having been observed in the bank of W. J. Ready, and Green and Harrison.

At G. E. Redford's yard, the clay shows an average thickness of 12 feet with a maximum of 17 feet, and is underlain by a hard bed of sand and gravel. It is a mottled gritty clay with scattered mica fragments and many limonite stains running through it; and it contains also many decomposed pebbles of crystalline rock. The clay pit is a large shallow excavation lying to the south of the yard and the working face has a height of from 6 to 8 feet. The material is red-burning, and for the manufacture of bricks the run of the bank is commonly used. This is necessary because the clay seems to vary somewhat in its physical character.

Thus, for instance, it is not safe to use that found in the north end of the pit alone, because it is very tough and cannot be used without cracking. It is mixed therefore with the more sandy portions of the bed.

Adjoining the yard of Redford on the west is that of W. B. Davis. This pit, which is a large shallow excavation, lies to the south of the yard, and has a working face of from 6 to 7 feet in height. The clay is similar to that in Redford's bank, but seems to contain fewer stones.

Adjoining Davis' yard on the east is that of W. J. Ready. The clay

The Powhatan Clay Manufacturing Company's plant, Clayville, Powhatan county.

BRICK PLANT, POWHATAN COUNTY, VIRGINIA.

pit which lies to the northwest of the yard is much deeper than the neighboring excavations and also lies at a slightly lower level, for the upper surface of the clay is uneven and slopes towards the river. The clay in general is somewhat similar to that found at the two preceding yards but contains more stones and boulders than are found in either Redford's or Davis' bank. The thickness of the clay is said to be at least 18 feet, and it is probably underlain by sand. Here in a working face of perhaps 200 feet in length they recognize three different kinds of clay, only one of which they claim can be used alone. If either of the other two is used by itself, it results in an imperfect product. The physical and chemical characters of these three clays are given in the table opposite page 175.

A plant is also operated by W. J. Ready near the West End yard and is located a quarter of a mile west of the track near the reservoir. The material is the usual mottled surface clay which is worked to a depth of about 7 feet, although a total thickness of 20 feet is claimed for it.

The yard of the Fulton Brick Company, which is commonly spoken of as Westford's yard, is located west of the Chesapeake and Ohio Railway round house. The clay used here is the ordinary surface clay and does not seem to run over 10 feet in thickness. It also contains many cobble stones. Underlying this is a fine sand which is at least 8 feet deep and is used for sanding the brick molds.

The Baltimore Brick Company operates two yards at Rockett, a suburb of Richmond. The yards are located near the intersection of Ohio and Williamsburg avenues. The clay is tempered in ring pits, molded by hand, and burned in dutch kilns. Some 12 years ago the company tried making soft-mud machine brick but gave it up for some unknown reason. The clay is obtained from under the surface at several points in the vicinity of the yard and averages from 15 to 18 feet in thickness with an underbedding of sand. The material is quite similar in character to that at Manchester, but lacks the stones and boulders.

Maynard and Powers operate a pit lying to the southeast of the Baltimore Brick Company's excavation. The working face here is about 12 feet high and shows a sandy, mottled, yellowish-brown and gritty clay similar to that occurring in the other pits in this vicinity. The company claims that its clay runs 20 feet in depth and is underlain by a bluish-gray sand. The chemical and physical properties of this clay (No. 1300) are given in the table opposite page 175.

A clay very similar in appearance to that on the Ball property, 6 miles south of the city, and probably of the same age is also found outcropping on the Williamsburg road leading to Stagg's Mill, about one-half mile to the west of where the road crosses the railroad. The clay is exposed on a sloping hillside, and in such position that a large quantity can be removed without having to take off much overburden. It is also well located for shipment. As far as could be ascertained the bed is not less than 20 feet thick. It (Lab. No. 1330) is a grayish clay, which slakes slowly and works up with 27.8 per cent. water to a mass of high plasticity. Its air shrinkage, 12.6 per cent., is somewhat high; so also is the average tensile strength, namely, 300.9 pounds per square inch.

This is a very plastic clay which becomes steel-hard at cone *05*. It gives a light red color up to cone *03*, but at cone *1* gives an excellent dark red color. Its point of vitrification is apparently reached at about cone *3*, and at cone *5* it was well passed vitrification and had swelled considerably. It is not as good a clay as that described from near Bermuda Hundred (Lab. No. 1317) or Curle's Neck (Lab. No. 1314).

The Fort Lee Area.

At Fort Lee on the Chesapeake and Ohio Railway, about 2 miles south of Richmond, there is a group of yards operated, respectively, by C. H. Oliver, J. M. Davis, and the Fulton Brick Company. The general run of the clays is not unlike those used around Richmond, but none of the pits show stony material, such as is found in some of the Richmond clay banks.

The most southern of this group of yards is that of C. H. Oliver, which is located one mile west of Fort Lee. The clay here is found immediately underlying the surface and the bank shows 12 feet of clay, although the total thickness of it is said to be 20 feet. Underlying it is a pit of gravel and sand of unknown depth. For making bricks the run of the bank is used. The general physical properties of this clay (No. 1202) are given on page 175.

Adjoining Mr. Oliver's yard on the west is that of J. M. Davis. The clay used is similar to that employed at Oliver's pit described above. It is molded by hand, dried on pallets, and burned in Dutch kilns. A few hundred feet up the track and on the north side of it are two yards operated by the Fulton Brick Company. The brick yard adjoins the clay bank on the west and the material is practically the same as that seen at the Davis place, but the methods used for winning the clay are more improved.

The dark-colored clays, similar to those described from south Chester, outcrop at several points around the base of Government Hill, especially along the Government road leading down from the top of the hill, but in nearly every instance they are covered with too much overburden to permit of their being profitably worked.

Summary.—It may be well to make a comparative summary of the clays found in the Richmond area. Those found near the city, and those which are worked at Manchester, Fulton, and near the reservoir, are to be classed as good common-brick clays, which burn to a good color, and also make a fair grade of front brick when repressed. They are too gritty and stony as well as too irregular in their character to be used for drain tile, hollow blocks, or red earthenware. The methods used for working them are usually crude, and therefore the yards are of limited capacity. The manufacturers claim, however, that owing to difficulties with labor, it is impracticable to use more improved methods, such as machine molding. Some also maintain that the hand-molded brick sells better on the local market.

The clays found at Fort Lee appear to be less stony and even less sandy than those occurring at Richmond, and they are susceptible of being worked by more improved methods. Of the yards located at Fort Lee one used a soft-mud machine, and another a stiff-mud machine. Even these clays however, are somewhat siliceous for any use other than brick, although it is probable that drain tile or hollow brick could be made from them.

Apparently the best clay in the Richmond area is that described from near Stagg's Mill on the Williamsburg road. This is more plastic, denser burning and less sandy, than any of the clays now being worked either around Richmond or Fort Lee. The deposit being located so close to the city, as well as close to a railroad line, should be investigated by clay manufacturers.

Large areas have already been dug over in the brick-making districts around Richmond, because the deposits are comparatively shallow, and the output of the yards has been large. Each manufacturer naturally excavates the clay nearest to his yard first, so that as year after year goes by the pit face recedes, and the clay haul becomes longer and longer. As the city of Richmond and its suburbs are growing, it will not be many years before building will encroach on the brick yards, and the latter will have to be moved. Being, as it were, temporarily located, there is therefore not much inducement for establishing an extensive plant.

The Curle's Neck Area.

About 1 mile north of Curle's Neck and 6 miles south of Richmond, there are a number of exposures of clay along the road, and also on the farm on the west side of the road, at a locality pointed out by Mr. W. A.

Ball, of Richmond. This material has been usually spoken of as fullers earth, and some sample car-loads have been shipped to cotton oil factories in order to test it for bleaching purposes. The material, however, is very plastic and on inspection one would be likely to form the opinion that it was a clay suitable for the manufacture of some red-burning ware. In fact it is stated that at one time a small stoneware pottery was in operation at this point and there is considerable evidence of this in the numerous fragments of stoneware which are scattered around in the field near the farmhouse. Three samples, Nos. 1314, 1315, and 1316, were tested from this locality, the results being given in the table opposite page 175.

The Chester Area.

There are no brick yards in operation at this locality, but a number of outcrops of clay are to be seen in the railroad and trolleyroad cuts in the vicinity. None of them, however, are suited to the manufacture of brick. About 2 miles south of Chester along the Atlantic Coast Line Railway there are several cuts, which show outcrops of a sandy, bluish fossiliferous clay. The material is not uniform in character, certain layers being highly fossiliferous, others very sandy, and still others very plastic. The exact thickness of the deposit is not known, but from the exposures, it is evidently not less than 30 feet thick. No attempts have been made to use it.

The general characteristics of the clay may be summed up as follows: Red burning, low fire shrinkage, and low fusibility. Difficult to burn. It is not to be recommended for anything but common brick, and even for this purpose it should be avoided if something better can be found.

The Bermuda Hundred Area.

Much clay is exposed at a point along the railroad from Chester to Bermuda Hundred and about 1 mile from the railroad station at the latter locality. The same material is also seen in the gullies in the neighboring fields. This clay is at the same level as that which is worked at Broadway, on the Appomattox river, and it is probable that the deposit extends in that direction, but they do not belong to the same formation.

The exposures in the railroad cut show a thickness of not less than 10 feet, and a thickness of 49 feet was proved by boring in one place. Although the clay along the railroad track does not show much variation on inspection, it is stated that at the northeastern end it is brick clay, while at the southeastern end it is tile clay. The properties of the brick clay (No. 1306) is given in the table opposite page 175.

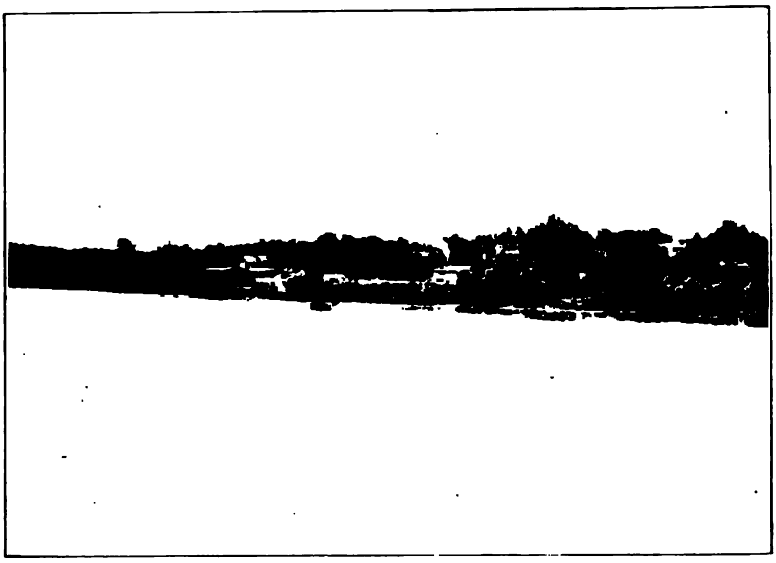


Fig. 1.—General view of Keeler's brick yard at Broadway on the Appomattox river. The clay bank lies at top of bluff to rear of yard.

Fig. 2.—Keeler's clay bank at Broadway on the Appomattox river.

CLAY BANK AND BRICK YARD ON APPOMATTOX RIVER, VIRGINIA.

Judging from the dense body of this material it would be worth experimenting with for paving brick, or perhaps pipe. The most serious objection to it is its high air and fire shrinkage.

This clay has been dug and shipped, occasionally, to the works of the Powhatan Clay Manufacturing Company, at Clayville, near Richmond.

The Petersburg Area.

There are three yards in operation near Petersburg. Two of these, operated, respectively, by W. R. Turner, and Brister and Harrison, are located in Ettricks, across the river from Petersburg; the third, that of the Chesterfield Brick Company, is situated about 2 miles from Petersburg near the line of the Petersburg-Richmond trolley road. They all make an excellent grade of red brick. The properties of these clays are given in the appended table opposite page 175.

The clay is molded on a plunger stiff-mud machine, dried on pallets and burned in scove kilns. The local contractors state that the supply of bricks from the yards around Petersburg is entirely sufficient to meet the demand in that city.

The Broadway Area.

The only brick yard in operation at this locality is that of Keeler and Son, which is located immediately at the foot of the bluff along the Appomattox river. The clay deposit lies about 75 feet above the river and the clay is being dug at a point in the terrace about 300 feet south of the yard. It is a tough, mottled material with a thickness of at least 15 feet, the upper 2 feet of which are weathered. Overlying this is about 18 inches of gravelly sand similar to that which occurs immediately under the surface throughout this region, on both sides of the river. The clay is underlain by a coarse gravelly sand which extends down to the river level and probably below it. The pit, however, is not over 7 feet deep, plate XXV, figure 2.

The clay burns steel-hard at cone *05* and at either this temperature or cone *03* it makes an excellent red brick. If burned to this cone, or better still, to cone *1*, the material would probably make a good pressed brick.

This is an excellent red-burning clay which could probably be used for making front as well as common brick, provided it is thoroughly pugged. At the present time it is utilized for making common brick and the run of the bank is used, leaving out the overburden of gravelly sand.

The City Point Area.

The Pleistocene clays outcrop in the bluff along the James river, about one-eighth mile south of City Point landing. Their distribution is evidently irregular, for in the first cut of the railroad after leaving City Point, there is nothing but sand exposed, although the bottom of the cut is not as high as the upper part of the clay along the river shore. I was informed that borings made to the south of the railroad cut had revealed the presence of the clay under the surface sand. Along the shore the clay is not less than 20 feet thick, but it contains occasional streaks of sand. There is also about 4 feet of sandy overburden. No brickyard is located at this point, although the deposit is at the water's edge and the product could be easily shipped. Occasional car-load lots have, however, been dug and shipped to the smoking pipe factory at Pamplin City. As for this line of ware, a small quantity of clay will go a long way, so that the amount that has been dug has produced little impression.

The characters of the clay (No. 1339) are given in the table opposite page 175. The main advantage of it is, that it is conveniently located for shipment by rail, an advantage not possessed by most deposits along the James river.

The Sturgeon Point Area.

W. C. Mayo and Sons operate a common-brick yard at this locality. The plant is located along the river's edge at the base of the bluff, while the clay is obtained from near the top of the bluff. The section at this point involves:

	Feet.
Loam	1 to 2
Clay	7 to 8
Sand	2
Mottled clay with iron streaks	9
Sand	20 to 30
Blue clay	3+

The sand mentioned in the lower part of the section extends down to the river's edge, and at that point it is underlain by a bed of dark bluish-gray, highly plastic clay, which is about 3 feet in thickness. The upper layer of clay was formerly worked and a considerable quantity of it has been dug. It was found, however, that it was so variable in its character and burning qualities that it was undesirable to use it, and consequently the raw material for the yard is now taken from the middle clay bed given in the section which yields a more uniform product.

It is claimed that this deposit of clay extends more or less continuously for at least 12 miles back from the river.

The Oldfield Area.

This locality lies about 4 miles south of Sturgeon Point and on the same side of the river. There is one yard in operation here, namely, that of the Oldfield Brick and Tile Company, plate XXI, figure 2, which is engaged in the manufacture of common brick. The clay here, as at Sturgeon Point, underlies the terrace which borders the river, plate XXI, figure 2, and the brick yard itself is located at the base of the terrace escarpment on the river's edge. It may be said that the materials underlying the terrace consist of dense or alternating beds of sand and clay overburden, and an upper bed of loamy clay underlain by a siliceous clay, which weathers to a whitish color and contains many cylindrical limonite concretions. The upper bed has an average thickness of about 3 feet, and this is first removed and utilized for the manufacture of common brick. The under bed seems to be variable in its thickness, but where best exposed at the south side of the deposit and nearest to the yard, the thickness is at least 7 feet. It is underlain by a tough sandy clay which is not used and which passes downward into a bed of loamy sand containing streaks of pebbles. The two kinds of clay are worked separately, the upper clay being used for common brick, and the lower clay, with the limonite concretions, known as the tile clay, being used for tile or extra hard brick, termed paving brick. A sample of each of these was tested and the tests given in the table opposite page 175.

The Belfield Area.

This town, which adjoins the better known one of Emporia, has one yard, whose product consists entirely of common brick, and which is operated by Dr. Wood, of Emporia. The soil is quite sandy around Belfield, and the surface flat, so that there are very few clay exposures. At the brick yard the clay extends nearly to the surface and averages about 5 feet deep, being bottomed on a coarse, whitish sand, which is not mixed in with the clay, as it does not seem to improve its quality. The clay burns to an excellent red color and makes a good common brick.

The Norfolk Area and Vicinity.

The cities of Norfolk, Portsmouth, and Newport News, are among the most important in the Coastal Plain area of Virginia, and in all, building operations are being carried on quite extensively. There is here consequently a good market for building brick, either common or pressed, and the supply is drawn from a number of points.

There are several yards in the immediate vicinity of these cities which deserve mention. E. W. Face and Son operate a yard on North Avenue, Atlantic City. The raw material is brought from a pit of Pleistocene clay on the Nansemond river, near Suffolk, and in its general character resembles that worked at the brick yards around Suffolk. It is a red-burning clay of excellent plasticity, which yields a good product for structural work. Before molding, the clay has a small quantity of fine coal mixed in with it, to help in burning, a practice somewhat unusual in the Coastal Plain area. It is molded on an end-cut auger machine, dried on hot floors, and burned in up-draft kilns with permanent side walls.

The plant of the Builders Supply Company is located on Middle street, Chesterfield Heights. The clay is a light-colored sandy material averaging about 3.5 feet in thickness. There are only a few inches of soil over it, and the clay is free from stones or shells.

G. A. Stephens' brick yard is located on the Princess Anne road near Godfrey Avenue. It is also working a surface clay, which, however, is somewhat different in its appearance from that at the preceding plant. The clay which immediately underlies the soil is a bluish-black, very stiff red-burning clay.

C. H. Phillips and Brothers operate a yard at Hampton, near Newport News, and here a reddish, sandy, surface clay is used, for making common soft-mud brick.

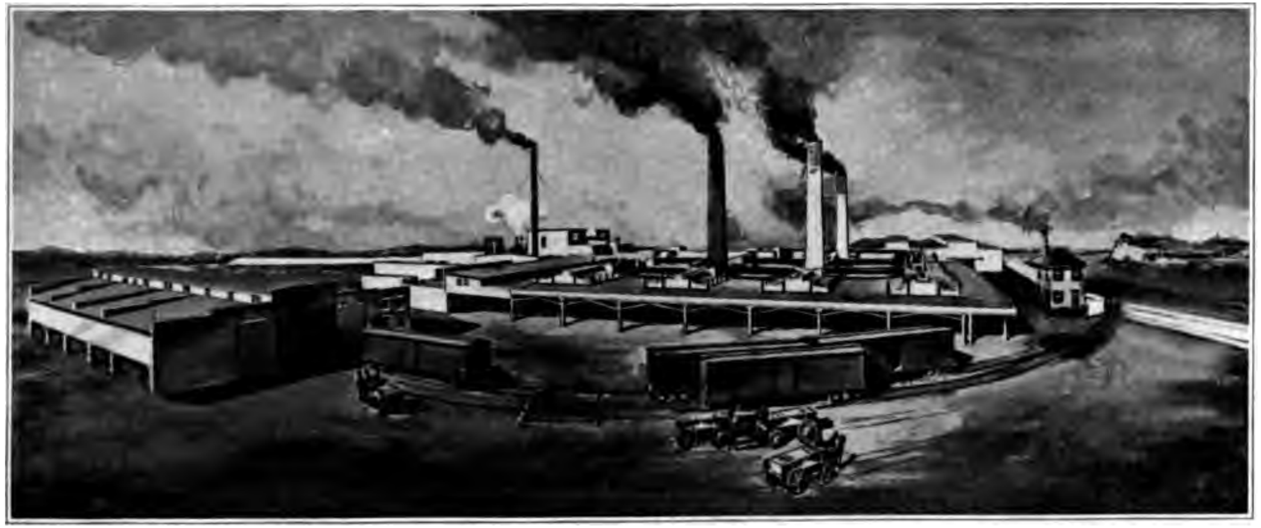
At Morrison, 1 mile north of the station, is the yard of the Booker Brick Company, whose product goes mostly to Norfolk. This is a shallow Pleistocene deposit, 3 to 4 feet in depth and underlain by sand. The material is red-burning and used only for the manufacture of common brick.

The Suffolk Area.

Four brick yards were visited at this locality, namely, those of the Standard Brick Company, Horrell and Company, Suffolk Clay Company, and West End Company.

The Standard Brick Company's yard is located about one and a half miles south of Suffolk along the Southern Railway. The surrounding region is underlain by a deposit of sand, often of coarse grain and variable thickness. Some of it might serve for molding sand, and much of it no doubt would answer for the manufacture of sand-lime brick. At the pit of the Standard Brick Company, there is a little stripping to be done before the clay is reached. The bed has a depth of about 6 feet, the lower two to three feet being a dark bluish-gray and the upper half discolored by weathering. The lower clay gives a harder brick but has a higher shrinkage than the top clay.

The yards of the Suffolk Clay Company, and the West End Company,



View of Washington Hydraulic-Press Brick Company's Works.

HYDRAULIC-PRESS BRICK PLANT, VIRGINIA.

are located west of Suffolk and on adjoining properties; in fact, the clay deposits worked at the two are probably continuous at the yard of the West End Company. The clay deposit varies from 5 to 15 feet in thickness with very little overburden. It is underlain by a bed of black sand, which in places is quite clayey, but is not mined with the brick clay. The clay has been traced horizontally for at least 200 yards, and contains few stones. No sample of this was tested. The clay is worked up in a stiff-mud machine, and dried in 24 hours in steam-heated tunnels.

At the bank of the Suffolk Clay Company, the section shows:

	Feet
Top soil	1
Yellow clay	3
Blue clay, lower foot sandy	9
Limonite sand	1
Sand	8
Blue marl	20

For brick making the run of the bank, including the sand layer, is used. The blue clay is not safe to use alone by any process of wet-molding, but it gives a harder, denser body. The properties of the brick mixture (No. 1345) and the blue clay (No. 1344) are given in the table, opposite page 175.

WESTERN VIRGINIA.

This part of the State (Mountain province, west of the Blue Ridge) no doubt contains clay resources of great value, which however are, as yet, but little developed. Associated with the coals are many beds of shale, some of which appear very promising, but up to the present time these have been but little utilized. These different shale deposits are indeed worthy of a careful and complete investigation and, when fully developed, will no doubt become a valuable source of revenue.

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PART III.

NON-METALLIC MINERALS.

I. ELEMENTS.

GRAPHITE.

General character.—Graphite, known also as plumbago or black lead, is a steel-gray to iron-black mineral having metallic lustre and a greasy feel. Chemically, pure graphite is composed of carbon but it is often impure from the presence of such mineral substances as those mentioned below. It is opaque and soft with a hardness of from 1 to 2, and a specific gravity varying from 2.09 to 2.23. Its most distinguishing features are its softness, greasy feel, and the property of soiling whatever it comes in contact with.

It is usually found in embedded foliated masses, scaly, or slaty, sometimes granular to compact, and at other times decidedly earthy. It has a perfect basal cleavage similar to mica; is a conductor of electricity, and is combustible only at very high temperatures.

The variations in color, hardness, and specific gravity, noted above are due to mechanically admixed impurities, such as iron oxide, clay, silica, mica, etc. The workability of the mineral depends largely upon the character of the impurities and the extent and accessibility of the deposit.

Occurrence.—Graphite occurs principally in the crystalline metamorphic rocks, both siliceous and calcareous, as embedded masses, scales, streaks, and fine-disseminated grains. Its occurrence is most frequently noted in granitic rocks, gneiss, mica schists, and crystalline limestones. It is rather widely distributed in nature and is found in many localities, but it occurs in only a few deposits of such character as to be of economic importance.

Distribution and localities.—From the nature of the occurrence of graphite noted above the Virginia region in which the mineral may be found, is the Piedmont Plateau or the crystalline area, east of the Blue

Ridge. It is rather widely distributed through the Piedmont area, occurring chiefly in the schists and gneisses but as yet no actual production of the mineral has been reported.

Extensive developments and preparation for mining and marketing the mineral have been in progress for some months in Albemarle and Orange counties at the mines of the Naylor-Bruce Graphite Company. The property of this company, comprising 624 acres of land on which graphite appears, is situated at the base of the foot-hills of the Blue Ridge, partly in Albemarle, and partly in Orange county. The graphite is reported as occurring in veins which vary from 13 inches to 8 feet in width, and dipping at an angle of 45° E. The associated rocks are gneisses and syenites. The graphite "veins" are sharply defined from the foot- and hanging-walls by clay selvages. The graphite is of good quality and single blocks weighing several hundred pounds are easily extracted. An analysis of the crude mineral made by Froehling and Robertson, of Richmond, gave 76.28 per cent. of graphitic carbon. Numerous openings have been made and a plant for refining the product is in course of erection.

Near Sommerset station, in Orange county, on the Somers place, a large exposure of graphitic schist occurs, and at the same place much graphite is reported mixed with pyrite of a pyrite vein. In Louisa county, near Green Spring, specimens of graphite of considerable purity are found. Good specimens of the mineral have also been obtained on the road from Drake's Branch to Saxe's in Charlotte county. It is reported from near Jefferson post-office in Powhatan county.

In Amelia county, about 2.5 miles north of Amelia court-house, a small opening was made some years ago on a reported good showing of graphite. Because of the long standing of the opening and the resulting filling nothing could be seen at the time of my visit in July 1906. On the Hubbard place in Nelson county, about 2 miles southwest of Roseland post-office and within a half mile of Tye river, a promising surface exposure of graphite occurs as disseminated scales in a gneiss of granitic composition. This property has not been opened but large masses of the rock are heavily charged with graphite.

Graphite has also been reported by Professor Rogers from Buckingham county, and by Professor Dana from Loudoun county. In addition to these occurrences of graphite in Virginia, graphitic schists, which in some places are worthy of consideration, are quite freely distributed over parts of the Piedmont region. Except the mines of the Naylor-Bruce Graphite Company described above, attention given the graphite at the numerous localities in the State has not progressed beyond the prospecting stage, and at many the only knowledge of the mineral is from surface indications.

Uses.—The uses made of graphite are numerous and varied. One of the principal uses of the mineral is in the manufacture of crucibles, retorts, and other refractory apparatus. It is also used in the manufacture of lead pencils, lubricants, stove-polish, paints, foundry-facings, glazing, electrotyping, steam-piping, etc. For some of these uses, especially the manufacture of refractory apparatus, the crystalline variety of graphite is essential, while for others the amorphous form is equally as good as the crystalline.

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II. SULPHIDES AND SULPHARSENIDES.

I. PYRITE.

COMPOSITION AND PROPERTIES.

The mineral pyrite, disulphide of iron corresponding to the formula FeS_2 and known also as iron pyrites, occurs in sharply defined cubes and their crystallographic modifications, or in granular masses of a brassy-yellow color. When chemically pure, pyrite contains iron, 46.6 per cent., and sulphur, 53.4 per cent. As mined, however, the ore is never chemically pure but contains admixtures of other metallic sulphides and, at times, considerable quantities of the precious metals, especially gold. Ordinarily, pyrite can be readily recognized by its hardness, color, crystalline form, and irregular fracture.

MODE OF OCCURRENCE.

Pyrite is one of the most widely disseminated of minerals and it is found in rocks of all kinds and of all ages. It occurs as disseminated grains through the rock mass; in contact positions between rocks of different kinds, especially between eruptive and sedimentary masses; as irregular concretionary masses in sedimentary rocks; as fissure veins; and as lenticular bodies, sometimes of immense size, lying conformable, or nearly so, with the structure (foliation) of the enclosing rocks.

The worked deposits of pyrite in Louisa and Prince William counties, Virginia, are grouped under the latter occurrence, as they form huge lenses which conform somewhat closely to the structure of the enclosing crystalline schists. Extending downward from the surface to approximately local water-level, the pyrite is altered by oxidation and hydration, forming the iron-cap or gossan of limonite, which is frequently mined as an ore of iron. The gossan of the pyrite ore-bodies in Louisa county, Virginia, was extensively mined as an ore of iron prior to the mining of the unaltered pyrite, and furnaced in the immediate locality.

DISTRIBUTION AND LOCALITIES.

Pyrite has wide distribution in Virginia, it being detected either in traces or in larger amounts in nearly every formation represented in the State. Seldom is it found, however, sufficiently concentrated to yield workable bodies of ore. Thus far, only two counties are known in Virginia to contain workable deposits of this mineral. These are Louisa and Prince William counties, situated in the eastern Piedmont region. Map, figure 29, shows the principal pyrite belt in Virginia. The pyrite mines of these two counties are probably the largest and most extensively developed in the United States and the product from them constitutes more than 50 per cent. of the total output of pyrite in the United States.

GENERAL GEOLOGY OF THE LOUISA AND PRINCE WILLIAM COUNTIES PYRITE AREAS.

Character and structure of the rocks.—The belt of rocks in Louisa and Prince William counties in which the pyrite ore-bodies or lenses are enclosed shows unmistakable evidence of sedimentary origin. They were, in many places, largely limy or calcareous sediments, as evidenced by the thin bands and stringers of pure and impure limestone which appear, and by the large development of lime-bearing silicate minerals that are present.

The rocks have been extensively metamorphosed and are now thoroughly crystalline schists, chiefly micaceous, with more or less hornblende and garnet developed in places. The normal rock is a mica-quartz schist where fresh and unaltered. Nearly all varieties are to be found

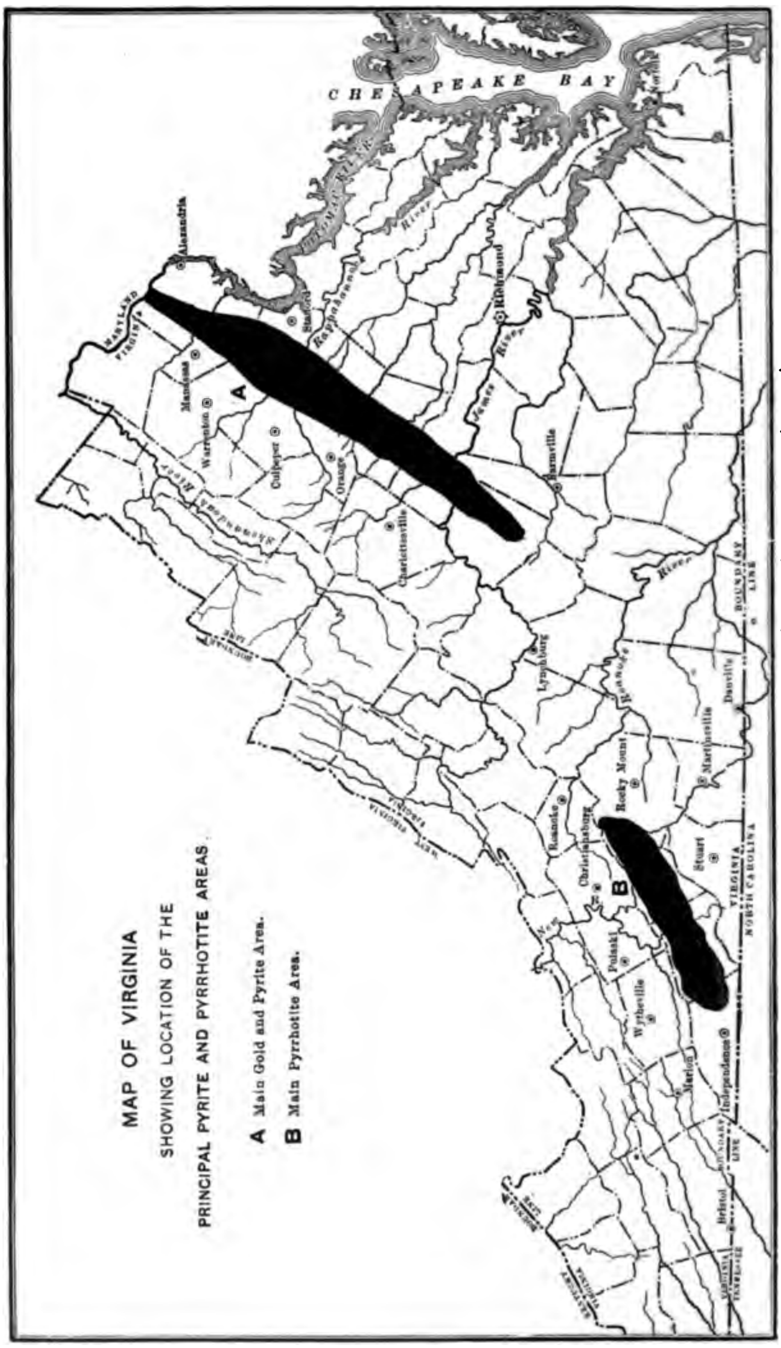

Fig. 29.—Sketch map of Virginia showing pyrite and pyrrhotite belts.

including mica schists without quartz largely altered to chlorite, quartz-sericite schists, talcose and chloritic schists, and hornblendic schists. In many places these various varieties of schist are garnetiferous, in others garnet is essentially or entirely absent. The impure limestone bands carry both black lustrous folia of biotite and large fibrous crystals of green-black hornblende.

The schists are completely and thinly foliated, so much so that the straighter thin-banded ones are locally called slates. Certain varieties of the schist, especially the highly micaceous ones, are frequently more or less distinctly crinkled. In the Prince William county area, a wide belt of true slates lies a short distance to the east of the ore-bearing schist series. Darton has designated this belt of slate the Quantico slate and it marks the position of the "fall-line" to the east of the Cabin Branch mine between the overlapping of the Coastal Plain sediments onto the crystalline rocks of the Piedmont region.

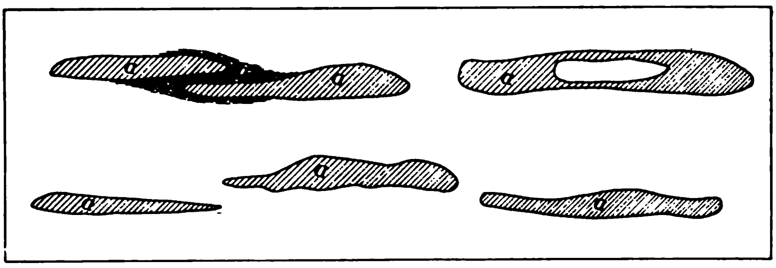

Fig. 30.—Plan of pyrite lenses in the Louisiana county area. *a*. Pyrite lens; *b*. Micaceous schists.

The general strike of the schist belt is N. 10° to 20° E. In Louisa county the schists dip from 60° to 65° southeast with flatter dips shown in places. In Prince William county, at the Cabin Branch mine, the dip of the schists is to the northwest, varying from 25° to 64°. The rocks, as well as the ore-bodies, are penetrated by several well-developed sets of joints and in the Cabin Branch mine cross-faulting is observed.

THE ORE.

General character and mode of occurrence.—As mined the pyrite consists of massive-granular ore which varies in texture from very fine- to moderately coarse-grained. The very fine ore is ordinarily composed of minute irregular grains without crystal boundaries but may be admixed with much or little pyrite in distinct crystals. On the other hand, the coarser types of ore are made up chiefly of pyrite cubes and their crystallographic modifications. Some of the ore is very hard and non-friable, but much of it is quite friable, and in some mines practically all of the ore is of the latter type. Much of the ore contains little or no admixed small crystalline grains of white calcite and quartz distributed through the mass, but usually more or less of these two minerals is present, the calcite greatly preponderating, and nearly all gradations are traceable from much calcite and less pyrite to practically all pyrite with little or no calcite and quartz. The associated metallic minerals are mentioned below.

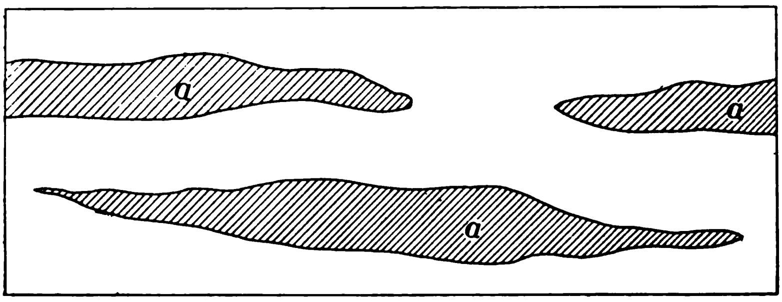

Fig. 31.—Plan of pyrite lenses at Sulphur mines, Louisa county.

The ore-bodies consist of a series of lens-shaped bodies conformable to the structure of the enclosing schists. (Figures 30 and 31.) The lenses follow each other in the direction of strike, and may or may not be connected by thin and lean stringers of ore. The spacing between the ends of lenses is variable. In a few instances, a partial overlap of the lenses has been observed as shown in figure 30. The lenses vary much in size. In the Louisa county mines, they usually measure several hundred feet long (700 feet being the longest one yet known) and in thickness as much as 60 to 80 feet. At the Cabin Branch mine, in Prince William county, the maximum thickness is probably 10 feet and one lens had the enormous length of approximately 1,000 feet.

As developed by the extensive mining operations, the ore-bodies are marked in places by rolls and swells and by pinching and narrowing. In the change from flatter to steeper dips, no indication was shown of unconformity of the lenses to the structure of the enclosing rocks or suggesting a vein that unmistakably cuts the rocks.

In the Louisa county deposits, the strike of the ore-bodies is N. 10° to 20° E. with an average dip of 60° to 65° to the southeast. In several places, measurements showed dips as flat as 35° on the 620-foot level in the Arminius mine. In Prince William county, at the Cabin Branch mine, the general strike of the lenses is the same as for those of Louisa county, but the dip is toward the northwest varying from 25° to 55°.

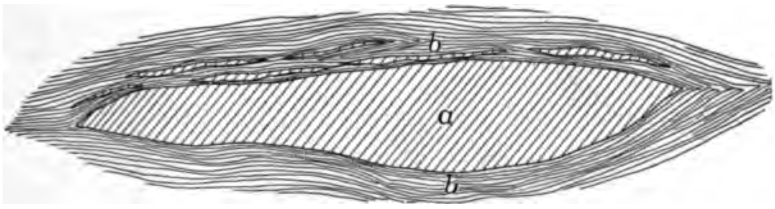

Fig. 32.—Plan of pyrite lens, showing stringers of pyrite interleaved with schists on the hanging-wall. *a*. Pyrite; *b*. Crystalline schists, chiefly micaceous. Arminius mine, Louisa county, Virginia.

The contact between the ore-bodies and the wall-rock is usually sharply defined but some grading into the country-rock by the ore is noted at times. Parallel interleaved thin stringers of solid ore, and of lean ore, to the large lenses characterize the walls of all the mines and are especially marked in the hanging-wall, as shown in figures 32, 33, and 36. Some post-mineral movement is shown in the ore-bodies, especially those of Louisa county, in the highly polished and slickened-sided surfaces along some of the fracture planes.

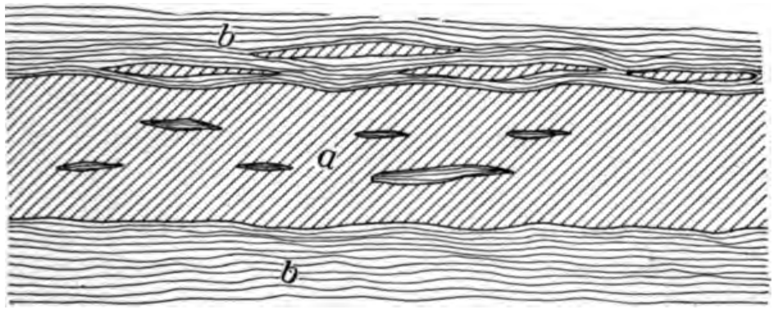

Fig. 33.—Portion of pyrite lens in Cabin Branch mine, Prince William county, showing pyrite stringers interleaved with schists on hanging-wall, and inclosures of sheet masses in the lens. *a*. Pyrite; *b*. Mica schist.

Composition of the pyrite.—The following analyses will show the general character of the Louisa county pyrite:

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.
Sulphur (S).............	48.02	50.00	46.40	50.00	49.27
Iron (Fe)................	42.01	43.00	——	——	43.62
Iron oxide (Fe_2O_3)........	1.93	——	——	——	——
Iron sulphide (FeS_2)......	——	——	——	93.80	——
Silica (SiO_2)............	7.60	——	——	——	——
Insoluble	——	6.02	——	6.20	4.23
Sulphur trioxide (SO_3).....	0.44	——	——	——	——
Copper (Cu) } Arsenic (As) }..........	none	——	none	none	1.50 ——
Zinc (Zn)...............	——	——	——	——	0.38
Lime (CaO) } Magnesia (MgO) }........	——	——	——	——	1.32

I. Dr. A. Volcker, analyst.
II. Sulphur mines reported by W. H. Adams.
III. Dr. W. H. Taylor, analyst.
IV. Charles Tennant and Company, analysts.
V. Arminius mine reported by W. H. Adams.

Adams reports that many analyses of the Louisa county pyrite ores give results from 46 per cent. to 51.5 per cent. of sulphur, copper from 0.5 per cent. to 9.72 per cent., and traces of gold and silver, but no arsenic. I am reliably informed, however, by the present management that analyses of the ore mined at present show traces of arsenic. According to Adams, there are easily traceable quartz veins in the hanging- and foot-walls in all of the properties, which are gold-bearing to the extent of from $4.00 to $15.00 per ton; but these veins are always narrow, ranging from 3 to 7 inches in thickness.

More or less copper, usually a small fraction of 1 per cent. in the form of chalcopyrite, is invariably present, inextricably intermingled with the pyrite. This is obtained from time to time from the mine water as cement copper by precipitation upon scrap iron and is dried, screened, and barreled for market. Lead and zinc are present in traces at times and occasionally they are appreciable in small masses of the ore. The form in which these are present is mentioned below under associated minerals.

The average in sulphur content of all ore shipped from these mines ranges from 43 to 45 per cent.

Associated minerals.—The mineral species associated with the pyrite lenses or ore-bodies include both metallic and non-metallic compounds. Named in the order of their importance the metallic minerals are blende (zinc sulphide), chalcopyrite (copper-iron sulphide), galena (lead sulphide), pyrrhotite (magnetic iron sulphide), and magnetite (magnetic iron oxide). Some of these are only occasionally met with and are limited more to some mines than to others, failing entirely in one or two, while others are usually present to some extent in all.

The two commonest non-metallic minerals are calcite and quartz, the small grains and crystals of which are intimately admixed with the crystals of pyrite, forming a more or less friable type of ore. Both minerals are occasionally met with filling fractures and cavities or vuggs in the massive-granular ore and in such cases are clearly of post-mineral formation.

In addition to these two, dark green hornblende and red garnet are extensively developed in some of the mines. As a rule, these are not found to any extent in the ore-lenses proper but are usually found near the margins of the pyrite bodies in the wall-rock. Garnet was observed in every instance in the latter position, while hornblende does occur in the ore-bodies proper, but more often is found as the garnet. Garnet is less common than hornblende and in the Cabin Branch mine, in Prince William county, it is but rarely met with. It is always in perfect large and small rhombic dodecahedrons of deep red color.

In the Arminius and Sulphur mines, in Louisa county, thin layers of a grayish-white limestone occur in the walls and in places is close to the ore-body, as evidenced by masses on the dump with stringers of pyrite attached to them. This limestone is banded with the dark ferromagnesian silicates. principally hornblende. Similar conditions are observed in the Cabin Branch mine in Prince William county. The limestone is impure, consisting of purer bands of limestone, an inch or more in thickness, interlaminated with bands of mica-schist and containing scattered crystals of hornblende.

GENESIS OF THE ORE-BODIES.

Without entering into a discussion in this volume of the evidence for or against any particular theory as to the genesis or origin of these ore-bodies, it may be stated that the facts gathered by me from a careful study of the belt strongly suggest a replacement of limestone by the sulphides. This is discussed at length by me in a paper shortly to be published elsewhere.

THE LOUISA AND PRINCE WILLIAM COUNTIES PYRITE DEPOSITS.

Louisa County.

Location.—The pyrite deposits of Louisa county are situated near Mineral City, formerly known as Tolersville, a station on the Chesapeake and Ohio Railway, and include three mines, two of which are extensively operated at present. (Map, figure 34.) The mines are located N. 20° E. from Mineral City at a distance of from 1.5 to 3.5 miles. Named in the order of their nearness to the station these are: the ***Arminius***, ***Smith***, and ***Sulphur*** mines.

The pyrite belt is crossed by the Chesapeake and Ohio Railway to the west of Mineral City and has been prospected for pyrite for a distance of 10 miles southwest of the Arminius mine, or about 8.5 miles southwest of Mineral City, Nothing, however, that seemed profitable in pyrite concentration has been found south of the railroad. A goodly number of gold mines have been worked at different points in the belt.

Historical.—The Louisa county pyrite mines were worked at different times for iron, copper, and pyrite. They were first opened and worked for iron in 1834 when the gossan or limonite cap, overlying the pyrite to a depth of from 40 to 60 feet, was mined for iron-making in the local furnaces. The gossan at the Arminius mine was practically exhausted in 1861, but that at the Sulphur mines was worked during the Civil War. The gossan ore mined on the Arminius property is reported to have been furnaced in the old Rough and Ready furnace, located about 1.5 miles north of Tolersville, now Mineral City; that from the Sulphur mines was furnaced in the Victoria furnace situated on the present mines property. Both of these furnaces are now entirely destroyed.

According to Adams the Arminius mine was opened for copper as early as 1847. It was operated for copper at a later date and prior to the mining of pyrite by the Virginia Central Copper Mines Company; and at a still later date, by the Arminius Copper Mine Company. The total production of copper from the Louisa county mines is reported as not being large, and represented chiefly ores of secondary enrichment beneath the gossan and at the surface of the pyrite.

According to the same writer the Arminius mine was first opened for pyrite mining in 1865. It was purchased in 1865 by a New York Company which worked it until 1877 for copper and pyrite. In 1883, it was purchased by W. H. Adams and was continuously worked for pyrite until June, 1894, when the present company assumed control.

THE ARMINIUS MINE.

This mine is located about 1.5 miles N. 20° E. of Mineral City and has been variously worked for iron, copper, and pyrite since 1834. Pyrite mining was begun at a much later date, 1865, after the working off of

Fig. 34.—Map showing location of pyrite mines in Louisa county. Mines indicated by heavy black dots; strike of schistosity by arrows. Based on the topographic sheets, U. S. Geol. Survey. Scale, ⅝ inch equals 1 mile, approximately. Contour interval, 50 feet.

the iron-cap or gossan ore. The mine has been constantly worked for pyrite for 23 years.

The ore-bodies are quite extensive and they conform to the structure of the enclosing schists, with local changes noted in both strike and dip of the ore-lenses and the rock. Both hard lump and friable ore are mined, only the latter being milled, which is sold as "fine." The lump ore is cobbed but not milled. The ore is massive-granular, the individual pyrite grains largely possessing crystal form, cubes and their crystallographic modifications. White granular calcite is the most abundant gangue mineral, with some quartz and less dark green hornblende.

Sphalerite, chalcopyrite and galena, named in the order of their abundance, are frequent accompaniments in small amounts of the pyrite. Some pyrrhotite and much magnetite are admixed with the pyrite locally. The ore is reported to contain traces of arsenic, gold, and silver. Of the associated metalliferous minerals, only copper is saved and this only occasionally.

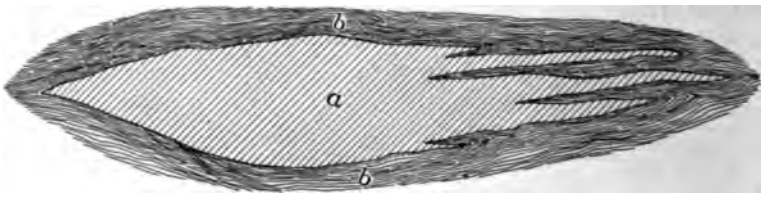

Fig. 35.—Plan of pyrite lens on 620-foot level, Arminius mine, Louisa county, showing feathering out at northeast end by interleaving of pyrite and schist. *a*. Pyrite; *b*. Schist.

The pyrite lenses vary in size but are usually very large, the largest one yet found measuring 61 feet wide by 700 feet long. The lenses will usually average about 20 feet wide and several hundred feet long. The mine has produced large quantities of ore; is developed by 4 inclined shafts worked on more than 8 principal levels run from opposite sides of the shaft and following the direction of the lenses. The slope of the shafts will average about 63° to the southeast. Of the 4 shafts, 2 were working during the summer of 1904; No. 3 shaft which has reached a depth of 875 feet, and No. 4 shaft which has reached a depth of 250 feet. The property has been extensively tested beyond the working area by much diamond drilling.

The lenses do not follow each other along an entirely straight line, but are offset both northeast and southwest without real overlapping, except

Fig. 1.—The Arminius pyrite mines, near Mineral City, Louisa county.

Fig. 2.—The Cabin Branch pyrite mine, near Dumfries, Prince William county.

PYRITE MINES IN VIRGINIA.

Fig. 1.—View of a part of pyrite lens in opening at the Sulphur mines, Louisa county. Pyrite lens is exposed in right half of picture.

Fig. 2.—View in same opening as Fig. 1, showing crystalline schists on hanging-wall of pyrite lens.

PYRITE LENS, LOUISA COUNTY, VIRGINIA.

in one or two cases. Figure 35 shows feathering out of one of the ore-bodies at the northeast end, on the 620-foot level, by interleaving of the pyrite and schist.

The surface plant of the Arminius mine, shown in plate XXVII, figure 1, is large and commodious, and is well equipped with all necessary modern machinery for the mining and milling of pyrite. The total output of ore from this mine is utilized for the manufacture of sulphuric acid. The average sulphur content of the ore shipped from this mine is from 43 to 44 per cent.

THE SMITH MINE.

The Smith mine, now owned by the Mining Department of the United States Fidelity and Guaranty Company of Baltimore, Maryland, is located three-quarters of a mile N. 20° E. from the Arminius mine. At the time of my visit to this mine, in the summer of 1906, operations were suspended pending litigation. The mine is reported to have been first opened about 20 years ago. It has been developed by 3 shafts and numerous drifts, the deepest being 300 feet, the other two 100 feet and more in depth. Ore has been mined on the following levels: 100, 150, 200, 250, and 300 feet.

The ore is of the friable type and of excellent quality, of which a large total output has been produced. The surface plant comprises a mill and all necessary machinery for pyrite mining and milling.

THE SULPHUR MINES.

The Sulphur mines are located 2 miles northeast of the Arminius mine and 3 miles northeast of Mineral City, a station on the Chesapeake and Ohio Railway. The mines are connected with the Chesapeake and Ohio Railway at Mineral City by a broad-gauge steam road, built in 1884. The gossan or limonite cap was first mined and furnaced prior to the Civil War in the old Victoria furnace on the present company's site, which was closed in 1877. Mining of pyrite was begun in 1882.

The property is developed by 8 shafts, 3 of which were working at the time of my visit in August, 1906. The greatest depth attained in the working of these shafts is 720 feet. The method of mining the ore is closely similar to that employed at the Arminius mine.

Many old cuts are now exposed from which the gossan ore was early mined. Several of these afford opportunity for observing the ore-bodies and their relations to the enclosing rocks as shown in plate XXVIII, figures 1 and 2. Careful measurement of the direction of strike of the lens in one of the largest and longest of the old gossan cuts gave N. 20° E. and dips ranging from 65° to 75° south 20° east, with an average dip of 66°. Entire conformity with the foliation of the enclosing rocks was noted at every point where observations were made. Here, as at the Arminius mine, slight local changes in the degree of strike and dip are noted while the general direction of each remains constant.

The ore-bodies, lenses, average from 40 to 50 feet in thickness and several hundred feet in length. The old gossan cuts, which are now badly caved, confirm these dimensions. The ore-lenses on this property lie apparently west of those at the Arminius mine, which gives an average width of the ore-bearing schist zone in Louisa county of from 800 to 1,000 feet.

The mineral associations are the same here as at the Arminius mine. Judging from a careful examination of the dumps chalcopyrite, pyrrhotite, and probably magnetite, are somewhat more abundant than at the Arminius mine, and calcite seems to have considerably greater development at the Sulphur mine.

Both hard and friable ore are produced, the latter existing in largest quantity. At present, only the low grade ore is milled. The milling scheme is closely similar at the two mines except at the Sulphur mines trommels and tables are used. The fine and coarse ore are separated at the tipple and all ore goes to the washer. The concentrates average 42 per cent. of sulphur. Three sizes of ore are shipped, all of which is used in the manufacture of sulphuric acid.

The Sulphur mines surface plant is very large and commodious and is well equipped with all necessary machinery for handling the ore in the mines and at the mill. Preparations were in progress during the summer of 1906 to enlarge and otherwise improve the present mill.

Prince William County.

THE CABIN BRANCH MINE.

Only one producing pyrite mine has been developed in Prince William county. This mine, known as the Cabin Branch mine, is located about 1.5 miles northwest of Dumfries. (Map, figure 36.) Some prospecting for pyrite has been done both to the southwest and to the northeast of the Cabin Branch mine. Two small operations, separated by a distance of several miles from each other, are reported opened about 12 miles southwest of the Cabin Branch mine, in Stafford county.

The Cabin Branch mine was first opened in 1889, but it was not continuously operated until several years later. It is developed by 3 shafts, the deepest one of which, is 1,000 feet on an incline which varies from 25° to 55°, the dip of the ore-body. The ore-body is worked on all levels from the surface to the depth of the shaft, 1,000 feet. This lens averages from 5 to 10 feet in thickness and is approximately 1,000 feet long. Unlike the pyrite ore-bodies of Louisa county, those developed at the Cabin Branch mine dip to the northwest with cross-faulting, ordinarily of slight displacement. Variations in dip of the lenses here are much greater than for those of Louisa county. The

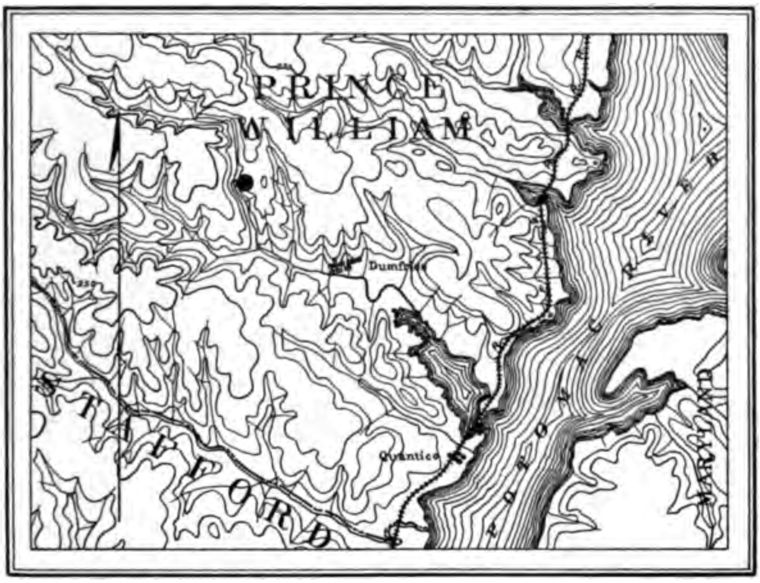

Fig. 36.—Map showing location of Cabin Branch pyrite mine, Prince William county. Mine indicated by heavy dot. Based on the Mt. Vernon topographic sheet, U. S. Geol. Survey. Scale, $\frac{3}{8}$ inch = 1 mile, approximately. Contour interval, 50 feet.

mineral associations are similar to those of the Louisa county mines. Chalcopyrite, a little pyrrhotite, and occasional galena and blende, are intermingled with the pyrite. Galena and blende are present in much smaller quantity than in the Arminius and Sulphur mines of Louisa county. Traces of gold are reported in the pyrite. No attempt is made to save any of these in the mining of pyrite at the Cabin Branch mine. Of the non-metallic minerals, calcite and quartz occur as at the other mines. Hornblende is found, but a careful examination of the dumps showed only an occasional red garnet.

The ore is closely similar to that of the Louisa county mines in general character and excellence, and similar grades of ore are marketed. The surface plant is extensive and modern and well equipped for handling the ore. Plate XXVII, figure 2, shows the Cabin Branch pyrite mine.

A narrow-gauge road is operated between the mine and Barrow Siding on the Richmond, Fredericksburg and Potomac Railway, distant about 6 miles. The company also controls its own wharf on the Potomac river which is connected with the mine by the above narrow-gauge road and offers magnificent facilities for ore-shipping by water.

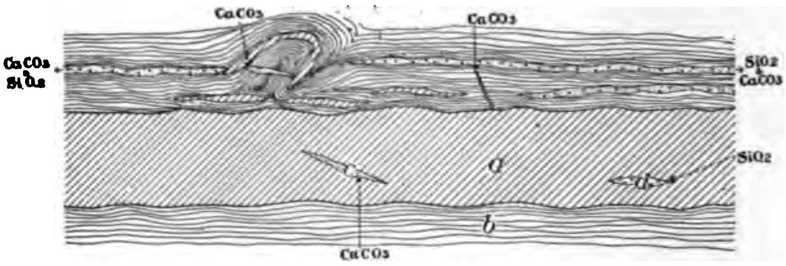

Fig. 37.—Plan of portion of pyrite lens at Cabin Branch mine, Prince William county, showing interleaved lenses of pyrite, quartz and calcite on hanging-wall, with minor folding. Inclosures of quartz and calcite in pyrite lens. These fill fractures in some cases and are subsequent.

METHODS OF MINING.

The methods employed in mining the ore at the different mines is, in general, closely similar, differing only in minor details. Since the ore-bodies dip from 25° to 65° the general practice is to develop them by inclined shafts sunk in the direction of dip. Levels are then run out from the shaft on the two sides in the direction of strike of the lenses and at convenient distances above each other. In the Louisa county mines, stopes are opened up by driving levels along the lens at intervals, which are connected by raises, and the ore broken down by overhand stoping. The walls are comparatively strong and but little timbering is necessary. At the Cabin Branch mine, in Prince William county, the conditions are somewhat different from those at the Louisa county mines and the methods employed differ slightly in details. At this mine, the lenses show a greater variation in dip, are cross-faulted, and the wells are apparently softer, which require more timbering. At all the mines the ore is raised by inclined cable and cars.

Fig. 1.—The Sulphur mines, near Mineral City, Louisa county.

Fig. 2.—View of shaft and dump at the Sulphur mines, near Mineral City, Louisa county.

PYRITE MINES IN VIRGINIA.

MILLING.

The ore is prepared and marketed in 3 sizes, lump, spall, and fine. The lump represents the first grade ore as broken in the mine and is free from all slate and lean material. Spall is clean lump ore broken to pass a 2.5 inch ring and is freed from finer material by screening. Fine ore is sized to pass a ⅝-inch screen and is usually washed or jigged to bring it up to grade. The ore is sold on a basis of sulphur content at a variable price per unit.

The following description of the milling practice at the Virginia pyrite mines has been abstracted from a published paper by Painter, in the Engineering and Mining Journal for July, 1905. The larger part of the output from the Louisa county mines consists of the grade "fine" ore. One mine turns all of its ore into "fine." At this mine, the skip dumps upon a grizzly of railroad iron set 3 inches apart. After picking and forking the slate from the 2 sizes, these go to their respective crushers at the head of the mill. The ore is reduced to jig size by crushing with breakers and rolls and screened by trommels, when it is fed by a distributer to the Hartz jigs. Jigging through a bed of cast-iron balls is employed, and the hutches discharge upon a belt-conveyor of ascending grade, which delivers to the stock piles where the ore soon drains.

At another mill the skip dumps upon a similar grizzly; the oversize is sorted into No. 1 lump for shipment, No. 2 lump to the mill, slate to the waste; the undersize falls upon a floor, where the slate is eliminated, the remainder going to the mill in a separate car by rope haulage. Usually, the better grade of lump goes to a jaw-breaker set to make spall ore, a fine-bar grizzly cutting out that under 1¼-inch size, which goes to the mill. After being inspected and the slate thrown out, the spall ore is loaded in box cars. The mill is arranged to crush the ore by successive steps in Blake crushers, roll-jaw crushers and rolls, with repeated screening to jig size. The same practice of jigging through a bed of cast-iron balls is employed; but the jigs discharge into a de-watering device which feeds a belt-conveyor delivering to the stock pile, bins or hearth drier, depending upon the weather. Tables are being installed to treat the overflow from the de-watering tank.

At the Cabin Branch mine, the skip dumps upon a 2.5 inch grizzly. The oversize goes to the lump-ore storage-bin, from which it is drawn off at intervals and sorted. Slate goes to the dump, first-class lump to the spalling floor and the remainder to a roll-jaw crusher at the head of the fine-jigging annex. The No. 1 lump is all spalled by hand to burner size and forked into measuring chutes delivering to the cars. The spalling is done by hand with long-handled hammers of 2-pound weight upon a thin layer of ore on the floor. The resulting "fine" is small in amount and is screened into the fine bin. The undersize from the grizzly goes to a revolving screen with 1.5-inch round holes, through which the ore is worked into the pebble-ore jig. The oversize goes to a slate-picking chute delivering upon a spalling floor. The pebble-ore jig is a 3-compartment Hartz jig fitted with No. 2 mesh, No. 8 iron-wire screens. It discharges from the spouts, clean pebble and middling; from the hutch, clean, fine middling and waste.

The clean pebble ore is elevated to a screen delivering to a skipping chute; the small ore is returned to the roughing rolls. The clean "fine" ore runs into the fine bin which is heated by exhaust steam. The fine middling is elevated to the roughing rolls. After passing through rough rolls, the crushed ore meets the No. 2 lump which has passed the roll-jaw breaker, and the product from the fine-crushing centrifugal rolls, and is elevated to a 2-unit centripact screen. The upper screen is 2⅝-inches aperture, and the oversize goes to the roughing rolls; the second screen is ⅛-inch, and the oversize goes to the fine rolls; the through size goes to the 2-compartment fine jigs.

Uses.

Pyrite is utilized chiefly for the manufacture of sulphuric acid. It is also used in the preparation of the iron salt known as green vitriol or copperas (iron sulphate). Very small amounts of the mineral are utilized in the preparation of vermillion paints and occasionally for jewelry. The entire output from the Virginia mines is reported to be consumed in acid-making.

Production.

The total production of pyrite in the United States is distributed among less than 10 states, of which Virginia produces more than one-half. On this basis, the following figures which represent the annual production of pyrite in the United States will afford some idea of Virginia's yearly output. The production of pyrite in Virginia for the years 1904 and 1905 was 120,671 and 123,153 long tons respectively, valued at $440,753 and $426,008.

Production of pyrite in the United States from 1882 to 1905 inclusive.

(Long tons.)

Year	Quantity	Value	Year	Quantity	Value
1882	12,000	$ 72,000	1894	105,940	$ 363,134
1883	25,000	137,500	1895	99,549	322,845
1884	35,000	175,000	1896	115,483	320,163
1885	49,000	220,500	1897	143,201	391,541
1886	55,000	220,000	1898	193,364	593,801
1887	52,000	210,000	1899	174,734	543,249
1888	54,331	167,658	1900	204,615	749,991
1889	93,705	202,119	1901	*a*241,691	1,257,879
1890	99,854	273,745	1902	*a*207,874	947,089
1891	106,536	338,880	1903	*a*233,127	1,109,818
1892	109,788	305,191	1904	*a*207,081	814,808
1893	75,777	256,552	1905	253,000	938,492

a Includes production of natural sulphur.

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2. PYRRHOTITE.

Pyrrhotite or magnetic pyrites, known also as mundic, is found in many of the crystalline or Piedmont counties of the State, but the largest concentration of this mineral yet known is that of the "Great Gossan Lead" in Floyd, Carroll, and Grayson counties, in southwest Virginia. (Map, figure 29.) Considerable prominence has been given to this "lead" in past years in the mining of secondary iron and copper ores derived from the alteration of the original sulphides, pyrrhotite, containing some chalcopyrite, of the surface portion of the vein. The importance of the "lead" as an iron-producer is discussed under Iron on pages 419-421, and as a copper-producer under Copper on pages 511-517. The general geology and character of the vein are given at some length under Copper on pages 511-513, and need not be repeated here.

Where found in Virginia, the pyrrhotite bodies occur as lenses in the crystalline schists and as well-defined veins, the best example of which is that of the "Great Gossan Lead" in southwest Virginia. This "lead," a well-defined vein of pyrrhotite, varying in width up to 100 feet, strikes southwestward from Floyd county, through Carroll into Grayson county, a distance of more than 20 miles. Map, figure 88, shows the position of the "lead," and plates XXX and LXXV are views of mines located on the "lead." Further description and illustrations are given under Copper, pages 491-519.

According to Moxham, an analysis of a sample of the mundic (pyrrhotite) given as coming from the surface of the "lead" shows:

	Per cent.
Sulphur	34.06
Copper	0.866
Iron	53.15
Phosphorus	no trace
Manganese	0.306
Silica	2.99

Before the Betty Baker mine, located near Sylvatus, was closed down in 1900, 1,800 tons of the pyrrhotite were shipped to the Southern Chemical Company at Winston-Salem, North Carolina, where it was used for acid-making. The ore contained 33 per cent. of sulphur and after roasting carried 58 per cent. of iron.

As Moxham states, whether the large amount of sulphur in this deposit is utilized or not, the main value will not be effectively realized until a process is developed by which the sulphur may be extracted from the ore upon a large scale, at such cost that the residue or "Blue Billy" will be available for the making of pig-iron.

General view of pyrrhotite vein, "Great Gossan Lead," at "Great Outburst," near Chestnut Yard, Carroll county.
(Photo. by W. H. Weed.)

PYRRHOTITE MINE, "GREAT GOSSAN LEAD," CARROLL COUNTY, VIRGINIA.

A considerable amount of sulphur can be driven off by pile-burning of the mundic as is shown in the following tests given by Moxham:

Lump ore.		Fine ore.	
Roasted	Per cent.	Roasted	Per cent.
Iron............	55.50	Iron............	48.99
Sulphur.........	7.69	Sulphur.........	5.51

The importance of the solution of this problem to the iron manufacturers need hardly be pointed out, as it would yield an ore containing approximately 60 per cent. of iron, with low silica and manganese, and no phosphorus—an ideal Bessemer stock.

In recent attempts to mine the ore for copper, the percentage of copper in the output of the mines was found to be too small to permit the working of the vein alone for copper. The future value of the "Gossan Lead" apparently lies mainly in the unworked iron ores and the utilization of the pyrrhotite, magnetic pyrite, for both acid- and iron-making.

An extensive plant, operated by the Pulaski Mining Company, has recently been completed at Pulaski for the purpose of utilizing the pyrrhotite of the "Gossan Lead" for both acid- and iron-making. For supplying this plant with ore, the pyrrhotite is being mined on the southwest end of the "lead," near Chestnut Yard, in Carroll county. Plate XXX is a view of the vein opened at this point.

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Moxham, Edgar C. The "Great Gossan Lead" of Virginia. Transactions American Institute of Mining Engineers, February, 1892, 6 pages.

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3. ARSENOPYRITE; MISPICKEL; OR ARSENICAL PYRITES.

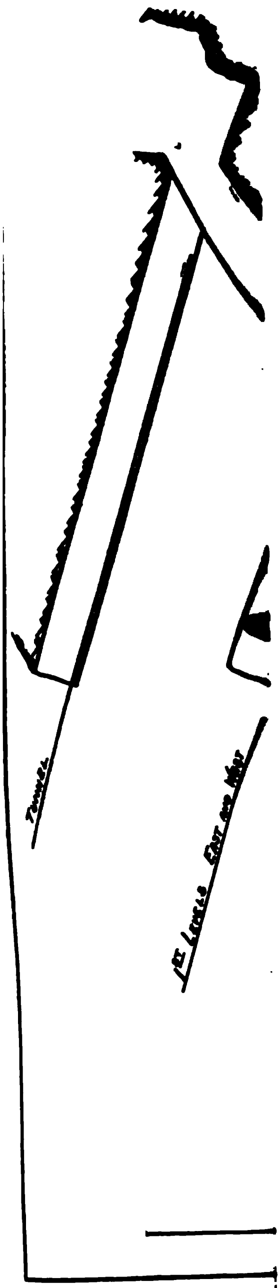
The mineral arsenopyrite, a double sulphide of arsenic and iron, FeAsS, has been noted in quantity at two localities in Virginia, one of which has recently been developed and has produced some arsenic. The localities are in Rockbridge and Floyd counties.

In the extreme northeast corner of Rockbridge county, in the Blue Ridge, arsenopyrite is found in association with pyrite and cassiterite in quartz-greisen tin-bearing veins, which penetrate coarse granite and are described at some length on pages 567-577. No attempt has been made to work the arsenopyrite at this locality.

Near the summit of the Blue Ridge in Floyd county at Rewald post-office, about 17 miles from Christiansburg, and at an elevation of about 3,200 feet above sea-level, a series of "veins" (lenses) of arsenopyrite in quartz-sericite schist occurs, which outcrop in places on the surface. A second principal rock-type is a biotite gneiss, closely associated with the quartz-sericite schist, but its relations to the schist and to the ore-bodies are unknown. The principal lens is reported to be 3 feet thick at the surface but it widens to a thickness of 14 feet at a depth of 120 feet. Numerous lenses are reported found over a distance of some 7 miles. The location of the mine is shown on the map, figure 99.

In 1903, the United States Arsenic Mines Company of Pittsburg, Pennsylvania, capitalized at $500,000, began to exploit the Floyd county arsenopyrite deposits. A 215-foot adit was driven into the mountain side, supplemented with a 55-foot drift extending to an 8-foot "vein" of arsenopyrite, of 25 per cent. arsenic. It is estimated that the arsenic ore can be mined at a cost of 75 cents per ton. The underground workings are shown in plate XXXI, a blue-print copy of which was kindly furnished by the company.

According to a writer in the Mineral Industry for 1903, the ore as mined is conveyed to a Blake crusher, from which it passes by gravity to rolls, where it is finely pulverized. It is then charged into Howell-White furnaces where the metal is volatilized, the vapors precipitated and further purified by sublimation. The plant comprises a building 300 by 70 feet for the mill and furnaces, besides dwelling-houses, shop, laboratory, office and other structures. Plate XXXII, figure 1, is a view of the milling-plant. The equipment consists of a 125-h. p. Westinghouse engine, 2 75-h. p. boilers, 4 dynamos, a 10- by 20-inch Blake crusher, a 27-foot Howell-White calcining furnace, a set of rolls for pulverizing, etc.



Plan of the underground w

Fig. 1.—General view of the milling plant and mines of the United States Arsenic Mines Company, Rewald, Floyd county.

Fig. 2.—General view of the main opening for nickel ore on Lick Fork, near Hemlock, Floyd county. Owned by the Virginia Nickel Corporation.

ARSENIC AND NICKEL MINES, FLOYD COUNTY, VIRGINIA.

The above plant for refining the product was started in October 1904, and shipped sample lots until January 1905, when the monthly capacity of the plant was increased to 90 tons of pure white arsenic. Operations at these mines are temporarily suspended at present, December, 1906.

Uses.—Arsenic is used in the form of arsenious oxide in dyeing, calico printing, in the manufacture of various pigments, fine-grade glassware and special enamels, in arsenical soaps, in the preparation of other salts of arsenic, and as a preservative.

References.

Cowan, J. L. The Arsenic Mines at Brinton, Virginia. Engineering and Mining Journal, 1904, LXXVIII, 105-106.

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III. HALIDES.

1. HALITE; SODIUM CHLORIDE; OR COMMON SALT.

Salt brines and rock salt both occur in the Holston valley in association with gypsum. The salt and gypsum deposits are confined to a narrow northeast-southwest valley of the North Fork of the Holston river, extending from Plasterco on the southwest, to within 3 miles of Chatham Hill post-office on the northeast, a distance of about 16 miles. The interbedded salt and gypsum shales with beds of rock salt and gypsum are regarded as of Mississippian (Lower Carboniferous) age. The geology of the valley and its deposits is described under Gypsum on pages 327-335. A general idea of the valley may be gained from plates XXXIII and XXXIV.

In 1871, Jefferson, in his *"Notes on Virginia,"* mentioned the occurrence of salt brine in the Holston valley, but it was not until 1840 that rock salt was discovered. In 1840, a shaft was sunk which struck a bed of rock salt at a depth of 210 feet. This shaft was sunk with the idea of securing salt water, but as the operators had no knowledge of rock salt at that time, or at least did not appreciate its value for saturating purposes, and as the shaft was practically a dry one, they considered their efforts and money as having been wasted, because they failed to find what they started after, that is salt water. The shaft was located about 200 feet up the "lick," that is southwest of the old brick office-building in the upper end of the valley. It is reported that this was the first discovery of a bed of rock salt in the eastern United States.

Eckel reports an analysis of the rock salt as follows:

	Per cent.
Sodium chloride	99.084
Calcium chloride	trace
Calcium sulphate	0.446
Iron, alumina, etc	0.476

In the early '70's, operations were again begun in the bottom of the old shaft sunk in 1840, and the depth was increased about 20 feet in the bed of fine white rock salt. A drift was started from the bottom of the shaft in a due south course and continued for a distance of about 92 feet, when a second shaft was sunk from the surface down to the end of the drift, the idea being to run water down the second shaft and pump brine out of the first one. The foreman's advice was not followed and the drift was run too near the top of the rock salt, which resulted in the roof being soon dissolved, and the overlying loose rock fell in and completely blocked the drift.

The first borings for salt in this valley were in the old swampy lake-covered area near the present site of the town of Saltville, which was drained before the sinking of the wells. Mining of the rock salt has not yet been attempted, the entire salt product coming from the salt brines of the wells. The entire salt industry is, at present, confined to the immediate vicinity of Saltville, and is controlled by the Mathieson Alkali Works.

As indicated in plate XXXIII, figure 1, a large number of wells have been sunk over the area, the earliest of which were about 200 feet deep and passed through clay, gypsum, and shales. Hayden reports that 6 wells had been put down by 1842, only two of which at the time of his writing were in operation. The more recently bored wells are much deeper than the earlier ones and they show considerable variation in depth, since the beds indicate a strong dip. The average depth of the present wells is not less than 1,000 feet, and some are 1,400 feet. These begin to strike salt at a depth of from 250 to 300 feet, passing through a mixture of salt shale and rock salt. The greatest depth attained in any one of the wells was 2,380 feet. There are 24 producing wells at the present time. Map, plate LII, will show the present salt-producing area.

In the early history of operations and, indeed, until within recent years, the product marketed was salt, which for many years amounted to between

Fig. 1.—General view of salt wells at Saltville.

Fig. 2.—General view of Saltville, Washington county.

SALT WELLS AND SALTVILLE, VIRGINIA.

a half million and a million bushels of salt per year. At the present time, no salt is made, the brines being utilized at the Mathieson Alkali Works at Saltville for the manufacture of sodium carbonate and caustic soda. It is reported that in 1842, two establishments were producing salt, with a total annual production of about 200,000 bushels. Analyses gave:

	Per cent.	Per cent.
Sodium chloride	98.540	98.146
Calcium chloride	.016	.034
Calcium sulphate	1.444	1.820

The following analyses of the rock salt and of the salt brines, the latter of which are of a very high degree of purity, show the general character of the Saltville, Virginia, material:

	I Per cent.	II Per cent.
Sodium chloride	99.084	93.05
Calcium chloride	trace	——
Magnesium chloride	——	——
Calcium sulphate	0.446	2.40
Magnesium sulphate	——	0.07
Alumina, silica, and iron	0.470	3.64
Water	——	0.30

I. Quoted from C. B. Hayden.
II. Quoted from Thomas Radcliffe.

Analyses of brines from Saltville, Virginia.

	I Per cent.	II Per cent.
Sodium chloride	97.792	98.39
Calcium chloride	.033	——
Calcium sulphate	2.17	1.22
Magnesium sulphate	——	.39
Alumina, silica, and iron	trace	——
Percentage solids in brines	24.60	26.40
Specific gravity	——	1.198

I. Quoted from C. B. Hayden.
II. Quoted from G. H. Cook.

Analyses of the commercial salt from Saltville, Virginia.

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.	VI Per cent.	VII Per cent.	VIII Per cent.
Sodium chloride	98.540	98.146	98.45	99.01	99.18	99.11	98.61	98.89
Calcium chloride	.016	.034	.95	.20	.27	.68	1.02	——
Magnesium chloride	——	——	.20	.09	.05	.11	.27	——
Calcium sulphate	1.444	1.820	——	——	——	——	——	——
Water	——	——	.40	.70	.50	.10	.10	——

I and II. Quoted from C. B. Hayden.
III to VIII inclusive. Quoted from G. H. Cook.

The Mathieson Alkali Works.—The Mathieson Alkali Works, a corporation organized under the laws of the State of Virginia for the manufacture of salt, alkali, and caustic soda, is located at Saltville, Smyth county, Virginia, on a branch of the Norfolk and Western Railway. The process used is that known as the Ammonia or Solvay, a process first made a practical working success by Ernest Solvey of Liege, Belgium, and is now almost exclusively used by all manufacturers of alkali. The Mathieson Alkali Works are not manufacturing salt at the present time, having closed down this portion of the operation in October, 1903. The manufacture of salt, however, will probably be resumed in the near future on an extensive scale. The particular product made by this plant is, and has been from the beginning, sodium carbonate, commercially known as "Soda Ash." This product is made in large quantities and in all of the different tests known to the trade. Caustic soda and bi-carbonate of soda are also manufactured, the former in strengths known as 60, 70, 74, and 76.

The first product turned out of the plant was in June, 1895; three years later, June, 1898, the company began the manufacture of bi-carbonate or cooking soda. This product has been of superior merit from the start, and because of this fact, a large and growing trade has been acquired. Plate XXXIV, figure 1, is a general view of the plant.

The company operates its own limestone quarry (plate XLVI, figure 2), which is located about 3 miles from the plant, the stone being conveyed from the quarry by means of an aerial tramway. The following are representative analyses of limestone from this quarry:

	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Calcium carbonate...	97.03	97.03	97.15	96.95	96.73
Magnesium carbonate	1.24	1.15	0.91	1.12	1.37
Silica, Alumina, Iron oxide	1.64	1.57	2.00	2.00	1.80

The Mathieson Alkali Works through their ownership of the Castner Electrolytic Alkali Company of Niagara Falls, New York, are the largest manufacturers of bleaching powder in the United States. They are also the only large manufacturers of chemically pure caustic soda, which is produced in large quantities at the Niagara plant in connection with the manufacture of bleaching powder.

All products are handled through the firm of Arnold, Hoffman and Company, Sales Agents, with offices in Providence, New York, Boston, and Philadelphia.

Fig. 1.—General view of the Mathieson Alkali Works at Saltville.

Fig. 2.—General view of salt wells and valley at Saltville.

MATHIESON ALKALI WORKS AND SALTVILLE, VIRGINIA.

Representative analyses of the Saltville, Virginia, salt brine made in 1906 show the following results, expressed in grains per liter:

Sodium chloride........	291.00	286.00	291.00
Calcium sulphate.......	5.18	4.71	4.21
Calcium chloride........	0.83	0.97	1.06
Magnesium chloride.....	0.53	0.23	0.19

References.

Radcliffe, Thomas. Analysis of Saltville, Virginia, Rock Salt. The Virginias, 1884, V, 138; Chemical News, No. 1038.

Taylor, S. Discovery in Virginia of the Regular Mineral Salt Formation. American Journal of Science, 1840, XLI, 214-215.

Rogers, Wm. B. A Reprint of the Geology of the Virginias, New York, 1884.

For other references on Virginia salt, see under Gypsum, page 335.

2. FLUORITE; OR FLUORSPAR.

The mineral fluorite, known commercially as fluorspar, a fluoride of calcium (CaF_2), is sparingly found associated with the ores of lead and zinc in the Cambro-Ordovician limestone of southwest Virginia; in the same limestone in Clarke and other counties of the Valley region in northern Virginia; in the mica mines of Amelia county; and as the principal gangue mineral at the zinc and lead mines in Albemarle county, near Faber, a station on the Southern Railway.

As yet known, the occurrence in Albemarle county is the only one of fluorite in the State where the mineral is found in quantity sufficiently large to make it of commercial value. Its occurrence in Albemarle county is described in some detail on pages 542-544. It is obtained in the Albemarle county mines as a by-product of the lead and zinc. The increasing demand for fluorite should make the Albemarle county deposit of some importance.

Uses.—The principal uses made of fluorite are in the glass trade for enameling, in the manufacture of steel and iron, and in the manufacture of chemical compounds of fluorine.

References.

Watson, Thomas L. Lead and Zinc Deposits of Virginia. Virginia Geological Survey, 1905, I, 156 pages.

Lead and Zinc Deposits of the Virginia-Tennessee Region. Transactions American Institute of Mining Engineers, 1905, British Columbia Meeting.

IV. OXIDES.

1. SILICA.

Quartz.—The mineral quartz, corresponding to the formula SiO_2 when chemically pure and easily recognized by its hardness, glassy luster, lack of cleavage, and insolubility in acids, is one of the most common and widely distributed of minerals. Quartz crystallizes in the hexagonal system, crystals of which are frequent in occurrence. Its common form is massive-granular occurring as veins in the older crystalline rocks.

Quartz has wide distribution in the State. It occurs as an essential constituent of granite, gneiss, and mica schist of the crystalline area; as the dominant constituent in the sandstones, quartzites, and conglomerates of the Piedmont and Valley regions; and in the form of sand in portions of each of the three larger divisions of the State. A principal occurrence of quartz in Virginia is as a chief constituent of the numerous pegmatite dikes and quartz veins penetrating the older metamorphic rocks of the crystalline or Piedmont region.

Quartz has been mined in Virginia in association with mica and feldspar from the large pegmatite dikes near Amelia court-house, in Amelia county; and from a bedded deposit in crystalline schists near Falls Church, in Fairfax county, where the quartz forms a hard and beautifully white, fine granular quartzite. A beautifully white and pure crystalline quartz occurs three-quarters of a mile west of Wirtz post-office, in Franklin county. Preparations are being made to mine the fine grade of white quartz sand in Catawba valley, Roanoke county, for glass manufacture.

Uses.—The purer clear grades of quartz are used to some extent for making lenses, and in cheap jewelry. Its principal uses, however, are as an abrasive, either as quartz sand or as sandpaper, and in the manufacture of pottery. The purer grades of quartz sand are used for glass manufacture.

Chert.—Chert, known also as hornstone, a term applied to any impure flinty rock, including the jaspers, is a chalcedonic variety of silica. Chert has wide distribution in certain beds of the Shenandoah or Valley limestone of the Valley region, in the form of irregular nodular masses of light nearly white, red, brown, and black colors. No special use has yet been made of the Virginia chert.

Diatomaceous earth.—When pure, diatomaceous earth is a soft, pulverulent, siliceous, clay-like material, very fine and porous in texture, somewhat resembling chalk and kaolin in its physical properties, and of white, yellow, or gray color. It is very light in weight. Its predominant siliceous character is shown in the analyses given below.

Origin and occurrence.—Deposits of diatomaceous earth are formed from the shells and tests of certain aquatic microscopic forms of plant life known as diatoms, which have the power of secreting silica in the same manner as mollusks secrete lime-carbonate. These low forms of organisms have a wide range of adaptability and are entirely aquatic, living both in salt and in fresh water under different conditions of depth and temperature. On the death of the organisms, the siliceous tests accumulate on the bottom of the lake, pool, or pond which they inhabited, forming, in the course of time, beds of more or less thickness. Although formed at various geologic periods, the beds of known commercial importance of diatomaceous earth, both in America and in Europe, are of Tertiary age, a period which was apparently particularly adapted to the growth of these organisms.

When examined under the microscope, the material from these earths always shows the remains of diatoms or rather similar species, composed, principally of silica with varying amounts of water. The deposits are frequently rendered impure from the admixture of clay and at times are discolored by organic matter. The siliceous nature of diatomaceous earth is shown in the analyses given below quoted by Merrill:

	I Per cent.	II Per cent.	III Per cent.
Silica	80.53	80.66	81.53
Alumina	5.89	3.84	3.43
Iron oxide	1.03	——	3.33
Lime	0.35	0.58	2.61
Soda	——	——	1.43
Potash	——	——	1.16
Water and organic matter	12.03	14.01	6 04

I. From Lake Umbagogue, New Hampshire.
II. From Morris county, New Jersey.
III. From Pope's creek, Maryland.

An analysis of diatomaceous earth from Richmond, Virginia, gave Mr. J. M. Cabell:

	Per cent.
Silica	75.86
Alumina	9.88
Ferric oxide	2.92
Lime	0.29
Magnesia	0.69
Soda	0.08
Potash	0.02
Nitrogenous matter	0.84
Water	8.37
Total	98.95

The description of the sample of earth yielding this analysis follows: "Sample was procured from the middle of the exposed bed of this earth just below the colored normal school on President Hill in Richmond, Virginia. Without any previous treatment the specimen proved to be almost exclusively of distinguishable infusoria. It is white with a tinge of yellow and feels a little harsh."

Analyses of diatomaceous earth collected from different points in Tidewater (Coastal Plain), Virginia, by Dr. Heinrich Ries, made in the laboratories of the Virginia Polytechnic Institute, at Blacksburg, and published in the Clay Report, Bulletin No. II of the Virginia Survey for 1906, gave:

	I Per cent.	II Per cent.	III Per cent
Silica	70.42	78.82	82.85
Alumina	15.15	9.24	6.76
Ferric oxide	5.17	5.42	2.34
Lime	.14	.04	.35
Magnesia	.79	.12	1.06
Soda	.39	.81	.99
Potash	2.24	1.51	1.07
Titanium oxide	.44	.33	1.09
Ignition	5.21	3.66	3.40
Total	99.95	99.95	99.91

I. Weathered diatomaceous earth from 7th street, near Richmond Locomotive Works, Richmond, Virginia.
II. Diatomaceous earth from along the Rappahannock river, south of Layton.
III. Diatomaceous earth from Wilmont, on the Rappahannock river.

Distribution.—The first bed of diatomaceous earth of any extent discovered in this country was in the Richmond, Virginia, area. It is commonly known as the Richmond bed, the limits of which are from Herring Bay on the Chesapeake, Maryland, to Petersburg, Virginia, and probably beyond. It is not less than 30 feet in thickness, in places, though very impure at times. It is of Miocene age and is exposed along the numerous streams close to their crossings from the crystalline rocks onto the sediments of the Costal Plain.

In the Eocene and above it, at a depth of about 558 feet, in the deep artesian well at Fort Monroe a stratum of diatomaceous earth was reached, which on critical examination by Samuel Wells yielded abundant diatoms, nearly all of which were identical with those of the Richmond bed.

The following detailed description of the Richmond bed of diatomaceous earth is quoted from Professor Wm. B. Rogers, in "*A Reprint of Annual Reports and Other Papers on the Geology of the Virginias.*"

"The material in question [diatomaceous earth], composing a thick stratum lying between beds of sand and clay, is more or less mingled with them, particularly in the vicinity of its bounding surfaces. But throughout most of its thickness, it presents a very fine texture, admitting of being bruised by the fingers into an almost impalpable powder, and singularly free from gritty particles. Its colour in the present specimens is a very light grey or white, but the fragments into which it spontaneously divides at the exposed surface of the stratum often present externally a slightly ochreous tinge. It is decidedly, though sometimes indistinctly, laminated, the planes of the thin flakes or sheets being horizontal. When moistened, it displays considerable tenacity, and hence has hitherto been regarded as a fine clay or fuller's earth."

"Of all its peculiarities, however, capable of being readily discovered, its great lightness is the most extraordinary and characteristic. When quite free from moisture, a pure specimen has a specific gravity of only 0.334, that is to say, only one-third the weight of water, bulk for bulk."

"In adverting to the curious and astonishing fact of its being composed almost entirely of the shells and other appendages of former races of animalculæ, it was also mentioned that unlike the microscopic remains composing the chief mass of chalk or the larger fossils of our marl beds, these minute relics consist entirely of *siliceous* instead of calcareous matter. For this reason it is, that the Leaf Tripoli, or Polir Scheifer of *Bohemia,* as well as other analogous Infusorial products, have so long been found valuable in giving a polish to metallic surfaces. Our Infusorial matter, when properly selected, is capable of being employed for this purpose with no less advantage, and from the trials I have made, I feel assured that when exempt from grit, it may be very usefully substituted for the finer varieties of the Tripoli or rotten stone of the shops."

"Of the minuteness of these objects, some idea may be formed from the following statements:"

"The cylindrical bodies of the medium size are from 1-300th to 1-400th of an inch in length, and from 1-1200th to 1-1600th in width, but many fall greatly short of these dimensions."

"The rings, which are found separate in great numbers, are usually from the 1-1500th to the 1-2000th of an inch in diameter."

"The circular discs and convex bodies, reticulated with cells, vary from 1-100th to 1-600th in diameter. In each of these are hundreds, and even thousands, of beautifully wrought cells. The predominance of these flattened forms appears to be the cause of the laminated texture already mentioned as exhibited by the Infusorial earth. It is obvious from these facts, that the number of such fossils comprised in each cubic inch of the material, can only be reckoned in millions or hundreds of millions, and that a bushel measure would contain a number of these skeletons and shells of former races or animalculæ, far exceeding the entire population of the globe...."

"The valley of Shockoe creek, lying between Shockoe hill and Church hill, affords numerous favourable opportunities of observing the position of the Infusorial bed, and the strata with which it is associated by explorations along the sides of the bounding hills and the deep ravines by which, in many places, they are abruptly trenched."

"The middle of this valley is occupied by coarse gravel, rarely discovering any materials *in situ*. Beside the stream, a little to the left of the crossing of Shockoe hill Main street, as continued over towards Church hill, a patch of primary is displayed, consisting of Gneiss containing some Hornblende, and intersected by several veins of Felspar."

"At the base of Shockoe hill, a short distance up the principal ravines, the felspathic sandstones and conglomerates may be seen, forming the channels of the little rivulets flowing in these hollows, and rising, when best exposed, to a height of about five feet above the bottom of the ravine. Of course, near the outlet of the hollow, the heavy diluvium from the upper part of the hill conceals or replaces everything else, and neither the felspathic sandstone nor overlying beds can be seen, until we enter some depth into the ravine. We may thence trace it upwards, until, in consequence of the slope of the surface, we reach a higher level than the upper limit of this rock, when it disappears from view. This stratum consists of the felspathic sand in irregular layers, loosely cementing

Fig. 1.—Diatomaceous earth overlain by Pleistocene clay at Wilmont.

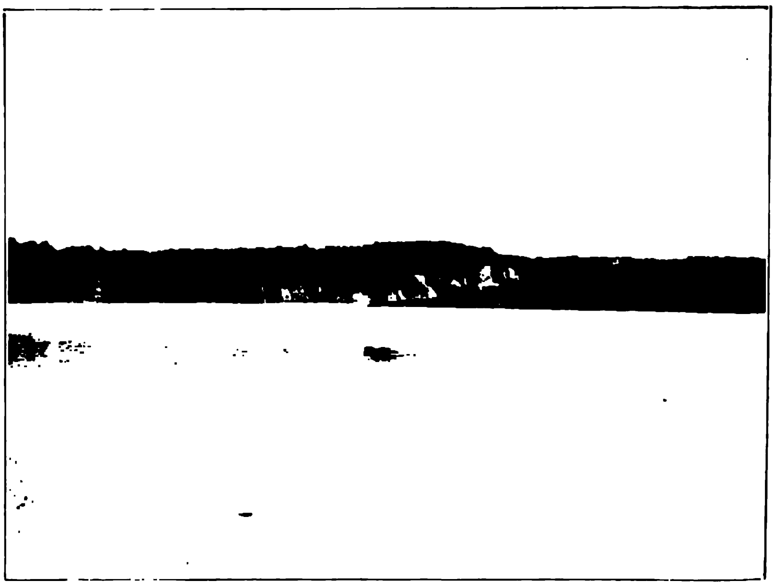

Fig. 2.—Bluffs of diatomaceous earth (Miocene age) along Rappahannock river, southeast of Wilmont.

DIATOMACEOUS EARTH. WILMONT. VIRGINIA.

pebbles of various dimensions from 1 to 4 or 5 inches, some of which belong to formation I. An analogous material is still more extensively exposed in the mill race at the mill, higher up the creek, and composes the low knoll on which the mill is placed. Here we find the felspathic sandstone in general much stained with ferruginous matter, overlain by a bed of very coarse conglomerate of an ochreous stain and unusual hardness. Similar sandstones and conglomerates are displayed at various points along the margin of the stream, for a thickness of several feet above its surface."

"Resting upon this sandstone and conglomerate, we meet with beds of sand and sandy clay of a dark greenish and lead colour, and of a light grey, mottled with yellow, containing Sharks' teeth and Eocene Carditas, Turritellas, Crassatellas, etc., in the form of casts, together with vague vegetable remains in a carbonized condition. The contact of these Eocene strata with the underlying sandstone, is well displayed at numerous points."

The diatomaceous beds of eastern Virginia are capable of supplying an unlimited quantity of excellent material, but as yet they have received only slight attention.

During his study of the Virginia Coastal Plain clays for the Virginia Survey in 1905, Professor Heinrich Ries gave some attention to the diatomaceous beds around Richmond. The description of these beds given below is taken from Ries' clay report.

Beds of diatomaceous earth outcrop in great thickness in the embankment along the tracks by the Richmond Locomotive Works, as well as along the sides of the valley to the west. The general character of the earth is that of a silty, porous clay, which breaks out in irregular lumps. In places, it is traversed by vertical fissures, which are filled with limonite. Along the Rappahannock river there are long exposures of the diatomaceous earth. In places, it forms great bluffs of a yellowish-white color, which stand out prominently in the sunlight and can be seen for a long distance (plate XXXV, figures 1 and 2). This earth appears to be purer and lighter than that around Richmond, but still in places it passes into a clay.

Samples were collected from several localities and examined with some care. Microscopically examined they proved to be somewhat disappointing for the reason that most of them contained very few diatoms, and in some, which to the feel appeared like diatomeceous earth, hardly any diatoms could be found. This is due to the fact that the diatoms are not uniformly distributed through the deposit, but are found chiefly in certain layers. The results of the physical and chemical tests are given in the table opposite page 175.

The analyses of the earths given in the table, opposite page 175, collected from different points, show their chemical composition.

The location of the samples of the Virginia earths collected by the Professor Ries and analyzed in the laboratories of the Virginia Polytechnic Institute, is as follows:

> No. 1322. Weathered diatomaceous earth from 7th street, near Richmond Locomotive Works, Richmond. This, after burning, closely resembles the diatomaceous earth from along the Rappahannock river, near Layton. It seems to be vitrified at cone *5* and at cone *8* is viscous.
>
> No. 1323. This sample was also collected from the same locality as No. 1322, but farther from the surface. It is quite impure, and shows a high air shrinkage. It burns red and becomes steel-hard at cone *05*. It is vitrified at cone *5*, and nearly viscous at cone *8*.
>
> No. 1358. Diatomaceous earth from along the Rappahannock river south of Layton. This burns fairly dense at the higher cones, and gives a clean color, but is quite porous at the lower cones.
>
> No. 1363. Diatomaceous earth from Wilmont. This burns to a very porous body as can be seen from the absorption figures. It has a low air and fire shrinkage.

It will be seen from an inspection of the chemical analyses (opposite page 175), that these earths show much variation in their chemical composition. All are quite siliceous, and one of them highly so. Nos. 1322 and 1323 represent the fresh and weathered parts respectively of the same bed. The weathered material is more siliceous and contains a lower quantity of fine particles and soluble substances, due probably to the leaching action of water filtering through it from the surface. The higher silica content seems also to affect its porosity and shrinkage in burning. It will also be noticed that the most siliceous one, namely, No. 1363 from Wilmont, is exceedingly porous after being burned.

Uses.—The chief use of diatomaceous earth is for polishing powders and scouring soaps. Its porous character renders it an excellent absorbent and it has been utilized to mix with nitroglycerine in the manufacture of dynamite. As a non-conductor of heat, it has been used for steam boiler packing, for wrapping steam pipes, and for fire-proof cement. It has also had a limited use in the preparation of the soluble silicate known as water-glass.

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2. CORUNDUM AND EMERY.

Corundum.—Corundum, the oxide of aluminum corresponding to the chemical formula Al_2O_3, has been noted in two counties in the crystalline area, east of the Blue Ridge. These are Louisa and Patrick. From the first of these, Louisa county, a large deep blue crystal of corundum was found some years ago by Mr. Louis Zimmer, in the soil, but the exact locality is not known.

Genth has described the occurrence of corundum in Patrick county, about 2 miles from Stuart, the county-seat, in mica schists on a knob of Bull Mountain. The mica schists are partly garnetiferous, and are intersected by granite. The corundum is found associated with andalusite, kyanite, chloritoid, and mica, in rough crystals and nodules up to 1 inch in length and half an inch in diameter. In color, it is grayish-white to white and colorless. It also occurs in finely divided microscopic grains in the mass of associated minerals. According to Pratt, the corundum of this locality is readily cleaned, and tests made for the cleaned product show that it is well adapted for the manufacture of the vitrified wheel.

Emery.—Emery, a granular corundum of black or grayish-black color, and containing intimately admixed magnetite or hematite, is found in considerable quantity about 1¾ miles west of Whittle station on the Southern Railway, in Pittsylvania county. It is found on the land of Keatts, Craddock, Hargrave, Nance and Yeates, but the only place where any attempt has been made to exploit it, is on the Keatts farm. Two openings about 300 feet apart and 20 feet deep have been made on apparently parallel "veins." Numerous smaller openings are made nearby. The rocks enclosing the emery are probably altered amphibolites or pyroxenites.

Miller describes the emery from the Pittsylvania locality as a black crystalline mass, magnetic, polar; with a specific gravity of 4.205, and a hardness of 8. An analysis of the emery gave Miller:

	Per cent.
Alumina	56.74
Ferric oxide	15.50
Ferrous oxide	20.77
Silica	0.68
Titanic oxide	1.86
Soda	3.95

Uses.—The principal use made of corundum is as an abrasive. The ruby and sapphire corundums are highly prized as gems.

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3. OCHER.

DEFINITION AND PROPERTIES.

As ordinarily used, the term ocher is applied to the earthy and pulverulent forms of the minerals, hematite and limonite (the anhydrous and hydrous oxides of iron, respectively), which are almost invariably rendered more or less impure through the presence of other metallic oxides and argillaceous or clayey matter. Ocher rarely occurs in nature sufficiently pure for immediate use, and it is usually necessary to prepare it by washing and grinding in order to free it from the common impurities.

Natural ochers show a variety of colors which depend in general upon chemical composition. Thus the hematites usually give ochers of red color, while the limonites give yellow or brown; each of these colors being subject to shade variations according to the amount and kind of impurities. More directly the natural colors of ocher depend on the degree of hydration and oxidation and the kind and amount of impurities. Both the red, yellow, and brown ochers are found in Virginia. According to their natural colors or sources, various varieties of ocher are distinguished.

ORIGIN AND OCCURRENCE.

The wide variation in the mode of occurrence of ocher in different localities indicates similar variation in its origin. Ocher may result from the leaching action of percolating waters and subsequent deposition; as residual products, formed by the removal on solution of the soluble parts of the original rock leaving the insoluble portions, clay and iron oxide, to form the different ochreous colored clays; from the decomposition of rocks rich in iron-bearing silicate minerals; from the oxidation of pyrite; from the alteration or decomposition of hematite; and from the alteration of the more compact forms of limonite. Lastly, as in the Cartersville district, Georgia, ocher may result from the molecular replacement of the rock in which the deposits are found.

DISTRIBUTION AND LOCALITIES.

Ocher of more or less purity is found, and to some extent has been mined, in each of the principal geologic divisions of the State, namely, the Coastal Plain, the Piedmont Plateau, and the Valley region. It has been mined at the following localities in Virginia: In the extreme eastern part of Chesterfield county, near Bermuda Hundred, on the Appomattox river; in the Little Catoctin Mountain, near Leesburg in Loudoun county; near Bedford City in Bedford county; in the vicinity of Marksville, in Page county; near Keezletown, in Rockingham county; from the western base of the Southwest Massanutten Mountain; and in Page and Rockingham counties along Naked creek, about 5 miles southeast of Shenandoah station on the Norfolk and Western Railway.

In addition to these, equally as good ocher deposits are found rather widely distributed over parts of the Valley and Piedmont regions, and to some extent the Coastal Plain, which have not been worked. In the Valley and Piedmont regions, the ocher deposits are frequently more or less closely associated with beds of iron ore. Deposits of ocher which vary from red, yellow, and brown in color, and which seem particularly promising but not yet developed, are found in Campbell and Bedford counties; near Bon Air, in Chesterfield county; near Fairfield, in Rockbridge county; near Waynesboro, in Augusta county; and near Roaring Run, in Craig county.

In his *"Reprint of the Virginias,"* page 49, Professor Rogers states that occasional layers of a beautiful yellow ocher are found with the beds of argillaceous clay of the Miocene in Tidewater, Virginia; and again on page 54, in the Miocene beds exposed along the Pamunkey river rests a thin ochreous clay as brilliant in its tint as the first chrome yellow. This ocher is of the most impalpable texture when dried, and would be found very valuable in coloring.

In Buckingham county, on Stonewall creek, near the Ross furnace, yellow ocher is reported by Professor Rogers in association with beds of iron ore, which occur in the micaceous and talcose schists. Also, it is found in similar association and traced for many miles southwestward from the furnace near New Canton.

DESCRIPTION OF INDIVIDUAL DEPOSITS.

Chesterfield County.

In the extreme eastern part of Chesterfield county, near Bermuda Hundred on the Appomattox river, an excellent grade of yellow ocher has been extensively mined. This bed of ocher is associated with the Tertiary clays and sands of the Coastal Plain.

The property was purchased in 1872 by the Bermuda Ocher Company of New York, which had an investment in the enterprise of $60,000.00 and employed a force of 40 men. The product was offered on the market in 1872 at 2¼ cents per pound in competition with the Rochelle ocher which was selling at 3¾ cents per pound. The effect of this competition was to further reduce the price of both ochers, that of the Rochelle ocher to 1¼ cents per pound in large lots, and that of the Bermuda ocher to 1⅛ cents per pound. The consumers freely admitted their preference for Bermuda ocher yet they insisted that it should be sold at a less price than the foreign article.

Volume XV of the Tenth Census for 1880, page 844, states that the Bermuda Ocher Company's mine produced in that year, 1,000 tons of ocher valued at $22,000.00; that the total number of hands employed was 30, and the total amount paid in wages was $10,500.00.

A writer in the Mineral Resources for 1885 says: "The crude ochre is washed, dried, and then ground into an article which in fineness of quality and in adaptation to all the purposes for which a light-yellow ochre is used, is unexcelled by that from any other deposit known in this country. Three grades are made, all of the same tint but of different degrees of fineness, namely, single washed, double washed, and extra floated. At the shipping point in Virginia these grades have a value, respectively, of $18, $21, and $27 per ton."

Loudoun County.

Beginning about 1 mile north of Leesburg, in Loudoun county, and traced for a distance of about 3 miles northward, ocher has been found at numerous points along the eastern base of Catoctin Mountain. Keith mapped and described these deposits in 1894 in the Harper's Ferry folio of the United States Geologic Atlas. He says:

"Ocher has recently been found at several points along the eastern base of the Catoctin Mountain in connection with the surface wash. The deposits occur beneath the surface of the peneplain at an elevation of about 350 feet. They are usually covered by a bed of gravel and sand from 2 to 8 feet thick, and lie under the bottoms and slopes where the mountain streams deposit their load of sand and gravel. The ocher appears to represent the iron taken in solution from the Catoctin schist and precipitated where it encounters calcareous solutions from the Newark conglomerate.

"The ocher thus far prospected is very fine and free from impurities. After the lighter part has been floated off, the small residue consists of grains of magnetite, ferric hydrate, and sand. The particles floated off are ferric hydrate and hydrates of alumina and magnesia. The natural colors of the ocher range from yellow into orange and gray; when mixed with oil, they change materially and give a great variety of reds, yellows, browns, and greens.

"In the same basins with the ocher, beds of reddle are developed, chiefly in the eastern part of the other areas. These are less unctious than the ocher, but very fine and tenacious. They are reddish-brown, and become darker when mixed with oil.

"The amount of the ocher deposits is apparently very great, though they have not been prospected over a wide area. Inasmuch as the streams and bottoms along Catoctin Mountain are similar to those already explored, it seems quite likely that most of them will be found to contain ocher. The depth of the ocher in the larger areas exceeds 30 feet."

Page County.

About 3 miles south of the village of Marksville, in Page county, and near the western base of the Blue Ridge, where the Shenandoah Valley Railway crosses Stony Run, ocher has been mined for some years. The Oxford Ocher Company of Detroit, Michigan, begun operations here on 30 acres of land, located on Stony Run, where the ocher was exposed in the bluffs along the stream. The company subsequently added 20 more acres. A plant for milling and preparing the ocher for market was built and, in 1876, 200 tons of ground ocher were shipped.

In 1877, the production amounted to 350 tons, and since then, about 1,000 tons per year have been produced. During the early years of mining, the product was hauled 18 miles in wagons to New Market and shipped over the Baltimore and Ohio Railway. Since then the ocher has been shipped from a nearer station on the Shenandoah Valley Railway.

The ocher is of very light brown color and occurs in the iron-bearing shales of Formation No. I, the Primordial (Cambrian) of Rogers. The deposit is an extensive one, as all the wells sunk between the company's mine and Marksville have gone through the ocher. It is of good quality and finds a ready sale.

Excellent ocher in the same geological horizon is reported further southwest along the western base of the Blue Ridge. According to Volume XV of the Tenth Census for 1880, 875 tons of ocher were produced in 1880, valued at $82,500.00. These mines are producing at present.

According to the Mineral Resources of the United States for 1885, an analysis of the ocher mined near Marksville in Page county, Virginia, gave:

	Per cent.
Iron peroxide	39.00
Alumina	15.00
Silica	33.00
Alkalies	.50
Water	11.50
Total	99.00

Rockingham County.

Along Naked creek, about 5 miles southwest of Shenandoah Station on the Norfolk and Western Railway, ocher occurs and has been mined, partly in Rockingham, and partly in Page county. The ocher occurs in the Potsdam (Cambrian) in close association with the brown iron ores worked by the Shenandoah Iron Company. The ocher beds are cut across by Naked creek which marks the boundary between the two counties. On the William Merica place in Rockingham county, both yellow- and orange-colored ochers occur. The ocher was first opened by the Virginia Mining and Manufacturing Company of Alexandria, and it was proposed that the crude ocher be shipped to Alexandria to be ground and prepared for market.

According to Volume XV of the Tenth Census for 1880, page 44, the production for the year 1880 was 112 tons, valued at $2,240.00.

Near Keezletown, in the same county and near the western base of Massanutten Mountain, brown ocher has been mined. The ocher at this locality was first operated by French, Richards and Company of Philadelphia. The ocher occurs near the contact of the Valley or Shenandoah limestone of Cambro-Ordovician age and the Hudson River slates of Ordovician age. It is of very fine texture, of brown color, and good body. An analysis by Professor J. L. Campbell dried at 212° F. gave:

	Per cent.
Ferric oxide	52.28
Manganese oxide	1.15
Clay with some sand	40.22
Water combined	6.35
Specific gravity	2.82

Augusta County.

Professor Fontaine has described in some detail the occurrence of several kinds of different-colored ochers on the Samuel Steele place, 2.5 miles a little northwest from the town of Waynesboro. The ocher occurs in the Shenandoah limestone of Cambro-Ordovician age, which rock is penetrated by a dike of diabase trending northeast-southwest and traceable for a considerable distance. Professor Fontaine says:

"A band of yellowish clay runs through Mr. Steele's land in a N. E. and S. W. direction following the strike of the strata as it seems, and forming apparently one of the more decomposable argillaceous layers interstratified with the limestone. The limestone next to this is, in places, very cherty and seems to have been disturbed. The clay is associated with a peculiar yellowish, to dark brown rock, that graduates from a nearly pure compact silica to an umber or ocher. Near Mr. Steele's house and for a short distance to the S. W., the rock is very siliceous and is accompanied by a dark to black wad of impalpably fine texture. This material seems to be composed of very fine manganese powder, clay, and iron, with some graphite. The manganese and graphite give its character to the rock. Sometimes it is purplish in spots, but the most of the mass is nearly black, or a very dark brown. It has a soapy or greasy feel, and clings most tenaciously to any object touched by it. The deposit of wad varies from 10-30 feet in thickness, and in length has been proved for several hundred yards, while in depth, the excavations show that it descends more than 30 feet. There is clearly an immense supply of it. Frequently lumps of manganese are found in it, sometimes as large as one's first.....The wad has been tried as a fireproof paint on boilers, and is reported to act finely. It mixes well with oil, and has so much "body," that little white lead is needed to mix with it: From all that I could see I consider this to be a valuable material, and I am surprised that it has not been utilized.

"A little to the N. E. of the deposit of wad, and apparently in the prolongation of it, we find no longer the wad, but the siliceous rock has become argillaceous, and decayed to a handsome ocher. This varies from a rich yellow to a dark brown. The dark brown ocher makes up much the larger part of the deposit. There are two beds of it lying in clay. The upper one shows a thickness of about 2 feet, and is separated from the lower one which is 3-4 feet thick, by 3 feet of clay. Some of this ocher is firm and looks like a rock, but it may be easily crushed. The yellow ocher occurs replacing a portion of the brown. Both of these appear to be suited for paint. This deposit of ocher appears to continue some distance to the N. E. and S. W. I was informed by Mr. W. B. Alexander that at Red Bank, about 7 miles N. E. of Waynesboro, and on a line bearing 40° E. of N. from Mr. Steele's place, similar brown and yellow ochers occur. Fauber's umber mine occurs some 4 miles to the S. W., in the prolongation of this line of deposits, and is, I think, the same material. There is little doubt that a series of ochers of various colors and excellent quality could be selected along the outcrops of this material. All of the ores and ochers thus far described, lie within a short distance of the Chesapeake and Ohio Railway, and the Shenandoah Valley Railway."

Rockbridge County.

According to Professor Fontaine, red ocher of good quality is found a half mile from the village of Fairfield in Rockbridge county. He describes it as being very fine-grained, rather firm in texture, decidedly gritty in feel, and most tenacious in its coloring properties. It is found on the land of Major DeVines and is reported in large quantity but has not been developed.

Warren County.

In Warren county, about a half mile east of the Shenandoah Railway, umber has been opened up near Major Overall's house. Tests are reported to have indicated an excellent grade of material. McCreath gives the following chemical analysis of it:

	Per cent.
Silica	31.640
Alumina	13.510
Ferric oxide	34.000
Manganese sesquioxide	6.209
Lime	.720
Magnesia	1.657
Alkalies and undetermined	3.390
Water	8.870

McCreath reports about 100 tons of the umber shipped to Pennsylvania markets prior to 1884.

Uses.

The principal use of ocher is in the manufacture of paints for exteriors of buildings, the rolling stock of railways, bridges and metal roofing. They are used as a pigment for coloring mortars and in the manufacture of linoleums and oil-cloths. They have been used to produce desirable colors in earthern ware when mixed with a certain proportion of manganese oxide. In addition to these, there are certain minor very limited uses made of ocher.

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4. ILMENITE; MENACCANITE; OR TITANIC IRON.

Ilmenite or menaccanite, known as titanic iron ore, is an opaque, iron black mineral, having submetallic luster and differing from magnetite, which it resembles, by its crystalline form and weak magnetic properties.

The mineral occurs in granular form admixed with white apatite in extensive dike-like masses near Roseland and Bryant, in Nelson county, and about 4 miles east of Roanoke, in Roanoke county. The rock occurring at the above localities and composed of the two minerals, apatite and ilmenite, is described at more length under Phosphates, on pages 300-302. For location of the Nelson county ilmenite deposit, see map, figure 38.

The mineral ilmenite though abundant and cheap has as yet proved of little economic importance. Should the mineral find an extensive use in the future, the Virginia localities noted above will prove to be of considerable commercial importance.

5. RUTILE.

GENERAL PROPERTIES AND OCCURRENCE.

Rutile is a titanium oxide corresponding to the formula TiO_2 and containing theoretically 60 per cent. of titanium. It has a hardness of 6 to 6.5; specific gravity 4.18 to 4.25; metallic adamantine luster, and is generally opaque, rarely transparent. Its usual color is reddish-brown to red and it is insoluble in acids and is infusible. It occurs chiefly in the older crystalline granitic rocks, schists and gneisses, but it is also found in metamorphic limestones and dolomites.

DISTRIBUTION.

The only locality in Virginia and indeed in the southeast Atlantic states where rutile has been mined is near Roseland, Nelson county, about 7 miles northwest from Arrington, a station on the Southern Railway. (Map, figure 38.) The deposit lies on both sides of Tye river near

Roseland post-office, and is owned and operated by the American Rutile Company. The entire limits of the deposit are yet unknown but comprise several hundred acres at least on both sides of the river. The country rock is a pronounced foliated gneiss, penetrated by an occasional diabase dike.

Nelsonite Rutile

Fig. 38.—Map showing location of rutile and Nelsonite (phosphate rock) in Nelson county. Based on the topographic sheets, U. S. Geol. Survey. Scale, ½ inch = 1 mile. Contour interval, 500 feet.

[illegible]

[illegible] present. [illegible] largest [illegible] primary [illegible] The [illegible] large [illegible] and [illegible]

[illegible] and [illegible] millimeters [illegible] through the [illegible] also [illegible] in the [illegible] through the [illegible] considerable [illegible] up to 15 per cent. [illegible] per cent. in the [illegible] the rutile is [illegible] with ilmenite, which is [illegible] from the rutile by the present methods of [illegible] the company.

[illegible] very large quantity in [illegible] made in the [illegible] bounding the [illegible] and [illegible] the ore was shipped to [illegible] a large and commodious mill was [illegible] for concentrating the ore.

[illegible] PROCESS

[illegible] The ore [illegible] weighing 750 pounds each. [illegible] the ore goes to [illegible] According to the [illegible] per cent. rutile. The [illegible] sacked in double sacks in [illegible] of the milled product are [illegible] averages from 90 to 95 per cent. [illegible] per cent. of rutile.

Uses

[illegible] of excellent quality, being very [illegible] yet limited. For the present uses made of [illegible] These include a limited quantity [illegible]

Fig. 1.—View showing method of side-hill cut mining of rutile along Tye river, near Roseland, Nelson county.

Fig. 2.—Same as Fig. 1, but taken from a different place in the area.

RUTILE OPENINGS, ROSELAND, NELSON COUNTY, VIRGINIA.

alloys and certain grades of steel, for the manufacture of artificial teeth, and of porcelain ware, serving in both as a pigment. Up to the present time, the demand for rutile in the United States has not exceeded 200 to 300 pounds annually. The Nelson county plant is capable of producing from 1,000 to 2,000 pounds per day.

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6. MANGANESE OXIDES.

INTRODUCTION.

Elementary manganese is found in nature in the form of oxides, carbonates, and silicates. Of these, only the oxides are of importance in Virginia. The principal known oxides are, pyrolusite, (MnO_2); psilomelane, (H_4MnO_5); hausmannite ($MnO.Mn_2O_3$); braunite ($3Mn_2O_3.MnSiO_3$); polianite (MnO_2); manganite ($Mn_2O_3.H_2O$); and wad, probably an impure earthy form of psilomelane. Except when well crystallized, it is often difficult to discriminate between the different oxides, as they are found admixed in nearly all proportions. Usually the well-defined species can be separated from one another by their physical and chemical properties as tabulated below:

Species	Hardness	Specific gravity	Color	Streak	Anhydrous or hydrous
Pyrolusite....	2-2.5	4.73-4.86	Iron black to steel gray	Black or bluish black	Anhydrous
Psilomelane..	5-6	3.7 -4.7	Iron black to dark steel gray	Brownish black	Hydrous
Manganite...	4	4.2 -4.4	Dark steel gray to iron black	Reddish brown to nearly black	Hydrous
Polianite....	6-6.5	4.99	Light steel gray	Black	Anhydrous
Braunite...	6-6.5	4.75-4.82	Brownish black to steel gray	Same as color	Anhydrous
Hausmannite	5-5.5	4.856	Brownish black	Chestnut brown	Anhydrous

separated, but they usually occur admixed in varying proportions. The ore is usually partially or entirely crystalline, of a dark steel-blue color, and the nodular type, which prevails nearly always, displays the complete or partially layered or concentric structure of concretionary masses.

THE COASTAL PLAIN REGION.

Manganese has been found in small pockets at several localities in the Virginia Coastal Plain area. Near City Point, in Prince George county, a deposit of manganese was worked which produced some hundreds of tons of ore before it was exhausted. Other deposits are reported to have been worked. It is not improbable that other deposits of small extent and similar to those mentioned above will be found in parts of the Coastal Plain area, but deposits of the extent of some of those worked in the Piedmont and Valley provinces of the State, cannot be expected in the Coastal Plain area.

THE PIEDMONT REGION.

Introduction.

The rocks of this area are crystalline schists, gneisses, and granites. They are derived in part from original sedimentary, and in part from original igneous, masses, by metamorphism. Manganese-bearing minerals, principally silicates, frequently enter into the composition of the metamorphic crystalline rocks of the Piedmont region which, when broken down by atmospheric decay, the manganese is liberated in simpler chemical form, usually the oxide, and is concentrated in the residual clays derived from the rocks through chemical and physical means, sufficient to afford workable deposits of manganese.

Because of the widespread occurrence throughout Piedmont Virginia, of rocks composed in part of manganese-bearing minerals, manganese is likely to exist, to some extent, in the residual clays derived from these rocks over much of the area, but not necessarily in sufficient quantity and concentration to be always workable. Workable deposits of manganese ores of good quality are found in the following counties of the Virginia Piedmont province: Albemarle, Amherst, Appomattox, Buckingham. Campbell, Nelson. Pittsylvania, and Spottsylvania. In some of these, mines yielding a large production of manganese ores have been operated for many years.

DESCRIPTION OF INDIVIDUAL AREAS.

Amherst County.

At Stapleton Mills in the southern part of Amherst county a manganiferous iron ore is found, which has been mined only to a limited extent. As indicated by the analysis below the quality of this ore is such that the deposit merits more serious consideration than it has apparently had. The quality of the ore is shown in the following analysis quoted by Weeks in the Mineral Resources of the United States for 1885.

	Per cent.
Manganese (metallic)	34.56
Iron (metallic)	22.57
Phosphorus	.08

Another deposit of manganese is reported from Walker's Ford Station, in Amherst county, but, so far as known, it has not been developed.

Appomattox County.

Deposits of good manganese ores are known to occur in Appomattox county, but, so far as the writer is aware, they have received little or no attention. Southeast of Mount Athos in the vicinity of Concord, several recent openings have been made exposing good ore. Froehling and Robertson report the following results on analysis of two samples of ore from these openings:

	I Per cent.	II Per cent.
Manganese (metallic)	66.60	52.92
Iron (metallic)	.28	2.53
Phosphorus	.174	.002
Silica	.99	10.53

Buckingham County.

Deposits of manganese ores are reported in Buckingham county in the vicinity of Willis Mountain and Spiers Mountain. No developments have been made, but good surface indications are present in these localities.

Campbell County.

In the northeastern and the middle western portions of Campbell county, near Mount Athos, Evington, and Lynch's to the east and south of Lynchburg, respectively, large deposits of manganese ores have been worked for many years. The principal mines operated in the county are the *Piedmont Manganese Company's mine* (formerly known as the *Lerner mine*) and the *Leets mine* near Mount Athos, the *Saunders mine* near Evington, and the *Bishop mine* near Lynch's. In 1883, a small pocket of manganese ore was opened at Leesville in the vicinity of Lynch's, which is reported to have yielded about 30 tons of ore. Prospecting for manganese ore has been in progress during the year near Lynchburg and Evington, with encouraging results at both places, and preparations are now being made to mine the ores.

The *Leets mine* is located about 7 miles east of Lynchburg and about 1.5 miles south of Mount Athos, a station on the James river at the crossing of the Norfolk and Western and the Chesapeake and Ohio railroads. Its production of high grade ores has been very large, probably ranking next to the Crimora mines, in Augusta county, in quality and quantity of ore produced. The ore is of the nodular or kidney type. The individual nodules show considerable variation in size and shape, and are generally assembled in the form of nests and pockets in a residual clay derived from a dark-colored micaceous schist. The ore is associated with iron. Analyses of the ore from this mine gave the following result:

	I	II	III
	Per cent.	Per cent.	Per cent.
Manganese (metallic)	43.58	45.87	44.18
Iron (metallic)	5.24	5.34	6.64
Phosphorus	.316	.257	.274
Silica	7.15	7.77	7.73

Ore of much better quality than is indicated in the above analyses was mined; and during the early period of mining the ore was of such superior quality that most of it was shipped to England for use in chemical purposes. Weeks gives the following annual production of ore from this mine, from 1880 to 1885, inclusive:

Year	Long Tons
1880	104
1881	50
1882	130
1883	40
1884	76
1885	500

The *Piedmont Manganese mine* is located about 8 miles east of Lynchburg. It was formerly known as the Oxford Furnace Tract and was worked by the Lerner Mining Company, which mined from 2,000 to 3,000 tons of ore. The Piedmont Manganese Company recently acquired the property and is actively engaged in mining the ore on a large scale. Mining has reached a depth of about 75 feet with no indications of the ore giving out. The ore is of excellent grade as shown in the analyses given below, and it is suitable for chemical, steel, and brick manufacturing purposes.

Analyses of the ore kindly furnished me by the President, Mr. D. W. Meyers, and made by Ricketts and Banks, are:

	Per cent.	Per cent.
Manganese (metallic)	54.50	50.18
Iron (metallic)	2.70	——
Silica	4.00	8.58
Phosphorus	.25	.15
Sulphur	.03	——
Water	——	6.26

The analysis in column II was made from average samples of a car of lump ore, which was poorly washed, and the sample dried at 212° F. A large mill is operated at the mines, equipped with all necessary machinery for grinding and preparing the different grades of ore for the market.

At Lynch's, a station on the Southern Railway, the *Bishop mine* produced 13 tons of manganese ore in 1885, which was shipped to England. The ore was of the same general character and quality as that mined at the *Leets mine* near Mount Athos, and the two mines were operated by the same party.

The *Saunders mine,* located about 1 mile east of Evington, a station on the Southern Railway, may be taken as a typical example of the manganese mines in the crystalline area or Piedmont Virginia. This mine was first worked about 20 years ago and it has yielded to date a total production of between 6,000 and 7,000 tons of ore. The rocks strike N. 30° E. and dip 65°-74° S. 60° E. The main rock is a thinly foilated mica schist composed largely of mica. The underlying rock on the northwest side, locally called "foot-wall," is a quartzite more or less schistose. The manganese ores occur in the residual clay derived from the decay of the mica schist. This decay is usually yellowish in color, often red, and at times is of lighter hues. The ore occurs in the form of irregular pockets, stringers, and reniform-shaped nodules. Also, it is found as stringers and thin sheets or crusts filtered in and downward along the foliation planes of the schist. Only the oxides occur, pyrolusite and psilomelane. It is partly crystalline and of excellent grade.

The property has been extensively developed by shafts, tunnels and open-pits. The greatest depth reached in mining will not exceed 150 feet, and the main tunnel, which produced large quantities of excellent ore, is

900 feet in length. This tunnel was begun a few feet above local stream level and driven from the base of and directly into a prominent northeast-southwest trending ridge.

On Wiley's Mountain, about 1¾ miles N. 80° E. of Evington, manganese ores have been worked by shafts and open-pits to a limited extent. The first work was done about 25 years ago and a shaft 105 feet deep was operated. In the valley adjacent to Wiley's Mountain on the northeast, a small amount of manganese ore has been mined on the Phillips, Martin, and Mortimer places. Some recent prospecting has been done on Wiley's Mountain, and the occurrence of the ore is quite similar to that described above at the *Saunders mine.* It is found in mica schist decay confined between two schistose quartzite bands. Strike of the schists is N. 40° E., dip N. 70° W. Other recent prospecting has been done on some of the adjacent ridges with, in some instances, encouraging results.

Nelson County.

In past years, several deposits of manganese ores have been somewhat extensively worked in Nelson county, although the ore is not mined to the writer's knowledge at any point in the county at present. The ore occurs in the southeastern portion of the county, located about 2 miles north of the James river, and in the vicinity of Warminster, and Midway Mills, stations on the Chesapeake and Ohio Railway. The occurrence of the ores is in the form of pockets in the residual clays of the crystalline schists. Four mines have produced considerable ore. These are the *Cabell, Bugley, Simpson,* and *Davis.* The *Cabell mine,* located within two miles of Warminster, has not been worked since 1871. In 1868 and 1869, 5,000 tons of ore were mined and shipped to New Castle-on-Tyne. A reported analysis of this ore shows 82.25 per cent. of manganese peroxide. Two other analyses of ore from this mine are reported by Weeks in the Mineral Resources of the United States for 1885 as follows:

	Per cent.	Per cent.
Manganese (metallic)	43.30	43.02
Iron (metallic)	3.67	4.24
Phosphorus	.243	.182
Silica	17.45	18.51

The *Bugley mine,* located about a half mile southwest of the *Cabell,* was worked about the same time and is said to have yielded about 2,000 tons of ore.

Southwest of Warminster, at Midway Mills, the *Simpson mine* was worked in 1882, which produced about 12,000 tons of high grade ore, shipped to Liverpool, England. The mine was developed by a shaft 150 feet deep which had to be abandoned on account of flooding from water. The grade of ore is reported as having improved on depth; that above the water-level yielded 70 per cent. of manganese oxide, and that below the water-level gave 80 to 85 per cent.

The *Davis mine,* operated in the early eighties, is said to have produced 1,000 tons of ore. Weeks quotes the following analysis made of a selected sample of this ore:

	Per cent.
Manganese dioxide	90.42
Iron sesquioxide	2.24
Alumina	1.13
Lime	1.22
Magnesia	2.28
Silica	1.12
Phosphoric acid	.43
Water	1.25
Manganese (metallic)	57.16
Iron (metallic)	1.56
Phosphorus	.188

An analysis of manganese ore from Monticello gave Mr. Charles Catlett:

	Per cent.
Manganese	46.99
Iron	2.60
Phosphorus	0.464
Sulphur	0.21
Silica	1.68

Pittsylvania County.

Deposits of manganese ores are known at several points along the Southern Railway in Pittsylvania county, but no attempt at mining them has yet been made. About one-quarter of a mile from the Southern Railway and on Roanoke river, in the northern part of the county, a deposit of manganiferous iron ore is found, samples of which gave on analysis:

	Per cent.	Per cent.
Manganese (metallic)	24.78	27.86
Iron (metallic)	29.86	28.14
Phosphorus	.362	.347
Silica	7.02	4.32

Recent openings in this vicinity indicate a good deposit of high grade ore. Other localities where manganese ores exist are in the vicinity of Sycamore and Toshes, stations on the Southern Railway. No developments have been made and the extent and quality of the ore are unknown.

THE APPALACHIAN MOUNTAINS REGION.

Introduction.

Under this division is included all those counties lying west of the Blue Ridge and embracing the Valley proper, and the area west of the Valley known as Appalachia. The principal sources of manganese ores produced in Virginia, and indeed in the United States, have been from the mines of the Valley region of Virginia, also known as the Shenandoah Valley. The principal manganiferous ore belt of this region lies along the western base of the Blue Ridge and on the eastern side of the Valley. This belt has a length of 300 miles in Virginia, and workable deposits of manganese have been found in each of the 12 counties bordering on the western base of the Blue Ridge.

Along this belt are found the large bodies of iron ore which are associated with the so-called Potsdam, or formation No. I of Rogers, and the ores of manganese are associated with those of iron. The manganese ores are usually found embedded in residual clays derived by decay from Cambrian ferriferous shales, which overlie the Potsdam quartzite. In other places over the Valley region, manganese ores occur similarly embedded in residual clays derived from limestone. Manganese and manganiferous iron ores are also found in this region associated with other rocks than those of the Potsdam and the Cambro-Ordovician limestones; especially have they been noted in the basal member of the Devonian, the Oriskany.

Located in the Valley region of Virginia is the famous Crimora mine of Augusta county, which has produced more ore than all other mines in the United States combined. The principal operations in the Valley province are described below by counties.

DESCRIPTION OF INDIVIDUAL AREAS.

Page County.

On the lands of the Shenandoah Iron Company near Milnes, a station on the Shenandoah Valley railroad, a large quantity of manganiferous ores were mined as early as 1884. In 1884, 208 tons of manganiferous ore were shipped from these mines, and in 1885 the production amounted to 2,155 tons. Weeks gives the average of analyses of these ores to be:

	Per cent.
Manganese (metallic)	28.00
Iron (metallic)	17.00
Phosphorus	0.15

The ore is associated with brown hematite in a wash deposit that is irregular and uncertain. Specimens of ore, collected by Mr. McCreath from a deposit on the Garrison tract, the top of which is described as a fine ore, but becoming coarser and harder on depth, gave the following results on analysis:

	Fine Ore. Per cent.	Lump Ore. Per cent.
Manganese (metallic)	52.691	53.656
Iron (metallic)	2.325	1.537
Phosphorus	0.324	0.237
Silica	2.795	1.955

Three miles east of Milnes station, a manganiferous iron ore has been worked at the *Kimball mine.* This is developed by 2 openings known as the Atwood and the Bolan, the largest proportion of manganese being found in the Atwood opening. According to Weeks, a mixed sample of the ores from 2 openings, in the proportion of two-thirds from the Atwood and one-third from the Bolan, gave on analysis:

	Per cent.
Iron (metallic)	40.857
Manganese (metallic)	7.349
Phosphorus	0.084
Siliceous matter	15.440

Weeks quotes a second analysis of the ore made by Bowron as follows:

	Per cent.
Iron sesquioxide	70.00
Manganese oxide	13.31
Phosphorus	trace
Silica	4.73
Alumina	0.86
Water	11.03

Mr. E. A. Schneider reports the following analysis made of manganese ore from the Round Head tract, near Marksville:

	Per cent.
Manganese	51.46
Iron	2.94
Phosphorus	0.23
Silica	4.17
Water	4.97

Two miles southwest of Marksville good surface indications of manganese occur over a considerable area. A sample of the ore was analyzed by Booth, Garrett and Blair with the following results:

	Per cent.
Manganese (metallic)	49.613
Iron (metallic)	1.050
Phosphorus	0.310

Augusta County.

This is the most important manganese producing county in the country, because largely of the famous Crimora mines, which have produced more ore than all other mines in the United States combined. Numerous other mines have been operated in Augusta county, which have been opened up near and along the Shenandoah division of the Norfolk and Western Railway, near Lyndhurst, Stuart's Draft, Vesuvius, and Waynesboro.

The most important mine in this county and indeed in the United States, is the *Crimora,* located 2.5 miles southwest of Crimora, a station on the Shenandoah railroad, with which it is connected by a branch road. A stock company bought the land containing this mine in 1867 and mining was continued until 1869, when it was alternately idle and worked until 1882. In 1882, the mines were leased and systematic production of ore on a large scale was begun. The ore is localized in an elliptical-shaped basin about 500 feet wide and 800 to 900 feet long of Potsdam quartzite, which is a very hard and dense, light-colored rock.

Figure 40 shows the ground plan of the immediate vicinity of the mine. Figure 41 represents cross-sections along the lines marked in figure 40. On the east side the quartzite dips to the westward along the line AA in figure 40. CC marks the position of an anticline the beds of which dip both toward the west and the east, forming a syncline to the east, the axis of which is indicated by the line BB.

The basin is filled with a clay derived by decay from an overlying Cambrian shale. The clay has been preserved from erosion through sharp synclinal folds. The ore, which is largely psilomelane, is irregularly assembled in the clay in the shape of nodular lumps and masses from the size of a small pebble to those weighing a quarter of a ton or more. In places, the ore seems to be distributed through certain layers of the clay more than through others, but, wherever found, its distribution is irregular and it does not conform to the bedding. The mine is shown in plate XXXVII, figure 2.

The clay filling the basin, through which the ore is distributed, is covered with a variable depth of drift, derived by wash from the adjacent mountain slope. This drift is composed of admixed clay and large and small quartzite fragments, and has a probable depth of 15 feet, which requires to be stripped from the ore-bearing clays underneath, before working. In color, the ore-bearing clay is yellow, buff, and of lighter

Fig. 1.—View of the Crimora manganese milling plant, Augusta county, Virginia.

Fig. 2.—Crimora manganese mines, Augusta county, Virginia.

CRIMORA MANGANESE MILLING PLANT AND MINES.

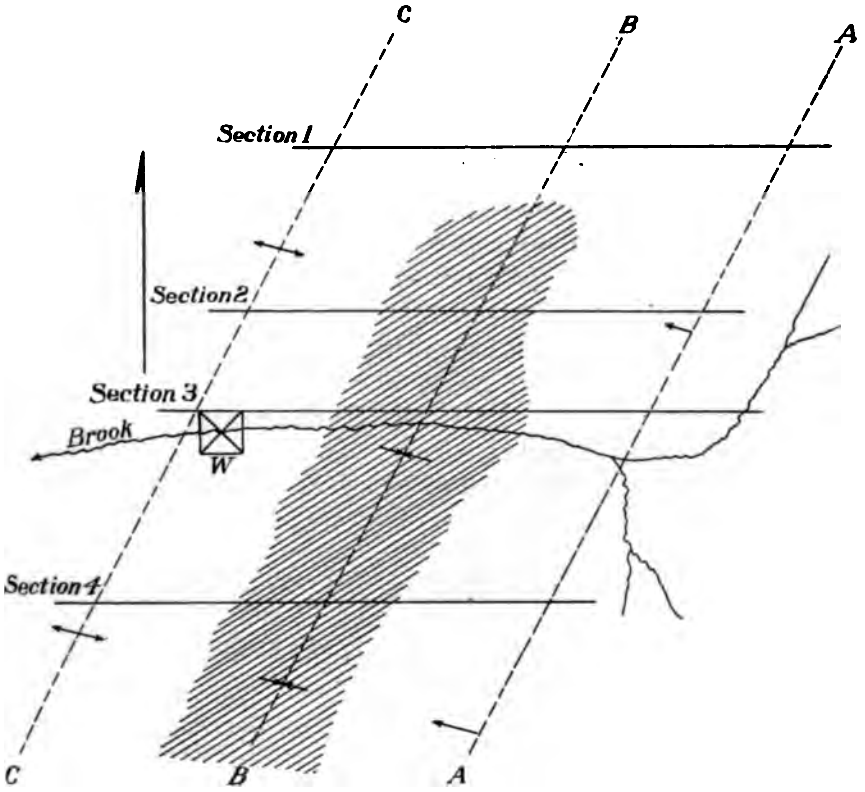

Fig. 40.—Ground plan of manganese deposits, Crimora. (After C. E. Hall.)

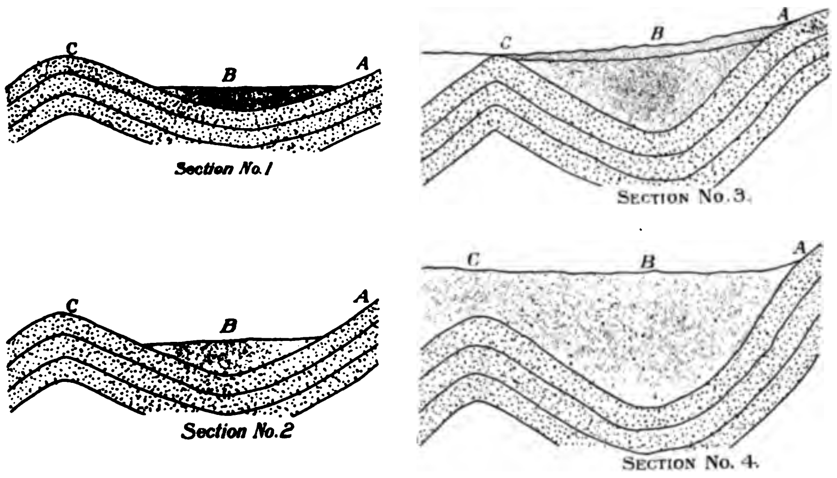

Fig. 41.—Sections through Crimora manganese deposits. (After C. E. Hall)

shades. The ore is further assembled in this clay in the form of nests, pockets, and stringers, which may or may not be connected.

The ore is principally psilomelane, with some pyrolusite, and wad. Quite a good proportion of it is crystalline in texture. A commodious mill for preparing the ore for shipping is operated at the mine and is shown in plate XXXVII, figure 1. At present, about 15 per cent. of the ore requires jigging and practically all of it is washed to free it from adhering clay. The ore, mined to date, will probably average 48 per cent. of metallic manganese, 1.5 to 2 per cent. metallic iron, phosphorus 0.05 per cent., and silica 7 to 8 per cent. The ore is characterized by uniformly low phosphorus, the highest not exceeding .112 per cent. In the jigged ore, silica will give a higher average than quoted above, sometimes exceeding the limit, 10 per cent.

McCreath gives the following complete chemical analysis of lump manganese ore, comprising 228 pieces from which the sample was prepared, from the Crimora mine:

	Per cent.
Binoxide of manganese	81.703
Protoxide of manganese	7.281
Sesquioxide of iron	.533
Cobalt oxide	.354
Nickel oxide	.096
Zinc oxide	.623
Alumina	.896
Baryta	.829
Lime	.880
Magnesia	.630
Phosphoric acid	.171
Alkalies	.467
Water	3.405
Silica	2.132
Manganese (metallic)	57.291
Iron (metallic)	.373
Phosphorus	.075

Weeks reports the following analyses of manganese ore from the Crimora mines:

	Per cent.	Per cent.	Per cent.	Per cent.
Manganese (metallic)	48.530	50.541	48.162	44.541
Iron (metallic)	1.985	1.957	4.568	3.263
Phosphorus	0.103	——	0.095	0.087
Silica	10.20	10.12	10.30	14.00

According to McCreath an analysis of the best grade of ore from the Crimora mine gave as above:

	Per cent.
Manganese (metallic)	57.291
Iron (metallic)	.373
Phosphorus	.075

Fifty-six acres of ground have been tested by 700 drill-holes put down to a depth of 150 feet. The underlying quartzite is reached by drilling at a depth of 212 feet. The greatest depth reached in working the ore is 198 feet. The total area of worked ground is about 12 acres. Of this acreage, the American Manganese Company worked about 8¼ acres; the additional 3 acres have been worked by the Crimora Manganese Company of New Jersey, which is operating at present. The worked area has been stripped to a considerable depth and is further developed by numerous pits, entries, and shafts.

Adjoining the Crimora mine on the south, is the mine of the *Old Dominion Manganese Company*. A number of openings were worked many years ago close to the line of the Crimora mine, but these are now entirely filled in and hardly any indication of them remains. A shaft has recently been sunk in a reef of hard quartzite near the old openings and near the line, from which both the Crimora Manganese Company and the Old Dominion Manganese Company are working. The former company is operating a drift from this shaft at the 186-foot level which passed through 2,800 feet of the quartzite before penetrating the clays. The Old Dominion Manganese Company is operating a drift from the same shaft at the 176-foot level.

In 1859, Sibert opened a mine on Bear creek, 2 miles southeast of Lyndhurst station, and close up to the western base of the Blue Ridge. A shaft was sunk which struck the ore at a depth of 45 feet. A drift 20 feet long was run from the bottom of the shaft and it is reported that 250 tons of ore were mined from the drift and shaft and shipped to London. Analyses of the ore taken from this mine made by J. Blodgett Britton, gave:

	Per cent.	Per cent.
Manganese peroxide	93.06	86.77
Iron peroxide	trace	2.98
Silica	.18	3.98
Alumina	.91	2.81
Baryta	2.81	.31
Water	2.75	2.93

A new shaft was sunk in 1885 and 1886.

Manganese ores were mined by Sibert before the War on the *Kennedy tract* at the foot of the Western Blue Ridge, 3 miles from Stuart's Draft, a station on the Shenandoah Valley railroad. It is reported that 100 tons of ore were mined here in 1859. Both manganese and manganiferous iron ores are reported on this property. An analysis of the manganese ores made by Professor F. P. Dunnington from the *Kennedy tract* gave:

	Per cent.
Manganese (metallic)	43.30
Iron (metallic)	3.88
Sulphur	.083
Phosphorus	.52
Barium	6.93
Silica, water, etc	17.69

Manganese and manganiferous iron ores have been mined from a number of places in the vicinity of the old Cotopaxi and Vesuvius furnaces, near the line between Augusta and Rockbridge counties, and close to the Shenandoah Valley railroad. The principal mines are, the *Blue, Fauber, Newton, Kelly,* and several others, on Big Mary creek. It is reported that Sibert mined 75 tons of nodular masses and lumps of psilomelane at the *Fauber mine.* Weeks reports an analysis made by McCreath of a sample of ore comprising 143 pieces, taken from along the face of the open-cut at the *Newton mine,* as follows:

	Per cent.
Iron (metallic)	41.125
Manganese (metallic)	8.221
Phosphorus	.265
Siliceous matter	14.830

The *Kelly mine* is in Rockbridge county and is a part of the old Vesuvius furnace property. Both iron and manganiferous ores are found, the latter occurring nearer the Potsdam than the former.

In the summer of 1906, the *Raymond Mining Company* was operating a property 4 miles east of Stuart's Draft on the Shenandoah Valley railroad. Manganese mining near Lyndhurst station was also in progress in 1906 by Kendall and Flick.

The above mines at Vesuvius and Lyndhurst have recently been acquired by the *Manganese Corporation of Virginia* and preparations are being rapidly made for the extensive mining and shipping of ore. The ore is reported to be of excellent quality, that from the *Vesuvius mines* showing from 45 to 47.72 per cent. manganese, and as low as 0.065 per cent. of phosphorus.

Rockingham County.

In 1894, the *Kendall and Flick mine,* near Elkton, in Rockingham county, is reported to have produced the largest amount of ore in the State. The production is given at 1,190 tons and the ore averaged from 48 to 49 per cent. of metallic manganese. It contained a small excess of silica but was within the limits in phosphorus. This mine continued operations in 1895 but is not now producing. An analysis of the ore gave:

	Per cent.
Manganese (metallic)	48.25
Iron (metallic)	2.70
Silica	10.50
Water	4.00

Professor F. W. Clarke reports the following analysis of manganese ore from the *Church Mountain mine.* A noteworthy feature is the high cobalt:

	Per cent.
Insoluble matter	22.11
Iron and aluminum oxides	5.14
Manganese	39.20
Cobalt	2.48
Ignition	11.30

Manganese ores, analyzed by Mr. Charles Catlett, from near Elkton, Rockingham county, gave:

	Per cent.	Per cent.	Per cent.
Manganese	43.94	49.66	48.75
Iron	3.43	8.53	2.79
Phosphorus	0.166	0.076	0.085
Sulphur	0.07	0.089	trace
Silica	15.88	1.80	15.08

Botetourt County.

The most extensively worked manganese mine in Botetourt county is the *Houston,* located about 1 mile from Houston, a station on the Shenandoah Valley railroad. The manganese deposits at this mine are situated well up on the west slope of the Blue Ridge at an elevation of about 400 feet above the drainage level of the surrounding country. Manganese ores are here found over a distance of nearly 1 mile extending in a N. 35° E. direction. Many openings have been made from which large quantities of ore have been taken. The rock associations here are apparently the same as those described above at the Crimora mine in Augusta county. The rock underneath the clays is the Potsdam quartzite.

The ore comprises manganiferous iron and manganese in close association. In the eighties, the *Houston mine* was the principal producer of manganiferous iron ores in Virginia. The manganese ores occur in a tough yellow clay assembled as nests and pockets, which yielded in some cases 100 to 150 tons of high grade ore in lumps the size of an egg and smaller, and sufficiently clean to require no washing. The pockets of manganese ore are sometimes found next to the iron ore. According to Weeks a selection of 115 pieces representing the iron ore, and 68 pieces representing the manganese ore, gave McCreath on analysis:

	Iron Ore. Per cent.	Manganese Ore. Per cent.
Manganese (metallic)	7.277	44.312
Iron (metallic)	47.150	12.325
Phosphorus	.061	.101
Siliceous matter	8.030	5.470

A selected sample of the manganese ore from the same mine gave:

	Per cent.
Manganese (metallic)	59.870
Iron (metallic)	.500
Phosphorus	.049
Silica	2.300

The production of ore from this mine for the years 1883 to 1885, inclusive, was 4,810 long tons proportioned as follows:

	Long tons.
1883	2,900
1884	828
1885	1,082

An analysis of manganese ore on the *Champman property* south of the Houston mines gave:

	Per cent.
Manganese (metallic)	45.80
Iron (metallic)	3.06
Phosphorus	.164

Frederick County.

The *Paddy Mills manganese mine* in the southwest corner of Frederick county has produced about 2,000 tons of manganese ore, mined mostly before the War. The mine occupies a conical-shaped hill about a square mile in area and rises to an elevation of about 150 feet above the drainage level of the surrounding country. The ore is pyrolusite associated with limestone. It averages about 50 per cent. metallic manganese, 4 per cent. metallic iron, and from .09 to .10 per cent. phosphorus. The greatest depth reached in mining is 50 feet.

Shenandoah County.

Manganese ores were somewhat extensively worked and shipped before the War at Van Buren furnace, in Shenandoah county. The ore is reported as having occurred in pockets that were more or less continuous and could be traced on the surface for a distance of more than 3 miles. The principal mine was located at the western end of Cupola Mountain, although good indications are reported in the broken hills to the southwest of this mountain. The washed ore is reported to have analyzed upwards of 70 per cent. manganese oxide.

At Powell's Fort on the northeast Massanutten Mountain, in Shenandoah county, manganese ores were mined at different times for many years. More than 1,000 tons of ore were shipped from this property prior to 1886. It was developed by 3 or more shafts of considerable depths. The ore is described as being remarkably clean; almost entirely free from foreign matter, and is a good grade of soft crystallized pyrolusite. According to Weeks, analyses of the ore yielded J. B. Britton 94.30 per cent. of manganese oxide in one sample, and 60.66 per cent. metallic manganese in another sample. A sample of ore taken from the mine of the *Manganese and Iron Company's property* was analyzed at the laboratory of the Albany and Rensselaer Iron and Steel Company, Troy, New York, with the following results:

	Per cent.
Manganese	59.302
Iron	0.844
Phosphorus	0.190
Silica	1.500

An analysis made of a specimen of manganese ore from Powell's Fort, east end of Massanutten Mountain, Warren county, gave Mr. Charles Catlett:

	Per cent.
Manganese	48.59
Iron	3.07
Phosphorus	0.349
Sulphur	0.12
Silica	9.20

Rockbridge County.

On Guy Run, about 6 miles south of Goshen, a station on the Chesapeake and Ohio Railway, an extensive deposit of manganese associated with iron has been worked at several different times. The manganese ores are embedded in clays in the form of pockets and are found in close proximity to the brown iron ores of the Oriskany horizon. An analysis of the manganese ore from this locality gave:

	Per cent.
Manganese (metallic)	64.59
Iron (metallic)	3.01
Phosphorus	.55

An analysis of manganese ore by Chatard from Harts Bottom gave:

	Per cent.
Manganese	41.59
Iron	2.18
Phosphorus	0.22
Sulphur	0.12

Other Valley Deposits.

Along the Cripple Creek extension of the Norfolk and Western Railway, numerous openings are made in Pulaski, Wythe, and Smyth counties, from which manganese and manganiferous iron ores have been mined.

Four miles east of Radford furnace, in Pulaski county, on Mack's Mountain, manganese ore associated with brown iron ore, occurs. An analysis made of a sample of 132 pieces of the ore by McCreath gave:

	Per cent.
Iron (metallic)	39.975
Manganese (metallic)	14.785
Phosphorus	1.074
Siliceous matter	5.840

Four miles southwest of Max Meadows, in Wythe county, and at the Noble furnace in the same county, manganiferous iron ores have been mined, which showed on analysis 49 to 51 per cent. metallic iron, and 3 to 5 per cent. metallic manganese.

At the *Razor bank* on the South Fork of the Holston river, in Rye Valley; on Chestnut Ridge, 6 miles from Seven Mile Ford Station; and near Marion, Smyth county, manganiferous iron ores have been opened. An analysis of a sample comprising 133 pieces of the ore from the *Razor bank* gave McCreath:

	Per cent.
Manganese (metallic)	10.181
Iron (metallic)	40.100
Phosphorus	.536
Siliceous matter	10.520

Likewise a sample of the ore from near Marion, Smyth county, gave on analysis:

	Per cent.
Manganese (metallic)	9.91
Iron (metallic)	45.32
Phosphorus	.086
Silica	1.76

Many outcrops and other indications of manganese ore are found in Craig, Giles, Bland, and Tazewell counties. Some of the ore has been mined to a limited extent in different places, but as yet no extensive developments have been made. These ores are usually associated with those of iron and are reported largely from the Oriskany horizon.

Seven manganese deposits have been opened on Gap Mountain, in Craig county, and the analyses given below of the ore from these openings show its character:

	I	II	III	IV	V
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Manganese (metallic)......	45.00	52.42	49.48	53.06	50.50
Iron (metallic)............	——	——	6.83	1.82	4.81
Phosphorus	.085	.303	.063	.058	.026
Silica	4.70	.46	2.53	1.67	.58

I and II. Analyses by T. T. Morrell, Cambria Iron Company.
III. Analysis by S. P. Sharpless.
IV and V. Analyses by Vulcan Steel Works, Saint Louis, Missouri.

Analyses of manganese ore from Lick Mountain, near Wytheville, Wythe county, gave Mr. Charles Catlett the following results:

	Per cent.	Per cent.	Per cent.	Per cent.
Manganese	41.89	57.67	51.05	44.60
Iron	2.57	1.98	2.92	3.96
Phosphorus	0.035	0.009	0.161	0.45
Sulphur	0.09	0.067	tract	tract
Insoluble matter.....................	4.05	1.85	4.32	15.81

Analyses of manganese ore from Cripple creek, 8 miles from Wytheville, Wythe county, gave Mr. Catlett:

	Per cent.	Per cent.
Manganese	24.85	32.55
Iron	2.72	3.61
Phosphorus	0.05	0.097
Sulphur	trace	0.030
Silica	47.30	27.86

METHODS OF MINING.

The nature of the manganese ores mined in Virginia is one of irregular distribution, in the form of nodules and pockets, through residual clays, which range in thickness from a few feet up to several hundred feet. The ore distribution varies considerably, and the deposits are limited both vertically and laterally; hence the methods for operating in one place will necessarily vary somewhat in detail from those in another. The method of mining will depend largely upon the location of the deposits and their depth below the surface. Open-pit and cut, shaft and tunnel, work are employed. These are often used together to advantage in the same place, especially where the ore begins at or near the surface and continues irregularly to some depth below. In such cases, open-pit and cut work is used, and from the bottom of the open work shafts are sunk and drifts are run at different levels from the shafts. Tunnelling becomes necessary in most of the steeper slope deposits. In the lower or flat-lying deposits, shafting is most advantageously employed. In most cases of tunneling and shafting in the larger operations, timbering is necessary on account of the liability of caving of the clays.

PREPARATION OF THE ORE.

The occurrence of the ores in the clay mean, usually, more or less admixture of the ore with clay. Usually, the only treatment of the ore necessary before shipping is to free it from adhering clay. Crushing and jigging are necessary in the spongy or porous type of ore, the numerous cavities of which are filled with the clays; also in those ores containing considerable free quartz grains and cemented fragments of the rock. Washing will usually suffice for cleansing the bulk of the ore. In the crushed and jigged ore, subsequent washing is also necessary.

For washing the ore the ordinary log-washer is used similar to that used for cleansing brown iron ores. Briefly, the log-washer consists of a long and stoutly built box, of sufficient length and depth to contain the log. The box or trough is elevated at one end. A log or central shaft 25 to 40 feet long, carrying heavy iron flanges, spirally arranged the length of the log, revolves lengthwise in the box or trough. The ore is fed at the lower end of the box and is gradually forced by the revolving log to the upper end, where it passes out. A constant stream of water plays on the ore in the box. The constant agitation and beating of the ore by the log and the washing by water frees it from adhering clay. Steam is the motive power.

Uses.

Penrose divides the various uses made of manganese and its compounds into three classes: (1) Alloys; (2) oxidizers; and (3) coloring materials. Each class includes the application of manganese in various manufactured products or as a reagent in the different metallurgical and chemical processes. The more important of these are given below:

Alloys.
- Spiegeleisen, Ferromanganese — Alloys of manganese and iron.
- Manganese bronze—Alloys of manganese and copper with or without iron.
- Silver bronze — An alloy of manganese, aluminum, zinc, and copper with a certain quantity of silica.
- Alloys of manganese with aluminum, zinc, tin, lead, magnesium, etc.

Oxidizers
- Manufacture of chlorine.
- Manufacture of bromine.
- As a decolorizer of glass (also for coloring glass, see below).
- As a drier in varnishes and paints.
- LeClanche's Battery.
- Preparation of oxygen on a small scale.
- Manufacture of disinfectants (manganates and permanganates).

Coloring Materials
- Calico printing and dyeing.
- Coloring glass, pottery, and brick.
- Paints
  - Green.
  - Violet.

In addition to these, a certain amount of manganese is used as flux in the smelting of silver ores, and its various salts are employed in chemical manufacture and for medicinal purposes. In the manufacture of glass, the manganese is used to remove the green color caused by the presence of iron and to impart various colors to the glass, particularly the violets, browns, and blacks. Manganese finds its principal use in the manufacture of iron and steel, chiefly in the production of steel and of a pig-iron rich in manganese for use in cast-iron car-wheels.

According to Weeks in the 16th Annual Report, United States Geological Survey, Part III, page 394: "It has been found in recent years that a chilled cast-iron car-wheel containing a percentage of manganese is much tougher, stronger, and wears better than when manganese is absent. For this reason large amounts of manganiferous iron-ores are used in the manufacture of Lake Superior charcoal, pig-iron intended for casting into chilled cast-iron car-wheels."

Production.

Virginia is the largest producer of manganese ores in the United States, and, with but 6 exceptions, has ranked first among the manganese-producing states in the United States for the past 26 years. The table below gives the production of manganese ores in Virginia from 1880 to 1906. The chief production of manganese in Virginia has been in the Shenandoah Valley. In this Valley, southwest of Roanoke, there are very promising indications of ore, but no great amount of ore has yet been raised. In addition to the ore produced in the Valley and in the Piedmont region, manganiferous iron ore has been produced in places in the Blue Ridge mountains proper.

Annual production of manganese and manganiferous iron ores in Virginia from 1880 to 1906.

Year	Manganese	Manganiferous iron	Value	Year	Manganese	Manganiferous iron	Value
	Long tons	Long tons			Long tons	Long tons	$
				1893	4,092	1,188	30,802
1880	3,661			1894	1,797		
1881	3,295			1895	1,715		
1882	2,982			1896	2,018		21,485
1883	5,355			1897	3,650		33,630
1884	8,980			1898	5,662		55,938
1885	18,745	3,237	168,942	1899	6,228		53,069
1886	20,567	497	232,594	1900	7,881		69,924
1887	19,835	1,025	253,833	1901	4,275		52,853
1888	17,646			1902	3,041	3,000	29,444
1889	14,616		156,257	1903	1,801	2,802	19,611
1890	12,699		125,121	1904	3,054		28,406
1891	16,248		180,533	1905	3,947		35,209
1892	6,079	2,842	58,966				

*Percentage of the total annual production of manganese ores in the United States, produced by Virginia.**

Year	Per cent.	Year	Per cent.
1880	63.5	1893	53.0
1881	67.3	1894	28.4
1882	65.8	1895	17.9
1883	87.0	1896	20.0
1884	88.2	1897	32.8
1885	80.6	1898	35.4
1886	68.1	1899	62.6
1887	57.4	1900	66.9
1888	60.4	1901	35.6
1889	60.3	1902	40.6
1890	49.4	1903	60.3
1891	69.3	1904	97.0
1892	44.7	1905	95.8

In 1889 and 1890, the *Crimora* and *Houston mines* produced nearly all the ore. During the same years the Leets mine near Mount Athos produced some high grade pyrolusite which was used in the manufacture of glass and bromine.

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*These calculations are based on the total production in Virginia and the total production in the United States by years as given in the Mineral Resources of the United States.

Fig. 1.—The New Homestead, Virginia Hot Springs, Bath county.

Fig. 2.—Buffalo Lithia Springs, Mecklenburg county.

MINERAL SPRINGS IN VIRGINIA.

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Each volume of the Mineral Resources of the United States from 1882 to date, contains some information on the Virginia manganese deposits. See also the volumes of the Mineral Industry.

7. MINERAL AND ARTESIAN WATERS.

Mineral Waters.—The mineral waters of Virginia are an important source of revenue. Virginia has a very large number of spring resorts and a great variety and abundance of well known commercial waters. Indeed, Virginia is par excellence a mineral spring state, occupying among the South Atlantic States the same position New York does in the North Atlantic section. Virginia is second only to New York in the number of springs that are utilized commercially, and exceeds New York in the number of resorts. The Hot Springs of Virginia, in Bath county, are among the most celebrated in the country. (See plate XXXVIII.)

Most of the best known springs in the State are located in the Mountain region, which includes the Blue Ridge and the Alleghanies. Many excellent springs occur in the Piedmont region, east of the Blue Ridge, and the waters from some of these are among the most celebrated in the country.

All classes of mineral waters are found in the State. They are naturally divided into (1) those containing mineral salts in such proportion as to give them medicinal value, and (2) those approximately pure waters which are sold extensively for table or domestic use. The thermal springs are entirely confined to the Mountain region.

Out of the total of 59 mineral springs credited to Virginia, 43 reported sales during the years 1904 and 1905. These were:

Ætna Lithia Springs, Roanoke, Roanoke County.
Alleghany Spring, Alleghany Springs, Montgomery County.
Augusta White Lithia Spring, near Augusta Springs, Augusta County.
Basic Lithia Spring, Basic City, Augusta County.
Bath Alum Springs, Bath County.
Bear Lithia Spring, near Elkton, Rockingham County.
Beaufont Lithia Spring, Beaufont, Chesterfield County.
Bellfont Lithia Spring, Manchester, Chesterfield County.
Berry Hill Mineral Spring, near Elkwood, Culpeper County.
Blue Ridge Spring, Blue Ridge Springs, Botetourt County.
Buffalo Lithia Springs, Buffalo Lithia Springs, Mecklenburg County.
Como Lithia Springs, East Richmond, Henrico County.
Crockett Arsenic Lithia Spring, Crockett Springs, Montgomery County.
Diamond Spring, 5 miles east of Norfolk, Norfolk County.
Farmville Lithia Spring No. 2, Cumberland County, near Farmville, Prince Edward County.
Fonticello Lithia Spring, near Richmond, Chesterfield County.
Golinda Lithia Spring, Augusta County.
Harris Anti-Dyspeptic and Tonic Springs, Burkeville, Nottoway County.
Healing Springs, Healing Springs, Bath County.
Hume Spring, Bancroft, Alexandria County.
Hunter Pulaski Alum Spring, Walkers Valley, Pulaski County.
Jeffress Lithia Silica Spring, Jeffress, Mecklenburg County.
Kayser Lithia Spring, Staunton, Augusta County.
Lone Jack Spring, Lone Jack Station, Campbell County.
Magee Chlorinated Lithia Spring, Clarksville, Mecklenburg County.
Massanetta Springs, Harrisonburg, Rockingham County.
Mecklenburg or Chase City Mineral Springs, Chase City, Mecklenburg County.

Montvale Hygeia Springs, Montvale, Bedford County.
Nye Lithia Springs, Wytheville, Wythe County.
O'Connell Lithia Spring, near Stribling Springs, Augusta County.
Otterburn Lithia and Magnesia Springs, Amelia, Amelia County.
Pæonian Spring, Pæonian Springs, Loudoun County.
Rockbridge Alum Springs, Rockbridge Alum Springs, Rockbridge County.
Rockingham (Virginia) Springs, near McGaheysville, Rockingham County.
Seawright Magnesia Lithia Spring, Staunton, Augusta County.
Seven Springs, near Glade Spring, Washington County.
Shenandoah Alum Springs, near North Mountain, Shenandoah County.
Stribling Springs, near Staunton, Augusta County.
Sublett's Lithia Springs, near Danville, Pittsylvania County.
Virginia Lithia Springs, Osceola, Chesterfield County.
Virginia Magnesian Alkaline Spring, near Staunton, Augusta County.
Wallawhatoola Alum Springs, near Millboro Spring, Bath County.
Wyrick Spring, Crockett, Wythe County.

Chemical Analyses.

It is only possible to give analyses of water from a few of the representative mineral springs in the State. The analyses of the springs represented have been selected with the view largely of indicating the variety of mineral waters in the State, which are of commercial value. Waters from some of the most important springs in Virginia are not included in the list for the reason that representative analyses were not available.

The following is an analysis of the Alleghany Springs water near Shawsville, Montgomery county, made by Dr. F. A. Genth:

One United States gallon of 231 cubic inches contains:

Calcium carbonate	3.61	grains
Magnesium carbonate	0.36	"
Lithium carbonate	trace	
Strontium carbonate	0.06	"
Barium carbonate	0.02	"
Magnesium carbonate	0.06	"
Iron carbonate	0.16	"
Cobalt carbonate	trace	
Zinc carbonate	trace	
Copper carbonate	trace	
Lead carbonate	trace	
Sodium sulphate	1.72	"
Calcium sulphate	115.29	"
Magnesium sulphate	50.88	"

Potassium sulphate	3.70	grains
Magnesium nitrate	3.22	"
Aluminium nitrate	0.56	"
Aluminium phosphate	0.03	"
Aluminium silicate	0.21	"
Sodium chloride	0.28	"
Calcium fluoride	0.02	"
Antimonium oxide	trace	
Silica	0.88	"
Crenic acid	trace	
Aprocrenic acid	trace	
Organic matter	2.00	"
	183.06	grains
Gases:		
Carbonic acid	0.56	cubic inches
Sulphuretted hydrogen	trace	

The following is an analysis of the Beaufont Lithia Spring water located in Chesterfield county, near Richmond, made by Froehling and Robertson:

One United States gallon of 231 cubic inches contains:

Magnesium bi-carbonate	.38956	grains
Calcium bi-carbonate	.35282	"
Sodium bi-carbonate	.34923	"
Iron (ferrous) bi-carbonate	.04741	"
Manganous bi-carbonate	trace	
Potassium sulphate	.13646	"
Potassium chloride	.12947	"
Sodium chloride	.35749	"
Sodium iodide	.00412	"
Sodium bromide	trace	
Sodium arsenate	trace	
Sodium phosphate	.00332	"
Lithium chloride	.02799	"
Alumina	.02099	"
Silicic acid	.96691	"
	2.78577	grains
Carbon dioxide free (gas)	8.5	cubic inches

An analysis made by Froehling and Robertson of the Blue Ridge Springs water, Botetourt county, gave:

One United States gallon of 231 cubic inches contains:

Magnesium sulphate	47.01306	grains
Calcium sulphate	100.13201	"
Sodium sulphate	.36740	"
Potassium sulphate	.65724	"
Magnesium carbonate	1.21885	"
Calcium carbonate	3.96562	"
Strontium carbonate	.29509	"
Barium carbonate	.02566	"

Manganese carbonate	.01749	grains
Nickel and cobalt carbonate	trace	
Iron (ferrous) carbonate	.10847	"
Lead carbonate	trace	
Copper carbonate	trace	
Sodium chloride	1.25967	"
Lithium chloride	.03732	"
Sodium arsenate	.00210	"
Sodium iodide	.00026	"
Sodium bromide	trace	
Calcium fluoride	.00146	"
Magnesium nitrate	.35574	"
Ammonium nitrate	.02814	"
Aluminium phosphate	.01575	"
Aluminium silicate	.15279	"
Silicic acid	1.35298	"
	157.00710	grains
Carbon dioxide combined	2.57648	"
	159.58358	grains
Gases:		
Carbon dioxide	38.2	cubic inches
Hydrogen sulphide	3.00	" "

The following analysis of spring No. 2, by Professor Wm. P. Joury of the Buffalo Lithia Springs water, Mecklenburg county, shows its composition to be:

One United States gallon of 231 cubic inches contains:

Magnesium sulphate	0.88	grains
Aluminium sulphate	9.07	"
Calcium sulphate	33.06	"
Potassium carbonate	29.30	"
Calcium bi-carbonate	14.96	"
Lithium bi-carbonate	2.25	"
Iron bi-carbonate	0.30	"
Baryta bi-carbonate	1.75	"
Sodium chloride	4.92	"
Silica chloride	1.87	"
Phosphoric acid	trace	
Iodine	trace	
Organic matter	small amount	
	98.36	grains
Gases:		
Sulphuretted hydrogen	8.30	cubic inches
Carbonic acid	59.20	" "

An analysis of the water from the Crockett's Arsenic Lithia Springs, Shawsville, Montgomery county, by Froehling and Robertson gave:

One United States gallon of 231 cubic inches contains:

Manganese carbonate	1.18	grains
Calcium carbonate	5.90	"

Strontium carbonate	0.09	grains
Barium carbonate	trace	
Lithium carbonate	0.07	"
Copper carbonate	trace	
Lead carbonate	trace	
Zinc carbonate	trace	
Manganese carbonate	trace	
Magnesium sulphate	3.04	"
Calcium sulphate	2.25	"
Potassium sulphate	1.25	"
Iron sulphate	0.04	"
Sodium sulphate	1.86	"
Sodium chloride	1.23	"
Sodium bromide	0.01	"
Sodium iodide	trace	
Sodium arsenate	0.02	"
Aluminium phosphate	trace	
Aluminium silicate	0.12	"
Ammonium nitrate	trace	
Silicic acid	1.29	"
	18.35	grains
Carbonic anhydride combined with monocarbonates to form bi-carbonates	2.23	"
	21.58	grains

The analysis of the water from the Fonticello Lithia Springs, in Chesterfield county, near Richmond, by Dr. Henry Froehling, shows the following composition:

One United States gallon of 231 cubic inches contains:

Magnesium bi-carbonate	.21636	grains
Calcium bi-carbonate	.48054	"
Sodium bi-carbonate	.31196	"
Ferrous bi-carbonate	.06205	"
Manganese carbonate	trace	
Potassium sulphate	.20001	"
Sodium sulphate	.05715	"
Sodium chloride	.47704	"
Lithium chloride	.03207	"
Sodium phosphate	.00309	"
Sodium arsenite	trace	"
Sodium bromide	trace	
Sodium iodide	.00302	"
Silica	.81645	"
Alumina	.00898	"
	2.66992	grains
Carbon dioxide combined with monocarbonates	.27526	"
	2.94518	grains
Carbon dioxide free	9.96	cubic inches

: following analysis by Professor J. W. Mallett of the water from the ıetta Springs, near Harrisonburg, Rockingham county, shows its ition to be:

One United States gallon of 231 cubic inches contains:

Calcium carbonate	12.10	grains
Magnesium carbonate	5.78	"
Iron carbonate	3.12	"
Manganese carbonate	0.43	"
Sodium carbonate	0.93	"
Lithium carbonate	trace	
Ammonium chloride	trace	
Potassium chloride	0.13	"
Potassium sulphate	0.09	"
Calcium sulphate	0.35	"
Alumina	0.13	"
Arsenious oxide (in salt)	trace	
Phosphoric acid	trace	
Silica	0.94	"
Organic matter	0.40	"
	24.40	grains
Carbonic acid united to carbonates as above to form acid salts	8.80	"

Temperature of water 55° F.

ı analysis of the water from the Otterburn Lithia Springs, near a, in Amelia county, by Froehling and Robertson gave:

One United States gallon of 231 cubic inches contains:

Calcium carbonate	2.43769	grains
Magnesium carbonate	1.48827	"
Iron (ferrous) carbonate	.13646	"
Sodium carbonate	.26009	"
Lithium carbonate	.03615	"
Magnesium chloride	.05656	"
Sodium chloride	.40647	"
Sodium sulphate	.08572	"
Potassium sulphate	.08047	"
Sodium iodide	.00609	"
Sodium bromide	trace	
Alumina	.03616	"
Silica	2.44352	"
	7.47455	grains
Carbon dioxide combined	2.38812	"
	9.86267	grains
Carbon dioxide free	18.4	cubic inches

n analysis made by Froehling and Robertson of the water from the

Swineford Arsenic Lithia Springs in Chesterfield county, near Richmond, gave:

One United States gallon of 231 cubic inches contains:

Magnesium bi-carbonate	0.14813	grains
Calcium bi-carbonate	0.11839	"
Manganese bi-carbonate	0.00420	"
Iron (ferrous) bi-carbonate	0.02040	"
Calcium sulphate	0.10031	"
Potassium sulphate	0.16154	"
Sodium sulphate	0.11314	"
Lithium chloride	0.00385	"
Sodium chloride	0.34116	"
Sodium bromide	trace	
Sodium iodide	0.00021	"
Sodium arsenate	0.00723	"
Sodium phosphate	0.00349	"
Silicic acid	0.60067	"
Alumina	0.01983	"
Total mineral matter	1.64256	grains
Carbon dioxide free	12.49	cubic inches

An analysis of the water from the Yellow Sulphur Springs, in Montgomery county, made by Professor William Gilham, gave:

One United States gallon of 231 cubic inches contains:

Calcium carbonate	8.64	grains
Magnesium carbonate	1.38	"
Iron carbonate	.62	"
Calcium sulphate	63.30	"
Magnesium sulphate	21.10	"
Aluminium sulphate	3.18	"
Potassium sulphate	.10	"
Sodium sulphate	.75	"
Iron protoxide	trace	
Calcium sulphate	.01	"
Magnesium phosphate	trace	
Potassium chloride	.10	"
Sodium chloride	.07	"
Organic matter	3.73	"
	102.98	grains
Carbonic acid	4.68	"
	107.66	grains

The composition of the Wolf Trap Lithia Spring, at Wolf Trap Station on the Southern Railway, in Halifax county, is indicated by the following analysis, made by Professor M. B. Hardin:

One United States gallon of 231 cubic inches contains:

Sodium carbonate	0.24027	grains
Lithium carbonate	0.01726	"

Ammonium carbonate	0.00128 grains
Calcium carbonate	7.41222 "
Magnesium carbonate	5.09221 "
Strontium carbonate	0.38489 "
Iron carbonate	0.06007 "
Manganese carbonate	0.0134 "
Copper carbonate	0.001234 "
Sodium chloride	2.62956 "
Sodium bromide	0.00630 "
Sodium iodide	0.00065 "
Sodium nitrate	2.62548 "
Potassium sulphate	0.06356 "
Sodium sulphate	0.06007 "
Aluminium phosphate	0.04432 "
Silica	2.01780 "
Barium carbonate	trace
Zinc carbonate	trace
Magnesium borate	trace
Calcium fluoride	trace
Titanic oxide	trace
Organic matter (yielding ammonia)	trace
	20.66836 grains
Carbon dioxide associated with the above carbonates in the so-called bi-carbonates	6.06682 "
Gases:	
Carbon dioxide, free	12.38 cubic inches
Nitrogen	3.60 " "
Oxygen	1.70 " "
	17.68 cubic inches

Production.

Of the 43 springs reporting sales, nearly four-fifths of the water is used for medicinal purposes. About half the total number of springs are used as resorts, having accommodations for several thousand people. At a number of the springs the water is used for bathing purposes. Among the most celebrated waters on the continent for bathing purposes, are those of the Warm Springs, in Bath county, a view of which is shown in plate XXXVIII, figure 1.

Year.	Number of springs reporting.	Product in gallons.	Value.
1900	38	1,141,859	$272,868
1901	41	1,562,781	335,869
1902	48	2,442,398	423,412
1903	41	2,561,502	477,410
1904	35	2,117,420	281,998
1905	37	2,340,287	549,102

References.

The literature relating to the mineral springs of Virginia is very extensive; only several of the more important ones are here noted.

Froehling and Robertson. A Hand-Book Prepared for the Virginia Commission to the Saint Louis Exposition. Richmond, Virginia, 1904, 97-159. Contains a large number of analyses of Virginia mineral waters.

Peale, A. C. Mineral Springs of the United States. Bulletin No. 32, U. S. Geological Survey, 1886.

The Natural Mineral Waters of the United States. 14th Annual Report, U. S. Geological Survey, 1894, Part II, 53-88.

See also the annual volumes of the Mineral Resources of the United States, published by the U. S. Geological Survey.

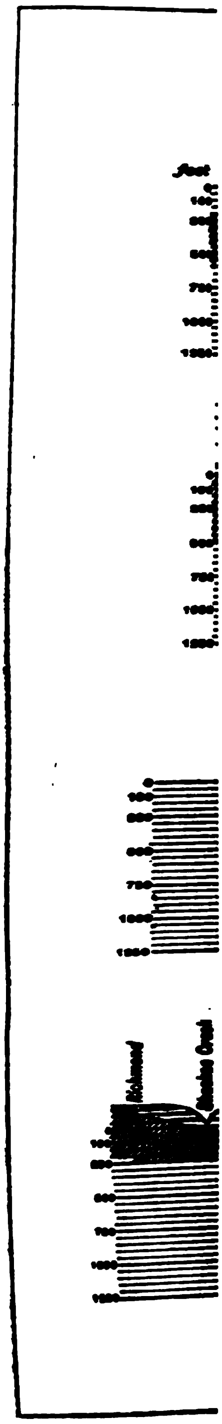
Rogers, Wm. B. Mineral Springs of Virginia. A Reprint of the Geology of the Virginias. New York, 1884, 549-566.

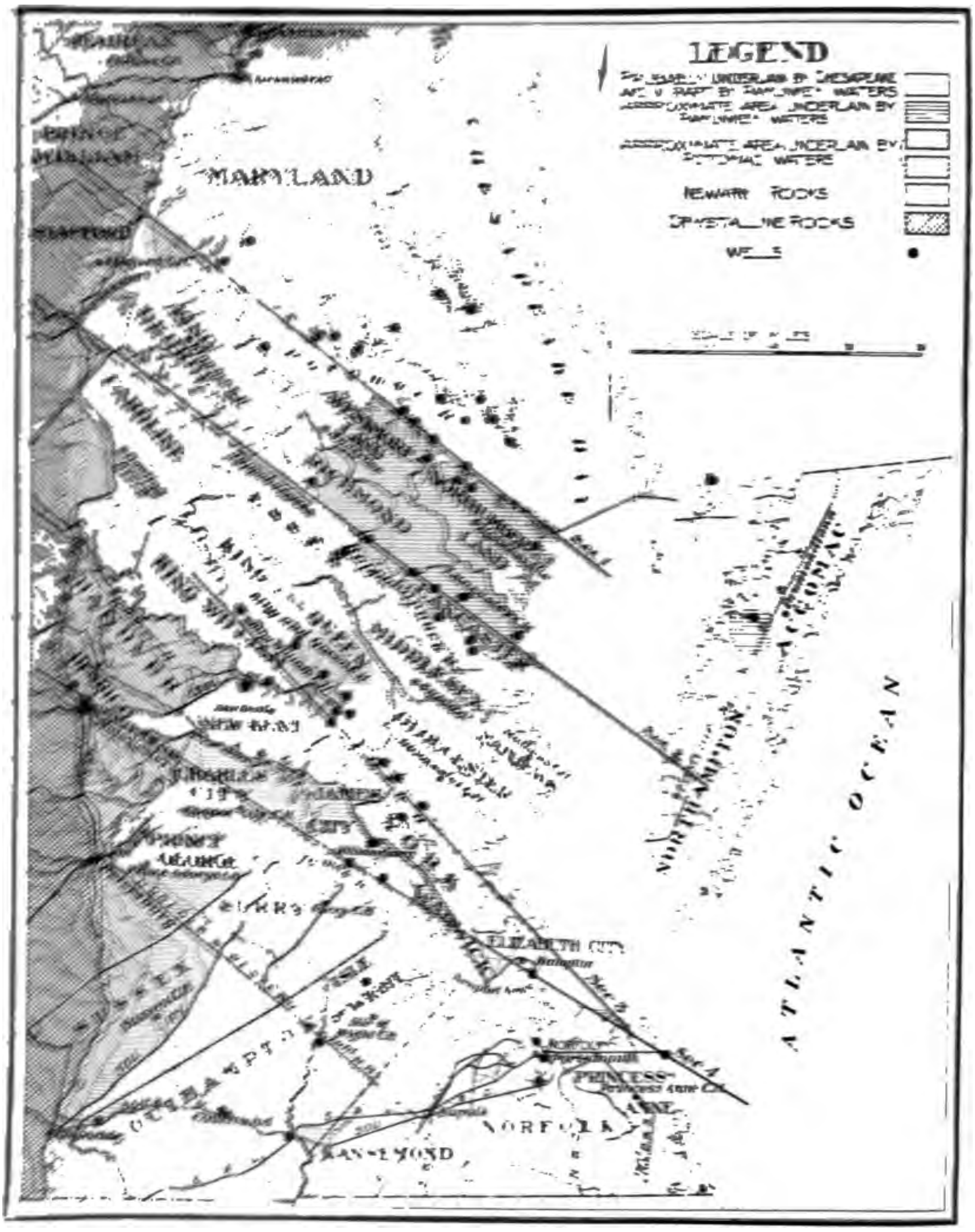
Artesian Waters.*—The underground or artesian waters are treated only for one province of the State, namely, the Coastal Plain or Tidewater region, for the reason, that, unlike the other two larger provinces, there are no large supplies of portable surface water found within the region. The rivers which traverse the region are either tidal estuaries or are widely bordered by swamps, and the water of their local branches is often of bad quality.

Tidewater Virginia extends eastward of a line passing through Alexandria, Fredericksburg, Richmond, Petersburg, and Emporia, and comprises an area of about 9,500 square miles. The general structural relations in Tidewater Virginia, so far as they are known, are shown in the sections on plate XXXIX. The Coastal Plain formations which outcrop in the State are as follows:

Formation.	Characteristics.	Age.
Columbia	Loams, sands, and gravels in terraces.	Pleistocene.
Lafayette	Orange sands, loams, and gravels	Pliocene (?)
Chesapeake	Clays, sands, diatomaceous earth, and marl.	Miocene
Pamunkey	Glauconitic marls and sands.	Eocene.
Potomac	Sands, sandstone, and clays.	Early Cretaceous.

*Compiled from various papers published by N. H. Darton and M. L. Fuller. The water resources of the Virginia Coastal Plain are being carefully studied by the U. S. Geological Survey and a report formulated. This report, when published, should contain much useful information that is of practical value.





. . . underground waters. (After N. H. Darton.)

WATER HORIZONS IN EASTERN VIRGINIA.

According to Darton, the greater part, if not all, of the Coastal Plain region of Virginia is underlain by water-bearing strata, of which, to the eastward, there are several horizons. The failures to obtain the higher water in some of the wells near the bay indicate that in this area at least, there are no good water supplies in the higher horizons, but the waters of the lower horizons have not yet been fully developed. The success of the new well at Fort Monroe definitely proves the existence of one of these.

The principal water horizons in eastern Virginia are the Chesapeake, Pamunkey, and Potomac formations, shown on map, plate XL.

Potomac.—There is more or less water in all of the coarser sand beds of the Potomac formation, but the principal supplies may be expected from the sands and gravels of the basal members, lying on the basement floor of the crystalline rocks. This horizon has been well explored about Washington and Alexandria, in most cases with great success, and was probably reached by the 210-foot well at Quantico. South of Quantico for some distance it does not appear to have been reached by any of the wells except one at Walkerton, on the Mattapony river; but from the general character of the formation as exhibited in its outcrops, and its productiveness of water northward, Darton says there is reason to believe that it is a great water-bearer throughout a wide extent. Its general relations are shown in the sections on plate XXXIX. How far eastward the coarse materials extend in the basal beds of the Potomac formation is not known, for they lie deeper than any of the wells appear to have penetrated. The North Point well is reported to have reached granite and found no water supply in the basal beds, but as elsewhere explained by Darton, the record and conduct of this well do not afford conclusive evidence either of the actual absence of water or of the presence of granite at the bottom of the boring. The well, no doubt, reached the Potomac formation, and it may have penetrated far into it. The water at the Chamberlain Hotel at Fort Monroe is thought to be from upper Potomac but the evidence is not conclusive as to the precise horizon.

Water occurs at various horizons in the Potomac formation above the basal beds, in sands intercalated among the clays. This water is an important source of supply in the District of Columbia, and it also affords a large yield at the well at Barrow, near Quantico. Only one of the wells south of Fredericksburg has penetrated to these waters so that their southeastern extension has not been well explored, but there is a fair possibility of finding one or more of them in that region. The 600-foot boring at Gloucester may have reached the Potomac beds, and even penetrated them for some distance, without finding water, but as this boring missed the higher waters that probably underlie Gloucester, it cannot be regarded as a decisive test for any of the waters.

Pamunkey.—The coarse gravel and sand at the base of this formation appears to extend far to the east, and it is a water-bearer throughout its extent. It was reached by the deep well at Naylor's Wharf at a depth of 386 feet, where sands with rock layers yielded a large flow of water which rose to 45 feet above tide-level. At Chapel Point, Maryland, at 237 feet, in the several deeper wells at Colonial Beach, at Lester Manor, at a depth of 200 feet, and at White House at a depth of from 180 to 230 feet, it furnishes a large supply of fine water under considerable pressure. These wells indicate a wide extent of the waters in a region which probably comprises the western half of the area indicated by a distinctive pattern for Chesapeake and Pamunkey waters on the map, plate XL. This horizon is about 250 feet below the Chesapeake water. The meager supply of water in the Clay Bank well and the failure of the deeper borings at Williamsburg and Gloucester probably indicate the limits of the horizon as a water-bearer to the eastward. It may extend under all of the region south of the James river, but none of the wells appear to have been bored sufficiently deep to reach it and higher waters are utilized. The experience of the unsuccessful boring to a depth of 386 feet at Dendron is not conclusive, for it probably did not reach the horizon, and if it did, may not have properly tested it; still, it is in line with the experience at Williamsburg and Gloucester. The latter criticism applies also to the North End Point well. It is to be expected that to the eastward the materials of this horizon finally become too fine-grained to carry water, and the eastern limits of conditions favorable for water-bearing appears to be at Clay Bank on York river.

Water also occurs in sands in the Pamunkey formation about 90 feet above its base as indicated by the water at 160 feet at Colonial Beach, and at 275 to 325 feet at Naylor's Wharf; but as it has not been further explored by other wells its extent cannot be discussed.

Chesapeake.—Lying between the clays, marls and fine sands of the Chesapeake formation and the top of the Pamunkey formation, there is a series of sands and gravels which may be regarded as the basal bed of the Chesapeake formation. To the eastward, this series contains thin interstratified rock strata which do not appear in the surface outcrops. In this series and in another similar one not far above, there is a large volume of water at a horizon or horizons which appear to be of wide extent in eastern Virginia. These waters have been explored by many wells and been found to underlie a belt of country about 20 miles in width, lying east of a nearly straight line extending from Mathias Point on the Potomac river to Emporia on the Atlantic Coast Line Railway. This belt has been indicated on the map, plate XL, by a distinctive pattern, and the relations of the waters are shown in the sections on plate XXXIX. The wells which reach these horizons in Virginia are given in the following list:

Locality	Depth	Remarks
RICHMOND COUNTY	Feet	
Naylor's Wharf	135	
Sharps' Wharf	235	
LANCASTER COUNTY		
Monatico Creek	250	
Whealton	230	
Monaskon	—	
Lancaster	250	
Carters Creek	330	
Weems	260	
Windmill Point	450	Well blocked by breaking of tools.
WESTMORELAND COUNTY		
Coles Point	220	
Ragged Point	225	
Sandy Point	235	
NORTHUMBERLAND COUNTY		
Kinsale	235	
Lewisetta	317	
Cowart	238	Water also at 270 feet.
Fairport	393	
Dymer Creek	443	
MATTAPONY RIVER		
Little Plymouth	168	
Sheppards Warehouse	160	
YORK RIVER		
Dudleys Ferry	175	
West Point	160	
Plum Point	168	
Gables Mill	226	
Bellevue	212	
Puritan Bay	215	
JAMES RIVER		
Williamsburg	280	
Homewood	290-317	
Jamestown	248	
Courtland	160	Horizon doubtful.
Arringdale	78	Horizon doubtful.

The horizon of the waters at 130 feet at Franklin, 161 feet at Zuni, and 190 feet at Mount Carmel is not certainly known, but it is thought to be in the Chesapeake formation considerably above its base. The Aringdale well at 75 feet and the Courtland wells at 160 feet are doubtfully referred to the basal Chesapeake beds, but the former may be down to a lower horizon.

Basal Chesapeake waters were apparently absent in the North End Point, Fort Monroe, Dendron, Clay Bank, and Gloucester wells.

There are several higher horizons of water in the Chesapeake formations and it is believed that the wells at Franklin, Zuni, and Mount Carmel are from Chesapeake beds about 100 feet above the base of the formation. The water of the Bowlers Wharf well at 143 feet is from about the same horizon, but water reported at 240 feet in the Dymers Creek well is somewhat higher than the others.

The salty water at 606 feet at Lambert Point and at 599 feet at Fort Monroe, and the ferruginous water at 562 feet at Money Point, all near Norfolk, are from somewhat higher horizons. The waters at 140 feet at Onancock on the eastern shore and at 70 feet at Virginia Beach are at still higher horizons. Darton states that he is not inclined to regard any one of these upper Chesapeake horizons as widespread, and with our present meager knowledge they cannot be predicted with safety.

WELLS IN EASTERN VIRGINIA.

Reference to the map, plate XL, will show a reasonably large number of wells in eastern Virginia most of which have obtained abundant supplies of water at very moderate depths. Numerous wells have been put down in the area since the publishing of this map in 1896, the records of which have not been available to me for this book and hence are not included on the map.

The following is a list of deep wells in eastern Virginia published by Darton in 1896.

Partial List of Deep Wells in Eastern Virginia.

Location.	Depth.	Size.	Capacity per minute.	Height to which water rises, *a*.	Horizon.	Remarks.
	Feet.	*In.*	*Gallons.*	*Feet.*		
Alexandria Brewery	430	8	90		Basal Potomac	Soft water.
Alexandria Ice Works	401	8	20	−12		Poor water at 300 feet.
Arringdale, 2 wells	75		Flows 10	+10		Slightly alkaline water.
Ashland	79	1½	Many.	− 4½	Granite (?)	
Ashland	100	4	Many.		Granite	
Barrow	195		Many.		In Potomac	No water below 148 feet.
Bellevue, 2 wells	212	1½	Flows 15-20	+4 to +6	Basal Chesapeake	
Bothwell	300	6	20	+ 7	Newark	
Bowlers Wharf	143	4	7	Flows.	Chesapeake	Soft water.
Carters Creek	330			+12	do	
Clay Bank	588	1½	Flows 2	+ 4	Basal Pamunkey	
Clifton, 2 wells	175	1½	Flows 10-12	+4 to +6	do	
Coan, 8 wells	270	1½	Flows 2½	+12	Basal Chesapeake	Water also at 240 feet.
Coan, 1 well	315	4	15	+12	do	
Coles Point	220	1½	8	+12	do	
Colonial Beach, 5 wells	250	1½	5	+8 to +15	Basal Pamunkey.	Water also at 160 feet.
Courtland, 30 wells	160		30		Chesapeake (?)	
Cowart	288	2	Flows 2	+ 6	Basal Chesapeake	
Ditchley	620	1½	Flows 2	4 to 6		
Dendron	386	6	None.			
Dudleys Ferry, 4 wells	175	1½	Flows 10	4 to 6	Basal Chesapeake	
Dymer Creek	443	3	Flows 7		Basal Pamunkey	No water 464-507½ feet; water also at 240 and 464 ft.
Fairport	393½	1½	Flows 2		Basal Chesapeake	Soft, good water.
Fort Monroe	907		None.		Potomac (?)	
Fort Monroe, Chamberlain Hotel	945		Flows 50	+10	do	Slightly saline water.
Franklin, 16 wells	130		Many.	Flow.	Chesapeake	
Gabel's Mill	226	1½	Flows 20	+10	Basal Chesapeake	
Gloucester Ct. House	600		None.		Pamunkey (?)	Stopped at rock stratum.
Homewood, 5 wells	317	1½	Flows 50		Basal Chesapeake	Fine water 54°; Sulphurous water at 270 ft.
Homewood, 5 wells	112	1	Fair supply.	+ 2	Chesapeake	Ferruginous water.
Jamestown	248	3	Flows 2½	+35	Basal Chesapeake	Fine water 68°.
King and Queen	200	2	Flows 1		Basal Pamunkey	
Kinsale	235	1½	5	+15	Basal Chesapeake	

a +, feet above the surface; −, feet below the surface.

List of Deep Wells in Eastern Virginia—Continued.

Location.	Depth.	Size.	Capacity per minute.	Height to which water rises. a	Horizon.	Remarks.
	Feet.	*In.*	*Gallons.*	*Feet.*		
Lancaster	250	....	Flows 12	....	Basal Chesapeake	
Do	285?	....	....	....	....	
Lester Manor, 3 wells	200	1½	Flows 12	+8 to +12	Basal Pamunkey?	
Lewisetta	317½	....	....	....	Basal Chesapeake	
Little Plymouth	168	2	Flows 2	....	do	
Monaskon	255	....	....	....	Basal Chesapeake	
Monatico Creek	250	1½	Flows 2	+	do	
Mount Carmel Church	190	....	Flows 1½	+ 6	Chesapeake	
Naylors	386	1½	Flows 3	+45	Basal Pamunkey.	Much water at 326 feet
Newcastle	187	1½	Flows 10	+ 2	....	
Newport News	±600	....	None	....	Chesapeake	
Norfolk	147	6 ?	Much	—6	do.	Very hard water
Norfolk, Lambert Point	610	....	65	....	do	Saline water
Norfolk, Money Point	562	....	Much	+ 5	do	Ferruginous water
North End Point	1,172	....	None	....	Potomac	
Oak Springs	400	1½	Flows 10-12	+ 6	....	
Onancock	140	4½	5	....	Chesapeake	140-486 feet; no water
Plum Point, 3 wells	168	1½	Flows 10-12	+8-12	Basal Chesapeake	
Possums Nose	200	....	....	....	Potomac	
Providence Forge	80	1½	None	....	Chesapeake	Unfinished
Puritan Bay, 2 wells	215	1½	Flows 10-12	+4-6	Basal Chesapeake	
Puritan Bay, 1 well	180	1½	Flows 10-12	+4-6	....	
Quantico	350	....	4-5	Flows.	Basal Potomac	
Ragged Point	225	1½	1	+12	Basal Chesapeake	
Richmond: Paper Mill	400	....	Fair	....	Granite	Surface contamination
Sherwood Park	900	....	None	....	do	
Sherwood Park, 1 mile northeast	250	....	None	....	do	
Ginter's farm	400	....	Satisfactory	....	do	Fine water
Sandy Point: Westmoreland County	235	1½	3	+12	Basal Chesapeake	
Fairfax County	560	....	Satisfactory	—24	Basal Potomac	No water below 270 feet; rock 270-560 feet
Sharp's Wharf	235	1½	Flows 12-35	+24	Basal Chesapeake	
Do	360	....	....	....	Pamunkey	Water also at 240 feet
Sheppard's Warehouse, 2 wells	160	1½	Flows 10-15	+6-8	Basal Chesapeake	
Swan Point	+100	....	....	....	Chesapeake	
Virginia Beach	70	....	Fair supply	....	Upp'r Chesapeake	Ferruginous water
Walkerton, 2 wells	315	1½	Flows 5-8	+4-6	Potomac	
Weems	260	....	....	....	Chesapeake	
West Point, 200 wells	160	1½	Average 12	Average. + 2	Basal Chesapeake	
Whealtons	250	....	20	....	Bas'l Chesapeake?	
White House, 3 wells	180-230	1½	1-6	+5-20	Basal Chesapeake	
Williamsburg	876	....	None	....	Potomac	
Do	280	....	Many	....	Basal Chesapeake	Under hard rock stratum
Windmill Point	430	....	None	....	Near to basal Chesapeake	To top of rock stratum
Zuni	161	....	Flows 2	....	Chesapeake.	

a +, feet above the surface; —, feet below the surface.

References.

ıe following list includes the principal publications which bear on nderground waters of eastern Virginia:

n, N. H. Artesian Well Prospects in Eastern Virginia, Maryland and Delaware. Transactions American Institute of Mining Engineers, 1905, XXIV, 372-397.

Artesian Well Prospects in the Atlantic Coastal Plain Region. Bulletin, U. S. Geological Survey No. 138, 1896, 162-190.

Preliminary List of Deep Borings in the United States. Water Supply and Irrigation Paper, U. S. Geological Survey No. 61, Part II, 60.

Geologic Atlas of the United States. Fredericksburg, Virginia Folio, No. 13. U. S. Geological Survey, 1894.

Geologic Atlas of the United States. Nomini Folio, Maryland and Virginia, No. 23. U. S. Geological Survey, 1896.

Geologic Atlas of the United States. Norfolk Folio, Virginia and North Carolina, No. 80. U. S. Geological Survey, 1902.

and Keith, A. Geologic Atlas of the United States. Washington Folio, District of Columbia, Maryland and Virginia, No. 70. U. S. Geological Survey, 1901.

and Fuller, M. L. Underground Waters of Eastern United States. Water Supply and Irrigation Paper No. 114, U. S. Geological Survey, 1905, 127-135.

V. SILICATES.

1. FELDSPARS.

Composition and Character.

ıe feldspar group includes a number of mineral species which chemically, silicates of aluminum with varying amounts of and the alkalies, potash and soda. The species belong- ɔ the feldspar group are alike in having two easy cleavages along they split with even, smooth, and shining surfaces, and are inclined ; another at right (90°) and oblique angles. In color they vary from colorless through white, gray, pink, red, and green; and they vary from transparent through translucent to opaque, the latter being the more frequent. They crystallize in the monoclinic and triclinic systems. In hardness, they vary from 6 to 6.5, and in specific gravity from 2.5 to 2.9.

Occurrence.

Of the nine known species of feldspar only a few are of commercial value; the principal ones being the potash varieties, orthoclase and microcline, and the soda variety, albite. The commonest species of feldspar is orthoclase, and it is the one commonly used by potters in this country. It is the most infusible member of the feldspar group. The feldspars are common constituents of certain types of rocks such as the granites, gneisses, and syenites, but as such they have no commercial value.

Commercially valuable feldspar occurs associated with quartz and mica as coarse crystallizations in pegmatitic dikes or veins, cutting granites, gneisses, and crystalline schists. In addition to quartz and mica, a great variety of rarer minerals are associated with the feldspar in the pegmatite dikes a list of which, for the Amelia county, Virginia, area, is given on page 282.

Distribution.

Pegmatitic dikes, containing feldspar as an important constituent, are quite widely distributed through the Virginia crystalline or Piedmont area, east of the Blue Ridge, where they are found penetrating the principal types of the older rocks of the area. Hardly a county within the Piedmont area is without them. Notwithstanding the abundance of these dikes in the middle province of Virginia, many of which contain commercially valuable feldspar, the attempts to mine this mineral are comparatively few and as yet the production is small. Up to the present time, the principal area in the State in which feldspar has been mined is in Amelia county, in the vicinity of Amelia court-house. Here the feldspar has been mined in connection with mica and a full description of the Amelia county pegmatite masses is given under Mica on pages 280-284.

In the feldspar-mica pegmatite dikes of Amelia county the potash varieties, orthoclase and microcline, and the soda variety, albite, occur. These are in large masses, usually of a high degree of purity, and white in color, though green is not uncommon. The following analyses of samples of these three varieties of feldspar from the Amelia county area show their composition to be:

	I Per cent.	II Per cent.	III Per cent.
Silica (SiO_2)	65.37	64.12	67.06
Alumina (Al_2O_3)	18.74	16.84	21.72
Iron oxide (Fe_2O_3)	0.13	2.28	——
Lime (CaO)	0.27	0.32	1.59
Magnesia (MgO)	——	0.26	0.03
Potash (K_2O)	12.98	13.34	0.38
Soda (Na_2O)	2.49	1.88	10.01
Total	99.98	99.04	100.79
Specific gravity	2.501	2.564	2.618

I. Orthoclase. E. B. Sloan, analyst.
II. Microcline (Amazonstone). C. C. Page, analyst.
III. Albite. Robert Robertson, analyst.

Mining of feldspar, in an extensive pegmatite, was recently begun on Otter river, about 3 miles southeast of Bells, in Bedford county, by the Blue Ridge Kaolin Company. The product is shipped to East Liverpool, Ohio, for use in pottery manufacture.

Uses.

The chief use made of feldspar is in the manufacture of pottery, wall and floor-tiles. For pottery-making, the feldspar is mixed in a finely pulverized condition with the kaolin or clay. It is also utilized to some extent in the manufacture of wood-fillers, scouring soaps, and glass.

References.

Musgrave, R. N. Analysis of Beautifully Crystallized Albite from near Amelia Court House, Virginia. Chemical News, 1882, XLVI, 204.

Page, C. C. Amazonstone from Amelia County, Virginia. The Virginias, 1885, VI, 24-25.

Robertson, R. Albite from Amelia County, Virginia. The Virginias, 1885, VI, 25.

Sloan, B. E. Analysis of the Feldspar Accompanying Microlite in Amelia County, Virginia. Chemical News, 1881, XLIV, 207; The Virginias, 1882, III, 4.

2. MICA.

GENERAL CHARACTER AND COMPOSITION.

Under the mica group is comprised a number of distinct mineral species which are alike characterized by highly perfect basal cleavage, parting readily into very thin, tough, and more or less elastic, sheets that are translucent to transparent. In most cases, they are chemically orthosilicates of aluminum with principally hydrogen and potassium or sodium, lithium, magnesium, and iron. Of the seven species of mica, only two are of commercial value, though a third one, lepidolite, may be a source of lithia salts, but it is not used for any of the purposes of a commercial mica. The other two micas, muscovite and phlogopite, comprise all the commercial mica that is marketed; and in the United States only muscovite is mined, because there are as yet no known commercial deposits of phlogopite. Muscovite is the white potash mica and phlogopite is the pearl gray magnesian mica.

OCCURRENCE.

Muscovite, the white mica, and biotite, the black mica, are very widely distributed and are among the commonest constituents of many of the crystalline and sedimentary rocks. It is only when muscovite occurs in blocks or masses of size that will split into sheets an inch or more in diameter that it has commercial value, which increases with the size of the cut sheets. Usually the commercial deposits of mica are found in pegmatitic dikes or veins of coarse crystallization, which penetrate granites, gneisses, and crystalline schists. In small veins the mica is frequently too small in size to have commercial value.

Quartz, feldspar, and muscovite are the principal minerals composing the pegmatite dikes. As a rule, these minerals are not uniformly distributed through all parts of the dikes, but, on the contrary, their distribution is very irregular, with first one and then another of the three minerals predominating in different parts. Besides the three principal minerals mentioned, there are large numbers of rarer minerals found in the pegmatite dikes, some of which occur only sparingly, others more abundantly. Some of these have commercial value as gem material, such as garnet and beryl, which occur in the Amelia county, Virginia, dikes and have been used for gem purposes.

Likewise, the quartz and feldspar of the pegmatite dikes are of value and are sometimes mined with the mica and utilized in the manufacture of pottery and for abrasives. Both the principal and accessory minerals enumerated above have been mined and marketed from the Amelia county, Virginia, area. In addition to these, the Virginia dikes have been a source of some kaolin, derived from the decay or kaolinization of a part of the feldspar in that portion of the dikes above the level of local ground water.

DISTRIBUTION AND DESCRIPTION.

From the description given above of the occurrence of mica, it follows that the distribution of this mineral in Virginia must be limited to the crystalline area or Piedmont Plateau, east of the Blue Ridge. Pegmatite dikes containing mica are somewhat abundantly developed over the Virginia crystalline area and many excellent surface indications for mica occur, but as yet prospecting and mining have been limited. Of the large number of counties in the Virginia area, mica has been either prospected or mined in the following: Amelia, near Amelia court-house, and near Jetersville; Bedford county, near New London on the John P. Thompson place; Goochland county, near the court-house where it was mined in a small way but afterwards abandoned on account of the influx of water; Pittsylvania, south of Chatham; Amherst; Henry county, at Ridgeway; and Hanover county, near Hewlett's station. The Hanover mine near Hewlett's has not been worked since 1872. In addition to the above, surface indications are noted in Powhatan, Cumberland, Caroline, Buckingham, Spottsylvania, and Franklin counties. Mica occurs in Franklin county in Snow creek valley on the south side of Chestnut Mountain.

At Ridgeway in Henry county, the Pittsburg Mica Company is engaged in developing a mica property. A commodious plant has been built and the development work comprises an open cut about 100 feet long and 40 feet deep, and about 1,000 feet of cross-cuttings. The dike is about 8 feet wide. The company expects to begin shipping mica not later than September, 1907.

Of the many localities where mica is found in Virginia only one has yet been seriously mined, namely, near Amelia court-house and near Jetersville, in Amelia county. Because of the prominence of the Amelia county area, it is here described in some detail.

THE AMELIA COUNTY AREA.

Mica mines have been opened at two localities in Amelia county, both of which are in close proximity to the Richmond and Danville division of the Southern Railway. These are (1) in the vicinity of Amelia court-house, and (2) near Jetersville about 8 miles south of west from Amelia court-house. The general topography of the two areas and location of the mines are shown on the map, figure 42.

Amelia Court-House District.

Openings from which mica has been mined and smaller pits are abundantly developed over an area stretching northeast from Amelia courthouse for a distance of 2 or more miles. So far as the writer can ascertain, the first mining of mica in this district was begun about 1873 on the Jefferson property described below. Mining has continued at intervals from 1873 to date, but in the summer of 1906 only one mine, the Pinchback, was operating.

The principal mines in this district which have produced mica are the *Jefferson, Rutherford, Berry, Winston,* and *Pinchback.* Most of these have been idle for the past 10 or 12 years and many of the openings which are reasonably large had been abandoned for so long a time at the time of my visit in July, that they had largely fallen in and were partially filled with water. The deepest would probably not exceed 100 feet, the work having all been surface mining, comprising cut and pit excavations.

Both sheet and scrap mica were produced at these mines. Some of the sheets measured after cutting as much as 12x14 inches. No sheets were cut smaller than 2x2 inches in size and all mica under this size was marketed as scrap.

GENERAL GEOLOGY.

As may be seen by reference to the map, figure 42, the surface of this district is a moderately undulating one without conspicuous elevations or depressions. The principal rock is a biotite gneiss of thin foliation not infrequently showing a distinct "augen" texture. It is quite dark in color from the presence of much biotite and is fine-grained in texture. Its origin is yet undetermined, whether an original igneous or sedimentary mass.

The mica occurs as a constituent of the pegmatite dikes which intersect the biotite gneiss of the district. It is found as a coarse crystallization with feldspar and quartz. The openings made on these dikes show a very variable ratio of the three principal minerals, mica, feldspar, and quartz. In places, the three occur in nearly equal amount; in others, dominant feldspar and mica with very little quartz; and others still show dominant quartz and mica with little or no feldspar. The feldspar of ikes include the potash varieties, orthoclase and microcline, and

Fig. 42.—Map showing location of mica mines in Amelia county. Mines indicated by heavy triangles in circles. Based on the topographic sheet, U. S. Geol. Survey. Scale, ½ inch = 1 mile. Contour interval, 50 feet.

the soda variety, albite, description and analyses of which are given on pages 276-277.

In addition to the three principal minerals, a large number of rarer minerals have been noted in the Amelia county pegmatites. These are microlite, fluorite, columbite, helvite, monazite, allanite, spessaritite (garnet), apatite, beryl, tourmaline, and zircon.

The rocks are everywhere mantled by a considerable depth of residual decay. Accordingly outcrops are rare, and since the openings, on account of long standing, show much caving from the sides, exact measurements of the dikes could not be made. As nearly as could be determined, the larger pegmatite dikes will measure more than 50 feet across, and they usually cut across the foliation of the enclosing or country rock. These dikes are not schistose but entirely massive and are cut by jointing.

The mica occurs as thick highly cleavable blocks and masses of varying size. That found on the dumps is invariably of light, white color, but in some of the openings the mica is very dark in color, nearly black. For a description of the feldspar and quartz contained in these dikes see pages 275-277.

MINES.

The Jefferson mines.—These were the first mines opened in the district and a large number of openings have been worked, the extreme northeast ones being about 2 miles N. 30° E. from Amelia court-house. Some of these openings are among the largest made in the district, and none of them have been worked for many years.

The Rutherford mines.—The Rutherford mines are located 1 mile N. 30° E. from Amelia court-house and are reported to have been first opened about 24 years ago. Two openings were worked, aligned in a nearly north-south direction, and are separated by a distance of about 100 yards. The last work done is reported to have been about 12 years ago. Much green feldspar occurs though the bulk of this mineral is white. The largest sheets of mica mined are reported to have cut 22x24 inches.

The Berry mine.—This mine comprises one large and deep roughly circular opening, immediately on the southeast side of the Southern Railway, about 1 mile northeast of Amelia court-house. No work has been done for many years.

The Winston mine.—The Winston mine is located on the north side of the Southern Railway about one and three-quarter miles N.70°E. from Amelia court-house. The principal opening is a large one and has not been worked in recent years.

Fig. 1.—Pinchback mica mine, near Amelia court-house, showing width of pegmatite dike containing the mica.

Fig. 2.—View of dump of scrap mica, near Amelia court-house.

MICA MINE AND DUMP, AMELIA COUNTY, VIRGINIA.

The Pinchback mine.—This was the only mine operating in the county in 1906. It is located about 2 miles northeast from Amelia court-house and about one-quarter of a mile southeast of the extreme opening on the Jefferson place. It was first worked about 18 years ago. Some half dozen or more openings have been made, the most recent one of which was made in the spring of 1906, and in July it had been worked to a depth of 28 feet. Plate XLI, figure 1, is a view of this opening. As exposed by this opening, the dike is about 40 feet wide composed of white feldspar and quartz and dark-colored mica and an occasional beryl crystal. Between the middle of the dike and the walling, the feldspar is entirely kaolinized to the depth of working, 28 feet, and much high grade kaolin is being removed and shipped. The feldspar is all partially kaolinized throughout the depth of working, and it rapidly slakes on exposure to the air. It is all saved and shipped to Trenton, New Jersey, where it is utilized in pottery manufacture. The largest sheets of mica taken out measured 12x14 inches after cut. The average size is probably about 4x6 inches and much of it cuts only 2x2 inches. Both sheet and scrap mica are produced.

The Jetersville District.

This area as shown on the accompanying map, figure 42, is 8 miles south of west from Amelia court-house.

The Schlegal mine.—Only one mine has been worked in this district, the Schlegal, which is located three-quarters of a mile N. 80° W. from Jetersville. It was worked by shaft and open-cut and was first opened about 24 years ago, and was last worked about 5 years ago. The shaft was worked to a depth of 100 feet with several drifts run from it.

The country rock comprises a gneiss of granite composition and a sheared, thinly schistose diorite. As measured at the top of the open work, the pegmatite dike containing the mica will not exceed 30 feet in width. The openings are apparently made in a curved or bent portion of the dike the two parts of which strike N.70°W. and S.20°W. The pegmatite cuts across the foliation of the country rock which at the openings strikes nearly north and south.

About a half mile N. 10° E. from the shaft, continuous exposures of a large pegmatite dike trending north-south are traced along the valley side of a small stream. No openings are made on this dike and it is regarded as a separate one from that on which the mine is opened.

A mill for grinding and crushing the feldspar which was shipped for use in pottery manufacture was operated at the mine. Blocks or masses of mica yielding cut-sheets of 8x12 inches are reported mined. The mica seen at the time of my visit in July was dark in color. In addition to the three chief minerals, quartz, feldspar, and mica, all of which were marketed, numerous small crystals of red garnet occur.

Uses.

Until within recent years, almost the only use made of mica was as cut sheets of different sizes in the doors or windows of stoves and furnaces, and in other similar places where transparency and resistance to heat were the essential qualities. During this period the small pieces and waste in mining and in cutting the sheets could not be utilized and were thrown away. At the present time, however, the demand for mica for electrical purposes is great and much of the small pieces that were formerly thrown away are now cut into small circular disks and rectangular pieces for insulation purposes in electrical apparatus.

The large amount of scrap mica, 75 to 90 per cent. in mining, which was formerly thrown away is now saved and used in the form of ground mica. The mica is usually ground to five sizes to pass through sieves of 80, 100, 140, 160, and 200 meshes to the inch, respectively. This ground mica is now utilized for a great variety of purposes, the principal ones of which are in the manufacture of fire-proof materials, chiefly paint; as a nonconductor for steam and water heating; as a lubricant; for decorative purposes; and in the manufacture of paints.

Production.

Almost the entire production of mica in Virginia has been from the Amelia county area. In some years the production from the mines of this area was quite appreciable but during the present year only one mine was in operation. Mica-mining in Virginia has been so irregular that accurate figures of producton are difficult to obtain. The years given below while not consecutive will probably afford some idea of the annual mica-production in the State:

Year.	Pounds.
1886	1,500
1887	3,500
1900	16,000
1902	96,000

References.

Campbell, J. L. The Steatite, Mica, Fire-Clays, Barytes, Etc., of James River Valley. The Virginias, 1882, III, 160.

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Merrill, G. P. The Non-Metallic Minerals. New York 1904, 163-180.

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3. ASBESTOS.

Composition and General Character.

The name asbestos was originally applied to a fibrous variety of the mineral amphibole, which is a normal metasilicate of calcium and magnesium, with frequently varying amounts of iron and manganese and, at times, smaller amounts of the alkalies. As now used, the term properly includes the fibrous varieties of the mineral serpentine, a hydrous magnesium silicate. These two minerals, the fibrous varieties of amphibole and serpentine or chrysolite, form the present sources of commercial asbestos. They are similar in their physical properties but are distinct chemically. Though equal in their heat-resisting properties, chrysolite is superior in strength and elasticity of fibre to any of the amphibole asbestos. The most marked character of asbestos is its fibrous structure. Chrysolite asbestos is usually greenish-white, yellowish to brownish in color, and has a pronounced silky luster. The amphibole asbestos varies from white to greenish and woody-brown. Its fibres are longer than chrysolite and are flexible and easy to separate.

Occurrence.

Asbestos occurs in those regions composed of the older eruptive and metamorphic rocks; hence the deposits of Virginia are limited to the Piedmont or crystalline area, east of the Blue Ridge. The amphibole asbestos is usually found in granite or schistose rocks either in pockets or in more or less well-defined veins, a fact which considerably lowers the cost of mining it. The chrysolite or serpentine asbestos is always found in serpentine rocks not in regular veins but as irregular seams which necessitate the mining of a large amount of rock in order to obtain a small amount of the mineral. Amphibole asbestos is less valuable. It is more easily mined, and where the strength of fibre is not essential it is as satisfactory as the more expensive and rarer chrysolite asbestos.

In Albemarle county, Virginia, asbestos is found in thin platy masses along slickensided zones in steatite (soapstone from altered pyroxenite), the fibres of which are parallel to the direction of movement.

Distribution.

So far as is known the asbestos found in Virginia is of the amphibole variety. It occurs in many of the Piedmont counties of the State and in a few it has been prospected and mined. Bedford is the only producing county at present. In Amelia county about 7 miles north of west from Mattox station, asbestos has been mined near the Appomattox river. A very promising grade of the mineral was opened some years ago in this vicinity on the Ligon place. It is found in the vicinity of Whitehall, and Willis Mountain in Buckingham county; and at several points in Powhatan and Goochland counties, although it has not been developed in any of these localities.

About 2 miles east of Rocky Mount, in Franklin county, asbestos of excellent grade has been mined to a limited extent. It is associated with soapstone in the form of pockets, is of the amphibole variety, and has a long and white silky fibre.

The only producing property at present in the State is that of the American Asbestos Company near Chestnutford post-office, in Bedford county. A number of veins or seams varying from 8 to 50 or more inches wide are worked. The company has recently completed a 40-ton plant erected for the purpose of crushing and separating the asbestos. A considerable amount of the crude rock has been mined.

Asbestos has also been noted in Floyd, Grayson, and Fauquier counties, but, as yet, it has not been worked in either of these counties. As stated above it is found in Albemarle county in thin platy masses in the soapstone of the Alberene lead, and is of the amphibole variety. Professor R. L. Packard analyzed a specimen of the amphibole asbestos from Albemarle county, which gave:

	Per cent.
Silica (SiO_2)	56.26
Alumina (Al_2O_3)	1.81
Iron oxide (FeO)	6.40
Manganese oxide (MnO)	trace
Lime (CaO)	11.98
Magnesia (MgO)	20.85
Ignition	2.65
Total	99.95

Doctor Merrill gives the following analysis, made by Packard, of an amphibole asbestos from Roanoke county, Virginia:

	Per cent.
Silica (SiO_2)	55.81
Alumina (Al_2O_3)	1.66
Iron oxide (FeO)	6.81
Lime (CaO)	12.74
Magnesia (MgO)	21.09
Ignition	1.81
Total	99.92

Uses.

The uses of asbestos are many and varied and are constantly increasing. Where the chief requirement to be met is non-conductivity of heat, the amphibole asbestos is ordinarily used, but where strength of the fibre is an essential as well as non-conductivity of heat, the chrysolite variety is used. Amphibole asbestos is largely used as an ingredient in fire-proof paints for wall plasters, boiler covering, packing in the manufacture of fire-proof safes, etc. The chrysolite variety is used in the manufacture of cloth, rope, felt, boards, tubes, washers, etc.

References.

Campbell, J. L. The Steatite, Mica, Fire-Clays, Barytes, Etc., of James River Valley. The Virginias, 1882, III, 160.

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4. GARNET.

Composition and Properties.

The garnet group comprises a half dozen mineral species which are essentially silicates of alumina with iron or lime, magnesia, manganese, and chromium. They crystallize in the Regular or Isometic system usually in the form of 12- and 24-faced crystals, known as the dodecahedron and the trapezohedron, with a hardness of from 6.5 to 7.5, and exhibiting a variety of color, the most common among which is some shade of red or brown. The specific gravity varies from 3.55 to 4.30. Probably the two most prominent species of garnet are *almandite,* the iron-alumina garnet, and *grossularite,* the lime-alumina garnet.

Garnet is a common mineral in many of the crystalline schists and gneisses, including those derived from sediments and from igneous rocks. It is ordinarily a subordinate constituent of these rocks although in some cases it becomes a chief constituent.

Distribution.

Garnet is a frequent constituent of many of the various types of crystalline rocks composing the Piedmont area, east of the Blue Ridge. Ordinarily it is only a minor constituent of the rocks in which it is found and, therefore, too sparsely disseminated to have commercial value. However, when of large enough size, or uniform color, and without fracture, it is of value as a gem. Very perfect and beautiful specimens of garnet have been collected from the pegmatite dikes in which mica has been mined near Amelia court-house, in Amelia county, and near Hewlett's station, in Hanover county. The former area has supplied a great many garnets to the trade, the particular species being the manganese-alumina garnet, *spessartite*.

An analysis of the spessartite from the Amelia county area, made by C. M. Bradbury, gave:

	Per cent.
Silica (SiO_2)	36.34
Alumina (Al_2O_3)	12.63
Iron oxide (FeO)	4.57
Manganese oxide (MnO)	44.20
Lime (CaO)	1.49
Magnesia (MgO)	0.47
Water (H_2O)	trace
Total	99.70
Specific gravity	4.20

An analysis by F. W. Clarke of spessartite from the mica mines of the same locality gave:

	Per cent.
Silica (SiO_2)	35.35
Alumina (Al_2O_3)	20.41
Iron oxide (Fe_2O_3)	2.75
Iron oxide (FeO)	1.75
Manganese oxide (MnO)	38.70
Magnesia (MgO)	none
Lime (CaO)	0.94
Ignition	0.27
Total	100.17

In Nelson county, about 4 miles south of Arrington, an attempt has recently been made to mine garnet in the high and steep bluffs along the northeast side of Tye river. Several openings have been made in a garnetiferous sericitic schist. The garnet is of dull red color, in well-defined crystals of small but variable size, and distributed irregularly through the schist. It is very abundant in some places and rather scant in others, a fact which seemingly indicates that the garnet is confined or limited to particular layers of the rock and not disseminated throughout all parts of it. It seems doubtful whether the garnet is sufficiently concentrated in the rock at this locality to be of commercial importance. As a gem mineral, garnet is described on pages 386-387.

Uses.

Garnet is used chiefly as an abrasive in the form of a sand for sawing and grinding stone and for making sandpaper. Its inferior hardness renders it of less value as an abrasive than corundum or emery. It is also used extensively as a gem, the use to which the Virginia garnet has been put.

References.

Clarke, F. W. Spessartite from Amelia County, Virginia. U. S. Geological Survey, Bulletin No. 60, 1890, 129.

Bradbury, C. M. Garnet (var. spessartite) from Amelia County, Virginia. The Virginias, 1885, VI, 25.

5. TALC AND SOAPSTONE.

COMPOSITION.

Talc, a hydrous silicate of magnesia, is rather a widely distributed mineral but rarely occurs in large quantities. It is characterized by extreme softness, being readily cut with a knife or scratched with the finger nail, soapy feeling and entire freedom from grit. Ordinarily it is distinctly foliated and of white, gray or greenish color.

The name soapstone (steatite an impure form of talc) is ordinarily applied to a dark bluish-gray, greenish rock composed essentially of the mineral talc. Like serpentine and talc it is a hydrous silicate of magnesia. It is never chemically pure but usually contains varying proportions of the minerals mica, chlorite, amphibole (tremolite), pyroxene (enstatite), together with quartz, magnetite, pyrrhotite, and pyrite. The stone is soft enough to be readily cut with a knife and has a pronounced soapy or greasy feel, hence, the name.

OCCURRENCE AND ORIGIN.

Talc is a secondary mineral representing the alteration product of other magnesia minerals such as tremolite, actinolite, pyroxene, or enstatite, and is frequently associated with talcose or chlorite schists, serpentine, and such basic igneous rocks as peridotite and pyroxenite.

Soapstone occurs chiefly associated with the older crystalline rocks. In some cases, it has been derived from an altered eruptive rock; in others, it has probably been derived from magnesian sediments by metamorphism. According to Keith, the soapstone found in Fairfax county, Virginia, was probably derived from the eruptive rocks peridotite and pyroxenite.

DISTRIBUTION AND LOCALITIES.

Talc.

The pure form of talc has only been met with in commercial quantity at one point in the State, namely, near Wiehle, a station on the Bluemont branch of the Southern Railway, in Fairfax county. The material is reported to be of a good grade of white foliated talc and is operated by a private party with a reasonably good annual production.

Soapstone.

Soapstone, the impure form of talc, has on the other hand rather wide distribution in the State, being limited to the area of older crystalline rocks, which compose the Piedmont region, east of the Blue Ridge. Deposits of soapstone have been noted in the following counties: Albemarle, Amelia, Amherst, Bedford, Buckingham, Campbell, Carroll, Fairfax, Floyd, Fluvanna, Franklin, Grayson, Henry, Louisa, Nelson, and Patrick. Many parts of the beds found in these various counties are of excellent grade, and the stone has been and is being quarried in at least six of the above named counties. As is noted in the table of production given on page 296, the quarrying of soapstone in Virginia has grown to be one of the important resources in the State, with every promise of greater expansion in the future.

FLUVANNA AND BUCKINGHAM COUNTIES.

In Fluvanna and Buckingham counties soapstone occurs west of the slate belt and is exposed near the mouth of Hardware creek. It was quarried on a small scale at this locality many years ago, strictly for local use as hearths, jambs, and other parts about chimneys. It was also made use of further east in the southern part of Fluvanna county at Bremo.

ALBEMARLE, NELSON, CAMPBELL, BEDFORD, AND FRANKLIN COUNTIES.

In Albemarle county, a little west of Green Mountain, is a belt of soapstone associated with micaceous schists, which is traced southwestward through Nelson into Campbell, Bedford, and Franklin counties. The belt widens in Nelson county and is associated with some serpentine. It passes thence as a narrow belt along the western base of Buffalo Ridge, in Amherst county, crossing the James river above Lynchburg, and is exposed about 2 miles west of the city on the road leading to Bedford City, and is exposed again 2.5 miles west of New London, in Bedford county. Continuing in the same direction, the stone is seen again at the meadows of Goose creek, where it has been quarried to some extent. Continuing still further westward it is exposed in several nearly parallel belts, of which the most eastern makes its appearance near Pig river in Franklin county. A second belt occurs in the same vicinity near the eastern base of Jack's Mountain; a third still further west about one mile from Rocky Mount; and a fourth yet more to the west on the eastern slope of Grassy Hill. The stone has been quarried in a small way at several places in Franklin county, near Rocky Mount, and used strictly for local purposes. Extensive quarrying operations are in force in the Albemarle-Nelson counties portion of the belt which is described in some detail below.

AMELIA COUNTY.

In Amelia county south of Chula and 4 miles N. 60° E. from Amelia court-house, occurs a belt of soapstone of good quality which was quarried quite extensively many years ago. A long opening was operated on the outcrop in the direction of the trend of the belt, which is N. 30° W., but is now fallen in and grown up in pine. Excepting huge boulders of the soapstone exposed in the bottom of the old opening, the rocks are entirely concealed beneath a heavy cover of decay. The width of the old opening, which probably represented the thickness of workable stone, will not exceed 50 feet.

A second belt of soapstone of good quality is found in Amelia county about 4.5 miles north of Jetersville, a station on the Southern Railway. The soapstone is exposed in numerous places on the north side of Flat creek in several parallel belts having a general northeast-southwest direction. Exposures of the rock along the roadside show a thinly foliated hornblendic schist, probably an altered diorite, and exposures of diabase are found in close association with the soapstone. On the head-waters of Walnut creek, a tributary to and on the north side of Flat creek, the soapstone has been quarried to some extent. Quarrying was begun in 1904, and during the summer of 1906, numerous smaller openings were put down on the belt on top of the hill several hundred yards northeast of the quarry on Walnut creek. The property, including the quarry and other openings, are controlled by a Philadelphia Company and preparations were in progress during the summer of 1906 to begin quarrying on an extensive scale.

LOUISA COUNTY.

A deposit of soapstone of very good quality occurs near Oakland in Louisa county. Some stone is reported to have been quarried but no systematic developments have yet been undertaken.

FAIRFAX COUNTY.

In Fairfax county, there are numerous deposits of soapstone and talcose schists, the former of which has been opened and quarried in a number of places. They form small bodies of lenticular shape in close association with eruptive rocks, especially the basic ones, and are common around the gabbro areas. According to Keith the soapstone consisting chiefly of impure talc was probably derived from pyroxenite composed of plagioclase and pyroxene. He suggests that rocks of more complex original nature are perhaps represented by the talcose schists.

The principal localities where these soapstone masses are found in Fairfax county are: Two miles east of Annandale, which is the largest area; 1 mile east of Tenley, the next largest body; and in the area east of Falls Church. All of these bodies have been worked to some extent and the stone used chiefly for local purposes. Considerable developments have been made in the large body east of Annandale and much stone has been quarried and sawed. The openings and outcrops show a thickness of 50 feet of soapstone. The rock is of good quality, even-grained, and of uniform light bluish-green color, without seams and schistose plains developed in it. Blocks of desirable size can be readily quarried.

GRAYSON COUNTY.

In Grayson county, in the vicinity of Mink Ridge south of Grant post-office, soapstone of good quality is reported. It is also found at other

points in the county and preparations are being made to quarry it in one or two places.

Professor Foutaine describes a belt of soapstone found 2.5 miles southwest of the Grayson Sulphur springs near the Carroll-Grayson counties line. It is reported to be of excellent quality, uniform composition, and compact texture. No foreign hard particles are contained in it and it may be planed and sawed with ease. It has a thickness of 8 feet, is traceable for 2 miles or more, and has been used locally about the fireplaces in the dwelling-houses.

CARROLL, FLOYD, AND PATRICK COUNTIES.

Currey mentions a thin seam of soapstone in Carroll county, beginning near Greeneville and extending north 54° east within 2 miles of Hillsville; thence through Floyd within 2 miles of the court-house. It forms large ledges in places, is soft and easily worked. A thin stratum of soapstone is reported by Currey on Colonel M. D. Carter's place in Patrick county, which, on account of its refractory nature, was used for hearthstones and other local purposes.

HENRY COUNTY.

In Henry county, near Spencer's store, quarries of soapstone were opened some years ago. The material was of excellent quality and blocks of any required dimensions were reported to have been quarried. These were sawn out and then finished by planing. They were used in the foundations of houses and for other purposes.

ALBEMARLE-NELSON COUNTIES SOAPSTONE BELT.

As described above, the Albemarle-Nelson Counties Soapstone belt lies a short distance west of Green Mountain and to the east, near and approximately parallel to, Hawkins, Findley, Ball, and Appleberry mountains. It is distant from this western line of mountains from a quarter to a half mile, and it has a general northeast-southwest direction. It further roughly parallels the main line of the Southern Railway and is distant therefrom 3 to 5 miles. Quarries have been opened on the belt at numerous points with an extreme distance between the two end quarries on the northeast and southwest of nearly 30 miles. At many places where quarries are opened, the belt is apparently separated into several (three) parallel members locally called "veins". The spacing between the different members or beds is quite variable with a probable extreme of from 500 to 800 feet. The deposits dip usually to the southeast in conformity with the enclosing rocks and at one point where the beds were favorable for measuring the dip was found to be 60°.

So far as they were measurable at the surface from the more or less altered rock and quarry openings the thickness of the separate parallel deposits of soapstone varies from 30 feet to 165 feet. A few of the quarries are opened at the point of greatest thickness of stone but the entire thickness is not worked. The ratio of worked stone to the total thickness at several localities varies as follows: Total thickness 120 feet, working thickness 100 feet; total thickness 150 feet, working thickness 75 feet; total thickness 125 feet, working thickness 65 feet. The above figures do not indicate that of the total thickness, only the width of the present workings represents the total workable stone, but that the present conditions do not warrant the working of a greater thickness.

The stone varies from light bluish-gray to darker greenish-gray and from very soft to a hardness greater than that of scratching with the thumb nail. It is not penetrated by seams and the jointing is usually sufficiently far spaced to admit of any size blocks being readily quarried. It is compact, of fine texture, and uniform, both in texture and color. A sprinkling of pyrite occurs in places but it is rarely in sufficient amount to be harmful to the stone. The stone is of excellent grade and is admirably suited for the various uses made of it.

The enclosing or associated country-rock is a variable crystalline schist. In mineral composition variation is from a typical mica-quartz schist of thin and irregular foliation to a micaceous sandstone or quartzite which may be close crinkled, or may be thin, or moderately thick and straight banded. In the Albemarle portion of the belt, a black graphitic schist is associated with the mica-quartz schist on the east side of the soapstone belt, and at several points further southwestward, the association is with an altered basic eruptive rock.

This belt, which is being actively operated at the present time, practically composes the soapstone industry in Virginia. As seen from the table of production given on page 296, the output in stone is large, and Virginia ranks as one of the largest soapstone-producing states. During the summer of 1906, there were 8 quarries producing and beginning to produce stone in this belt. Two of the most extensively worked quarries have reached depths of 120 and 130 feet, respectively. The quarries operating

Fig. 1.—View in soapstone quarry in Nelson county.

Fig. 2.—View in soapstone quarry in Nelson county.

SOAPSTONE QUARRIES IN VIRGINIA.

Fig. 1.—Partial view of the Schuyler Soapstone Company's plant, at Schuyler, Nelson county.

Fig. 2.—View in the National Soapstone Company's quarry, Nelson county.

SOAPSTONE QUARRIES IN VIRGINIA.

in this belt beginning with the most southwesterly one in Nelson county are as follows:

Name	County
The Piedmont Soapstone Company	Nelson
The Phœnix Soapstone Company	"
The American Soapstone Company	"
The National Soapstone Company	"
The Plumbers Soapstone Company of America	"
Virginia Soapstone Company	"
The Old Dominion Soapstone Corporation	Albemarle
Albemarle Soapstone Company	"

Map, plate XLII, shows the location of the above quarries in the Albemarle-Nelson counties belt. Plates XLIII, XLIV, XLV, and XLVI, show views in the various quarries located on this belt of soapstone.

The larger quarries in this belt are well equipped with all necessary modern machinery for getting out the stone. Channelling machines are used in quarrying the rock. At each quarry is located a commodious mill for sawing, dressing, rubbing and polishing the stone and other machines for grooving and drilling holes. The entire product of one or two of the plants goes into the manufacture of laundry tubs, where polishing is unnecessary and hence polishing machinery is not installed.

The excellent quality of the stone from this belt is adapted to a wide range of uses. The principal ones include laundry tubs, sanitary purposes, electrical purposes, sinks, and cooking utensils. The mill of the Albemarle Soapstone Company, located 4 miles southeast of North Garden, is the most extensive in the South and it manufactures a much greater variety of products for utilization than any other. It has a very extensive stockyard where a large stock of the manufactured material is kept on hand. The product from this plant is marketed over the entire United States and in many foreign countries including Germany, France, England, South America, and Mexico.

Uses.

Soapstone is one of the most durable of rocks, but on account of its sombre color, greasy or soapy feel and softness, it is undesirable for general structural purposes. Because of its ready workability due to softness, insolubility and heat-resisting qualities, it is suited for a considerable range of application. Most of the soapstone quarried at the present time is used chiefly in the manufacture of wash or laundry tubs, electric switchboards and insulators, and laboratory sinks. It was formerly used to some extent for the manufacture of stoves for heating purposes, and to some extent for fire brick, the well-seasoned stone being thoroughly fireproof, but in recent years its use for these purposes has not been so great. The waste material from the quarries or, in some cases, the entire output, is pulverized and used as a lubricant. The principal use made of the Virginia soapstone is given above. Much of it was formerly used in the manufacture of slate pencils but very little, if any, is now used for this purpose.

Production.

The production of talc and soapstone in Virginia is given for the years 1898 to 1905 inclusive.

Year	Quantity Short tons	Value $
1898	10,059	119,480
1899	10,886	107,062
1900	9,806	116,930
1901	12,511	232,900
1902[1]	13,221	372,163
1903[1]	13,118	243,552
1904[2]	17,625	339,928
1905[2]	21,700	499,780

(1) Includes Maryland.
(2) Includes North Carolina.

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6. FULLERS EARTH.

Definition and Properties.

Under the term fullers earth is included a variety of clay-like materials which have the property of absorbing greasy substances. The materials are prevailingly greenish-white or gray, olive or olive-green, or brownish in

Fig. 1.—View in one of the Alberene soapstone quarries, Albemarle county, illustrating weathering of soapstone.

Fig. 2.—View in one of the Alberene soapstone quarries, Albemarle county.

SOAPSTONE QUARRIES IN VIRGINIA.

Fig. 1.—View in a recently opened soapstone quarry in Nelson county.

Fig. 2.—Limestone quarry of the Mathieson Alkali Works, near Saltville.

SOAPSTONE AND LIMESTONE QUARRIES IN VIRGINIA.

color. They resemble clay superficially, but differ from it usually, by having lower plasticity and a higher percentage of combined water in proportion to the alumina content. Chemical analysis is usually of little value, and a practical test is necessary in order to determine its worth.

Distribution and Localities.

Fullers earth has been reported from a number of localities in eastern or Tidewater Virginia (Coastal Plain) but as yet it has not been investigated and very little is known of it in Virginia. Darton has mentioned its occurrence in Westmoreland and Richmond counties, Virginia, and St. Mary's county in Maryland. He says:

"Eastward in the Chesapeake formation the beds of infusorial or diatomaceous remains are often sufficiently pure for commercial use as "fuller's earth". The largest deposits are near the base of the formation, and they are best exposed in the bluffs along the Potomac at the mouth of Pope Creek, Maryland, where at one time they were working for shipment. The deposits underlie the western part of Westmoreland, Richmond, and St. Mary counties and the southeastern part of Charles County, and they are exposed at many points along streams and in road-cuts. The purity of the material is diminished in some portions of the district by admixture with clay or sand, but over much of the area there are large supplies of relatively pure deposits."

Professor Rogers refers to the beds of infusorial or diatomaceous earth in the Tertiary formations around Richmond as having been regarded as a fine clay or fullers earth.

Uses.

The material was formerly used chiefly by fullers for removing grease from cloths. It is now principally used in deodorizing and clarifying fats, oils, and greases.

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VI. NIOBATES AND TUNGSTATES.

1. COLUMBITE.

The mineral columbite, a niobate and tantalate of iron and manganese, occurs in the mica mines of Amelia county with microlite in fine crystals, but so far as is known not in sufficient quantity to be of commercial value. Except as mineralogical specimens and in the preparation of the salts of columbium and tantalium the mineral has but little demand.

An analysis of the columbite from Amelia county gave Professor Dunnington the following results:

	Per cent.
Nb_2O_5	31.40
Ta_2O_5	53.41
SnO_2	trace
FeO	5.07
MnO	8.05
CaO	1.27
MgO	0.20
Y_2O_3	0.82
Total	100.22
Specific gravity	6.48

2. SIPYLITE.

The mineral sipylite, the niobate of erbium chiefly with the cerium metals, has been described by Dr. J. W. Mallett as occurring sparingly at the northwest slope of Little Friar Mountain in Amherst county.

An analysis of the mineral from this locality by Professor W. G. Brown gave:

	Per cent.
Nb_2O_5	48.66
WO	.16
SnO_2	.08
ZrO_2	2.09
Er_2O_3	27.94
Ce_2O_3	1.37
La_2O_3	3.92
Di_2O_3	4.06
UO	3.47
FeO	2.04
BeO	.62
MgO	.05
CaO	2.61
Na_2O	.16
K_2O	.06
H_2O	3.19
MnO	——
Li_2O	trace
Total	100.48

3. WOLFRAMITE.

The mineral wolframite, a tungstate of manganese and iron, occurs in the Blue Ridge in the extreme northeastern part of Rockbridge county at Irish creek, in association with the tin ore, cassiterite. It is not known whether the mineral occurs at this point in any quantity. The principal use made of the mineral wolframite, when found in sufficient quantity, is for tungsten, which is utilized chiefly in the manufacture of the so-called self-hardening steel. The material is introduced either as a ferro-tungsten or as the powdered mineral.

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VII. PHOSPHATES.

1. APATITE AND PHOSPHATIC MARL.

Like most of the mineral deposits of Virginia the phosphate deposits await investigation. So far as we have knowledge of these, three forms of phosphatic material are found, the first type of which occurs in the Coastal Plain region and includes the phosphatic marls described on pages 397-399; the second in the Blue Ridge region and includes a phosphatic rock composed of apatite and ilmenite; the third in the Paleozoic sediments west of the Blue Ridge and includes a pebble phosphate.

The Coastal Plain phosphatic material is discussed, so far as we have knowledge of it, under Marl on pages 397-399.

NELSONITE (PHOSPHATE ROCK).

A unique and interesting as well as extensive occurrence of phosphatic material is noted at two localities in the Blue Ridge region, namely, in Nelson and Roanoke counties. The rock is closely identical in the two localities; that occurring in Nelson county being known for many years, and has been extensively prospected on many farms, while that in Roanoke county has only recently been noted but actively prospected. For this type of rocks, I have elsewhere proposed the name *Nelsonite,* for the name of the county in which it was first found.

Nelson County.

The phosphate rock in Nelson county occurs in the foot-hills of the Blue Ridge, near Roseland, about 7 miles northwest of Arrington, a station on the Southern Railway, and again 5 miles northeast of Roseland at Bryant's post-office. (Map, figure 38.) It is found at a distance of from a quarter to a half mile west of Roseland on both sides of Tye river, and has been traced for a distance of 2 miles southwest of the river on the Giles place and in a northeastward direction to a point about half a mile east of Bryant, giving a total distance of about 7 miles along a northeast-southwest direction, as shown in figure 38, on page 233.

When fresh, the phosphatic material is a hard rock composed of granular white apatite and black ilmenite. It has been extensively prospected near Roseland and Bryant by means of pits, open cuts, and shafts; and near Roseland by numerous additional diamond drillings. The deepest shaft is reported to be about 65 feet and the drillings were put down to a depth of 150 feet and more.

Open cuts made near Roseland and Bryant afford some information as to the mode of occurrence of the apatite-ilmenite rock. At both places, the rock exposed in the cuts shows dike-like characters in relation to the enclosing decayed gneisses and schists. As nearly as could be determined it conforms approximately to the structure of the enclosing schistose rocks with sharply defined contacts on the two sides. The greatest exposure in the cuts, which was at Bryant post-office, gave a width of the apatite-ilmenite rock (Nelsonite) from wall to wall of 8 feet. (Figure 43.) Greater widths than this are shown at places on the surface by the weathered outcrops of the phosphatic rock.

The rock is penetrated by several sets of intersecting, closely spaced joints, which break it into small blocks when struck with the hammer. The ratio of apatite to ilmenite is variable, ranging from a rock composed of dominant apatite to one composed of dominant ilmenite, with all intermediate gradations.

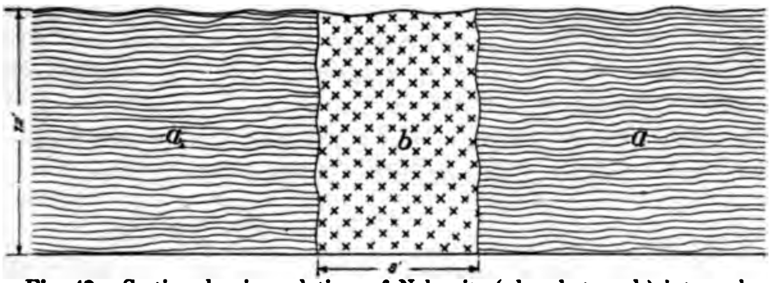

Fig. 43.—Section showing relations of Nelsonite (phosphate rock) *b* to enclosing schists *a*, in open cut near Bryant, Nelson county.

The Virginia Phosphate and Paint Company was organized some years ago for the purpose of working the rock near Roseland for the phosphate which it contains. Should some extended use be found for the mineral ilmenite, these deposits will be of considerable commercial value both for the phosphatic mineral apatite as a source of phosphoric acid and the mineral ilmenite.

Roanoke County.

About 2 miles east of Vinton and 4 miles east of Roanoke, a similar deposit of the apatite-ilmenite rock (Nelsonite) to that described above in Nelson county, is found occurring on the Valley side and near the base of the Blue Ridge, at an elevation of about 1150 feet above sea-level. Like the Nelson county deposit, the Roanoke county mass shows similar dike-like characters and its traceable on the outcrop in the direction of strike for some distance. It occurs near the contact of the Valley limestone of Cambro-Ordovician age and the crystalline rocks of the Blue Ridge.

Although found less than two years ago, the rock has been extensively prospected on a number of adjoining farms by shafts, pits, and open cuts, for the purpose of ascertaining its value as a source of phosphate. Specimens of the rock show a considerable preponderance of apatite over ilmenite.

PEBBLE PHOSPHATE.

Doctor R. S. Bassler, of the U. S. National Museum, noted, during some recent field studies in Virginia, the occurrence of phosphatic nodules at the base of the black shale (Romney) of Devonian age, at Clifton Forge. In a private communication to me, Dr. Bassler states that the noting of the occurrence of these phosphates at Clifton Forge was purely incidental. Thus far only the concretionary or conglomeratic phase of the phosphate has been noted in Virginia. Since no special search has yet been made for these phosphates in Virginia, it is not possible to predict whether commercial deposits of them exist or not.

An analysis of one of the phosphate pebbles from conglomerate layer at the base of Romney shale, at Clifton Forge, Virginia, gave:

	Per cent.
Insoluble matter	25.26
Organic matter	.32
Ferric oxide	1.21
Alumina	1.04
Lime	30.86
Magnesia	.27
Phosphoric anhydride	27.62

2. DUFRENITE.

The mineral dufrenite, an hydrous phosphate of iron, is found in Rockbridge county where it forms radiated coarsely fibrous masses of a dark greenish brown color, forming an irregular bed of about 10 inches in depth, underlying limonite.

Analyses of the dufrenite from Rockbridge county, made by Professor J. L. Campbell and Mr. Massie, gave the following results:

	Massie Per cent.	Campbell Per cent.
Ferric oxide (Fe_2O_3)	50.89	50.85
Ferrous oxide (FeO)	6.30	6.14
Phosphoric oxide (P_2O_5)	31.66	31.76
Water (H_2O)	8.35	8.53
Alumina (Al_2O_3)	0.25	0.21
Magnesia (MgO)	2.16	0.76
Lime (CaO)	——	1.12
Manganese oxide (MnO)	0.24	0.40
Silica (SiO_2)	0.20	0.12
Total	100.05	99.89

3. STRENGITE.

Dr. Koenig has described the mineral strengite, an hydrous ferric phosphate, as occurring in distinct crystals in cavities in dufrenite in Rockbridge county. He gives the following analysis of this mineral from Rockbridge county, Virginia:

	Per cent.
Iron oxide (Fe_2O_3)	42.30
Phosphoric oxide (P_2O_5)	39.30
Water (H_2O)	19.87
Total	101.47

4. MONAZITE.

Monazite, essentially an anhydrous phosphate of the rare earths of the cerium group containing usually a variable amount of thorium, which element gives the mineral its commercial value, has been found only in one locality in the State, namely, Amelia county. The mineral occurs at the mica mines near Amelia court-house in large coarse crystals and masses in association with microlite etc., but not in commercial quantity.

Analyses of monazite from Amelia county, Virginia, gave:

	Per cent.	Per cent.
Phosphoric acid	24.04	26.12
Cerium oxide (Ce_2O_3)	16.30	29.89
Lanthanum oxide (La_2O_3)	10.30	——
Didimium oxide (Di_2O_3)	24.40	26.66
Yttrium and erbium oxides	1.10	——
Silica (SiO_2)	2.70	2.85
Thorium oxide (ThO_2)	18.60	14.23
Iron oxide (Fe_2O_3)	0.90	——
Alumina (Al_2O_3)	0.04	——
Ignition	——	0.67
Total	98.38	100.42
Specific gravity	——	5.30

The principal use made of monazite is in the manufacture of electric and incandescent lamps.

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VIII. NITRATES.

1. NITER; POTASSIUM NITRATE.

General properties and occurrence.—Potassium nitrate, known commercially as niter, when pure, is white in color, subtransparent, and tastes saline, and cooling. It dissolves readily in water and deflagrates vividly on burning coals. Hardness, 2; specific gravity, 2.09 to 2.14.

The mineral usually occurs in minute needle-like crystals and as crusts on the surface of earth and rocks; and scattered in the loose soil of limestone caves and similar dry and protected places.

Distribution.—In Virginia, niter is limited to some of the numerous caves and caverns in the Shenandoah limestone of Cambro-Ordovician age, of the Valley province, on the west side of the Blue Ridge. It is found mingled with the earth in many of the caves of the Valley region and has been procured from time to time in considerable quantities from this source, although there is no actual production. As found in the Virginia caves, the niter is often of impalpable fineness and, at times, contains a considerable quantity of the lime salts.

Concerning the origin of the niter earths in the caves of the middle and southern states, Professor Rogers states that the niter was chiefly derived from the overhanging and adjacent rocks and not from sediment brought in to the cave by existing or former streams. This view has been confirmed by more recent study of the source of nitrates in cave earths.

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IX. SULPHATES.

1. BARITE; HEAVY SPAR.

COMPOSITION AND PROPERTIES.

The sulphate of barium, known as the mineral barite or heavy spar, is, when pure, a heavy white mineral with perfect prismatic cleavage, translucent to transparent, and about as hard as common calcite, from which it can be distinguished by its greater weight and its not effervescing with acid. It is found in granular, compact and earthy masses, and in single and clustered, broad and stout crystals. In nature it is rarely pure, but is nearly always contaminated with other substances, the most common of which, in the commercial deposits, are manganese and iron oxides, limestone, sand, and clay. It is known commercially as barytes.

HISTORICAL.

Barite is found and has been mined for many years in various parts of Virginia. Probably the earliest mining of this mineral in the State was in Prince William county, within 200 yards of the Fauquier county line, about 4 miles south of east from Catlett, a station on the Southern Railway. It is claimed that the mineral was mined here as early as 1845.

Developments in Campbell and Pittsylvania counties in the Piedmont region, and near Marion, in Smyth county, southwest Virginia, were begun since the close of the Civil War. Mining operations were begun in these two areas at about the same time, dating back about 30 years. Mining and milling of barite in Tazewell and Russell counties on a commercial scale are more recent, and commenced about 15 years ago.

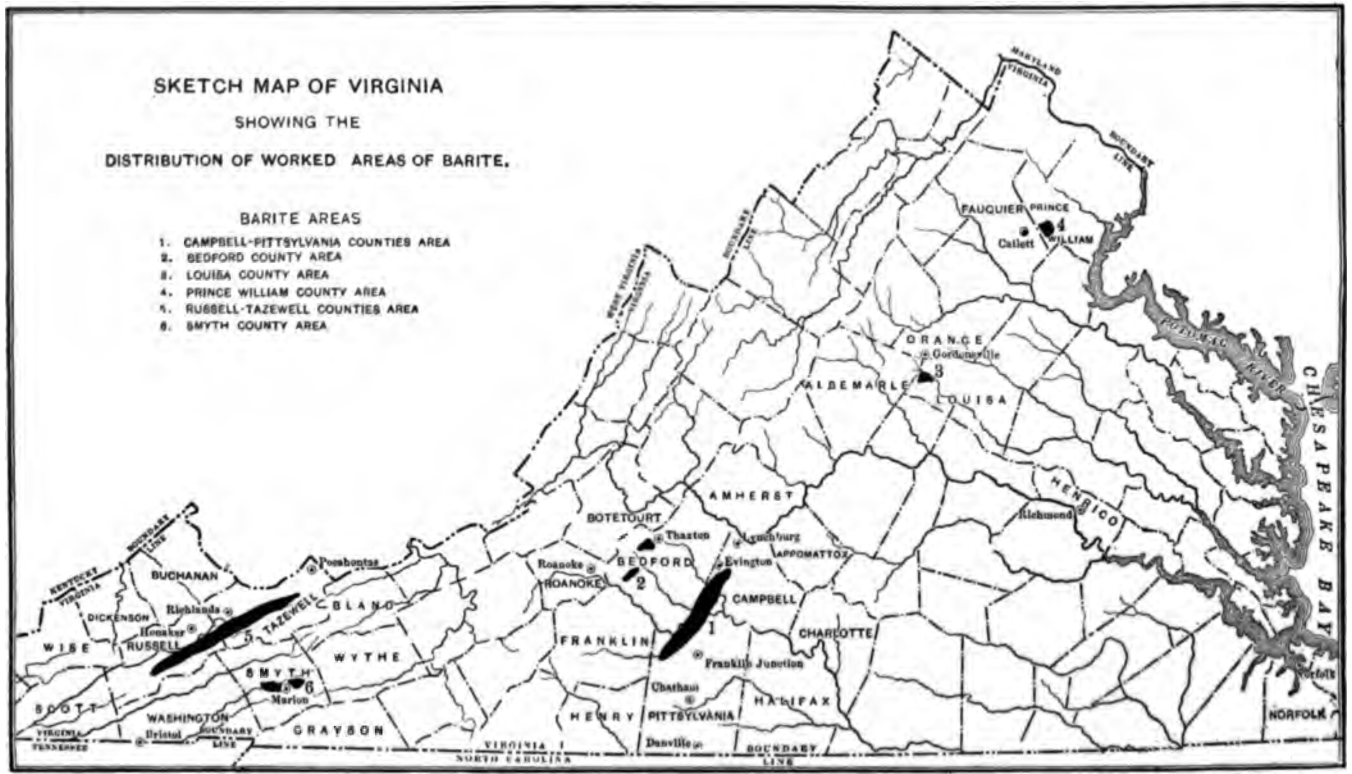

Fig. 44.—Sketch map of Virginia showing distribution of worked areas of barite. (After Watson, Trans. A. I. M. E.)

DISTRIBUTION.

Barite is found in a large number of counties in the State but the industry has been confined to only a few of them. (Map, figure 44.) The counties in which barite is found in the State, are (1) those which lie east of the Blue Ridge in the crystalline area or Piedmont province and include Bedford, Campbell, Pittsylvania, Nelson, Buckingham, Amherst, Orange, Louisa, and Prince William; and (2) those counties which lie west of the Blue Ridge and are in the Paleozoic sediments of the Mountain region and comprise Tazewell, Russell, Bland, Wythe, Washington, Scott, Smyth, Montgomery, Botetourt, Rockbridge, Warren, and Frederick. Of these, Bedford, Campbell, Pittsylvania, and Prince William, of the Piedmont province; and Smyth, Tazewell, and Russell of the Mountain province have practically yielded the entire production of the State. In 1906, operations were confined to five counties, namely, Bedford, Louisa, Pittsylvania, Russell, and Tazewell. In Bedford and Louisa counties there was no production, the work being in the nature of development preparatory to shipping.

Geologically, the barite deposits in Virginia are grouped into three unlike areas: (1) Those deposits in the red shale-sandstone series of Triassic age; (2) those of the crystalline metamorphic area; and (3) those of the Mountain region, associated for the most part with the Shenandoah limestone or its residual decay. (1) and (2) compose the Piedmont province which stretches eastward from the Blue Ridge.

GENERAL OCCURRENCE.

Barite is a frequent accompaniment of metallic ores, but as such it has not proved of any value commercially. As a rule, the deposits which have been worked for barite alone are associated with limestone as pockets or lenticular masses, and it follows the structure of the rock with which it is associated. In the Virginia localities which have yielded commercial quantities of barite, the mineral is associated with limestones, largely in the nature of a replacement. In southwest Virginia and elsewhere in the Mountain region, where the barite occurs in the limestone, it is often found as superficially loose lumps and nodules of irregular shapes and sizes embedded in residual clays derived from the decay of the limestone.

In Bedford, Campbell, and Pittsylvania counties of the crystalline area, a part of the ore has a similar occurrence in a dark manganiferous and ferruginous clay, locally known as umber, which is derived from the decay of the more or less impure calcareous rocks. At other points in Piedmont

Virginia, the occurrence of barite is in siliceous crystalline rocks, remote, so far as known, from calcareous masses. One of the best illustrations of such an occurrence is near Thaxton, in Bedford county, where the barite fills an irregular fracture in a coarse-textured granite. The local differences in the mode of occurrence of barite in Virginia are best brought out in the description of the three geologically unlike areas below, in which deposits are found.

THE TRIASSIC AREA.

As yet only one deposit of barite of commercial importance has been developed in the somewhat extensive areas of Triassic rocks occurring east of the Blue Ridge. About 4 miles south of east from Catlett station, in Prince William county, and within 200 yards of the Fauquier county line, barite has been mined at different times since its opening in 1845. It was last worked in 1903 with a production of 1,500 tons of ore. The opening of this deposit probably marks the first barite mining in Virginia.

The property is developed by 3 shafts and a number of open cuts with the greatest depth reached in mining 108 feet. The grinding and preparation of the ore for market were conducted in a mill built for that purpose at the openings. This mill was afterwards burned, and in its place now stands a partly completed crushing-house, located near the main shaft, as shown in plate XLVII, figure 1.

The geological position of this deposit is within the eastern margin of the red shale-sandstone series of the Triassic area, which crosses the Potomac river west of Washington and terminates abruptly south of Culpeper, the Virginia portion of the New York-Virginia area as defined by Russell. The rocks of the immediate barite locality consist of ferruginous red sandy shales and a light-colored crystalline limestone. The measured dip at numerous places west of the mine gave 10° to 15° west of northwest. Between Catlett station and the mine, the shales are penetrated by occasional diabase dikes.

Much of the material composing the dumps at the mine is a limestone breccia, in which red shale fragments are cemented by an impure crystalline limestone. Fractures are frequent and are filled with barite and occasionally with calcite crystals. These facts suggest that the barite deposit occupies a crushed or fractured zone in the Triassic rocks induced, probably, by faulting, although no evidence for such is apparent on the surface. The very gentle northwestward dips of the rock would preclude folding as a possible cause of the crushing. Faulting is a characteristic structure of the Virginia Triassic areas, and indeed of the same areas,

Fig. 1.—Barite mine in Prince William county, near Catlett station on Southern Railway.

Fig. 2.—Shaft at barite mine in Prince William county, near Catlett station on Southern Railway.

BARITE MINE IN PRINCE WILLIAM COUNTY, VIRGINIA.

further north, and it seems reasonable to ascribe the brecciation in the Prince William county barite locality to faulting.

The barite is associated with both the red shales and the impure limestone, usually as a deposition product from solution, filling fractures in the red shales. The widest of the barite-filled fractures are reported to be 4 to 8 feet and these form the chief source of the minable mineral. The barite also occurs as thin tabular cleavable masses in the limestone. It is of good white grade, both finely and coarsely crystalline massive, and judging from the ore on the dumps, quite free from most of the common impurities, especially manganese. It is reliably reported that the association of ore with limestone increases in depth.

THE PIEDMONT PLATEAU REGION.

Barite is reported found in the following counties of the Piedmont region east of the Blue Ridge: Campbell, Bedford, Pittsylvania, Nelson, Buckingham, Amherst, Louisa, and Orange. Also it is found near Marshall and Upperville in the crystalline rocks of Fauquier county, west of the Triassic area described above. Practically the total production of barite in the crystalline area has been from 3 counties, namely, Campbell, Bedford, and Pittsylvania. In these counties the ore has been mined for 30 or more years. Prospects in some of the other counties mentioned above in the crystalline area, where the mineral is known to occur, promise well, and, doubtless, further developments in the future will prove the existence of deposits of commercial importance. Exploitation of the mineral in the crystalline area should be especially directed in those localities where lenses or bands of limestone are found and indications of the mineral exist.

The Campbell-Pittsylvania Area.

Beginning in the middle-western portion of Campbell county, a few miles east of Evington, a station on the Southern Railway, and about 15 miles south of Lynchburg, a belt of barite deposits is traced southwestward to 3 or more miles south of Sandy Level in the northwestern part of Pittsylvania county, a distance of about 30 miles. Numerous openings have been made at different points on the belt, many of which have been extensively worked and have produced large quantities of excellent ore. Figure 45 is a sketch map of the belt showing the various openings made. It will be observed that the belt is near the Southern Railway for its entire distance, which offers abundant facilities for shipping the ore. At every point opened, the barite is reported to have outcropped on the surface.

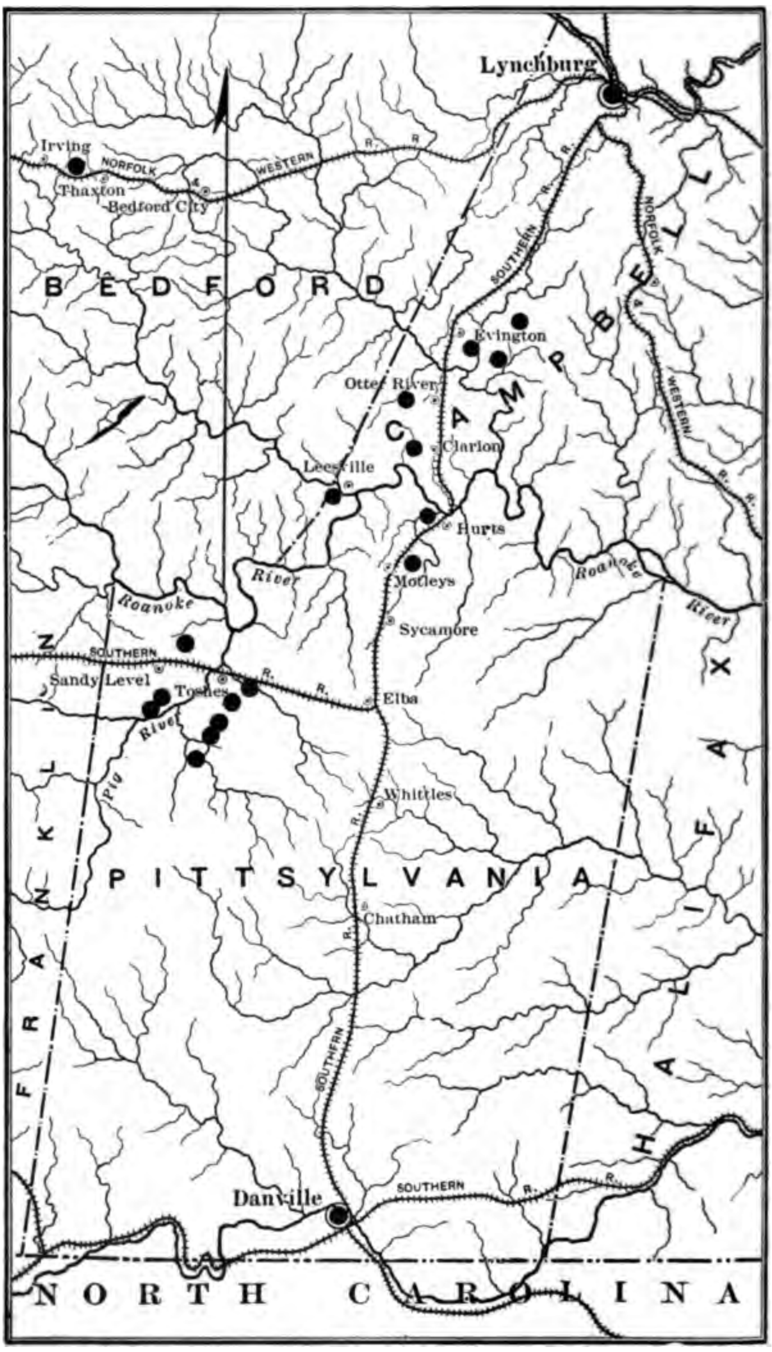

Fig. 45.—Map showing location of the principal barite mines in the Bedford-Campbell-Pittsylvania counties area. (After Watson, Trans. A. I. M. E.)

The most extensively worked deposits on the belt are grouped about two centers which occupy the northeast and southwest extremities of the belt, namely, Evington in Campbell county, and Toshes and Sandy Level in Pittsylvania county. Operations were begun in the two counties within a short time of each other, with probably the Hewitt mine in the vicinity of Evington the first to open, which dates back to 1874. The mines in the vicinity of Toshes and Sandy Level in Pittsylvania county were opened not less than 25 years ago. and in both counties, the mines have been operated almost continuously from the beginning to the present time.

In Campbell county, the principal mines are the *Hewitt, Saunders, Phillips,* and *Anthony* grouped near together and within a few miles east and southeast of Evington. Of these the *Hewitt* has been the most extensively worked. It is located on the west side of Flat creek, about 2.5 miles from Evington, and about the same distance from the *Saunders* and *Phillips mines.* It was worked almost continuously from 1874 until 3 years ago, when it was abandoned on account of water. It is developed by numerous shafts and drifts with the greatest depth reached in mining about 160 feet. This is some depth below the local water-level, making it necessary to pump the water from the openings, which was troublesome and finally led to suspension of work. At the openings the foliation of the rocks strikes N. 55° E. and dips quite steeply to the southeast. The limestone, with which the ore is associated, has a thickness of about 60 feet and is underlain by a quartzite schist on the northwest side, locally designated the foot-wall, and overlain by a thinly foliated mica-schist on the northeast side, locally called the hanging-wall. As described above, here and elsewhere in this belt, the ore occurs as irregular bodies replacing the limestone, and as irregular rounded nodules and masses in a black manganiferous and ferruginous clay, locally called umber.

The *Saunders* and *Phillips* mines are located on adjoining properties, opened on the crest of a well-defined northeast-southwest ridge on the east side of Flat creek and about 3 miles east of Evington. The developments comprise shafts, pits, and tunnels, the deepest one of which does not exceed 100 feet. The first openings were made about 20 years ago. The rock associations are identical with those described at the *Hewitt mine.* Strike of the schist is N. 30° E. and dip N. 60°-65° W. About 2 miles southwest of the *Saunders mine* is the *Anthony mine,* which has produced considerable ore.

The barite area in the extreme northwest corner of Pittsylvania county has been more entensively worked than that of any part of the belt. It has been developed by a large number of mines, which are grouped in two nearly parallel belts on either side of Pig river and just south of its entrance into Roanoke river. Beginning at the northeast end of the easternmost belt trending approximately northeast-southwest, it has been

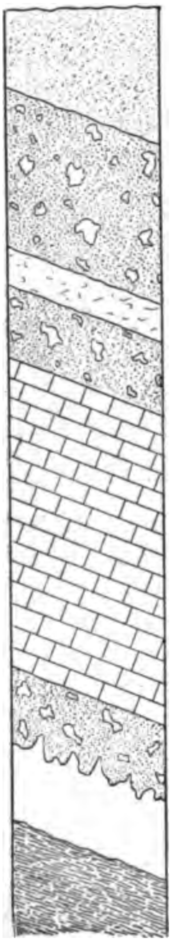

Fig. 46.—Generalized columnar section at the Bennett barite mine, Pittsylvania county. (After Watson, Trans. A. I. M. E.)

developed by the following mines which are aligned along the strike of the rock, *Berger, Ramsey, Bennett, Parker, Thompson,* and *Dryden Wright.* This belt is three-quarters of a mile east of Toshes, a station on the Rocky Mount division of the Southern Railway. The second or westernmost belt is developed by the *Tom Wright mine*, 1 mile east of Sandy Level, a station 3 miles west of Toshes on the Southern Railway and by the *Hatchet, Mease* and *Davis mines* southwest of Sandy Level. The *Davis mine* is the most southwesterly one and is 3 miles from Sandy Level.

The *Thompson mine* is reported to have been the first one opened in the area, followed by the *Parker, Berger, Bennett,* and *Ramsay,* in the order named. The first four of these were worked more than 25 years ago and the production of barite from each mine was very large and of

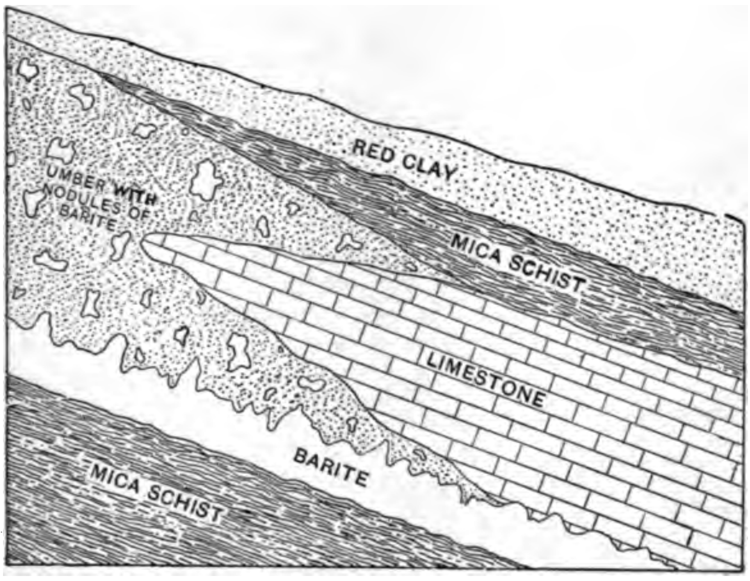

Fig. 47.—Section at the Bennett barite mine, showing mode of occurrence of the barite and its relations to the rocks. (After Watson, Trans. A. I. M. E.)

excellent grade. Except the *Bennett,* which is operating at present, they have all been idle for some years and very little could be seen at the time of my visit in September 1906. The ore from the Campbell-Pittsylvania area is shipped to the city of Lynchburg, Virginia, nearby, where it is cleaned and ground preparatory to shipping.

The mines were developed by numerous shafts and drifts and some open work. The greatest depth yet reached in mining is 120 feet, the depth of the working shaft at the *Bennett mine.* A description of the *Bennett mine,* one of the most extensively worked in the district and the only one in operation in 1896, may be taken as typical of the area.

The rock succession at the *Bennett mine* is shown in figure 46, which represents a vertical section made of the 120-foot shaft. As shown in this figure and also in figure 47, the wall rock is a coarse-grained, thinly foliated mica schist intersected by pegmatite dikes, composed of coarse crystallizations of feldspar and quartz. The fresh mica schist is shown in the bottom of the shaft where it is penetrated for a depth of 20 feet, the overlying rock being a black manganiferous and ferruginous clay, thinly foliated, and derived from a calcareous schist in composition. A similar black clay also underlies the limestone occurring between it and the fresh mica schist. The limestone, which is a white coarsely crystalline marble and charged to a small extent with both sulphide and silicate minerals, is 40 feet thick and occurs between the two layers of black clay.

The ore, barite, is associated with both the limestone and the black clay, in part as a replacement of limestone and as irregular rounded masses and nodules in the over- and under-lying clays. The largest concentration of ore is between the limestone and the schist and has an average thickness of about 10 feet. The contact between the barite layer and the limestone is very irregular, the ore often penetrating far into the limestone, as shown in figure 47. The lower contact between the barite and the mica schist is sharply contrasted with that made with the limestone and is sharply defined and quite regular. The barite is massive granular, moderately coarsely crystalline, and of good white color. Five grades of the ore are made and marketed.

Other Prospects.—Openings have been made and some ore mined at the following localities between the two developed areas of this belt: One mile northeast of Motley's station on the Vaughan place; near Hurt station on Major John L. Hurt's place; about 3 miles southwest of Hurt's on the Hamner place; one mile west of Lynch's station. Also 3 miles southwest of the *Hewitt mine*, the *Maddox mine* was operated about one mile southwest of Otter River station. Barite of good quality and in large quantity was mined here, but it has not been worked in recent years on account of water, which makes the mining too expensive.

MODE OF OCCURRENCE.

At the various openings made along the Campbell-Pittsylvania belt the ore was exposed at the surface. Two characteristic occurrences of the barite are observed, always in association and equally as strongly emphasized in one part of the belt as in the other. The first and principal occurrence is in intimate association with the crystalline limestone as irregular lenticular bodies or pockets, which measure 100 to 200 feet or

Fig. 1.—The Bennett barite mine, near Toshes, Pittsylvania county.

Fig. 2.—Opening from which gypsum was mined, near salt plant, Saltville.

BARITE AND GYPSUM MINES IN VIRGINIA.

more, replacing the limestone. At the Hewitt mine, in Campbell county, some of the barite pockets were reported entirely enclosed by limestone. The ore observes the same coarsely crystalline massive structure as characterizes the limestone, and in several places gradation of the ore into the limestone has been observed. For the depths attained in mining immediately below and above the limestone is a variable thickness of a nearly black clayey mass, usually foliated and colored black from manganese oxide, derived from the decay of limestone schist. Through this black clayey mass is usually distributed in irregular fashion lumps and nodules of barite of large and small size. Occasionally barite stringers of slight thickness are formed along the foliation planes of the clay. Figures 46 and 47 illustrate the different occurrences described above.

ASSOCIATED ROCKS.

The principal rocks of the barite belt in Campbell and Pittsylvania counties are crystalline schists with intercalated thin beds of coarsely crystalline limestone. Of the former, two distinct types are differentiated, namely, mica and quartz schists. The immediate rocks with which the barite is associated are marked by the essential absence of feldspar. The schists are composed of mica with minimum quartz, and they otherwise bear all the ear-marks of altered sediments, without the slightest suggestion of derivation from original igneous masses. Undoubted igneous rocks of basic composition occur near Toshes depot in the vicinity of the Bennett mine. Again, an irregular biotite gneiss of granitic composition is found within three-quarters of a mile northeast of the same mine; the origin of this gneiss, whether sedimentary or igneous, has not been determined.

In the Evington portion of the belt, the underlying rock immediately in contact with the limestone masses on the northwest side is a fine-grained quartzite schist of considerable purity, and containing small brightly reflecting scales of white mica developed mostly along the planes of schistosity. The rock immediately in contact with the limestone lenses on the northeast side is a variable mica schist always of fine texture and thinly foliated. Variation is from a moderately fine-grained muscovite-biotite schist at the Saunders-Phillips mines to a very fine-grained lustrous sericite schist at the Hewitt mine. A fine-textured mica schist, heavily charged with minute grains and crystals (octahedra) of black magnetite, forms an additional facies of the schist at the Hewitt mine. The mica schists are composed essentially of mica without feldspar.

Those mines developed on the southwest end of the belt in the vicinity of Toshes, Pittsylvania county, indicate an enclosure of the limestone masses by a much coarser textured biotite-muscovite schist on the two sides. Feldspar is only recognized as a scantily developed constituent of the rock, but thin stringers of quartz are interleaved at times with the schist and small dike-like bodies of a coarse crystallization of pink feldspar and quartz frequently cut across the foliation of the mica schist. The kaolinized equivalents of these dike-like masses are found in the same position in the residual clays derived from the schist. (Figure 46.)

Where exposed in mining this belt, the limestone is a coarsely crystalline marble of considerable purity in places. In color it is generally white, occasionally pink, and sometimes greenish. It contains ferromagnesian silicate minerals, especially biotite and tremolite, and is frequently charged with chalcopyrite and pyrite. Manganese and iron oxides are noted in places. The limestone widens and narrows alternately, forming lenticular masses with an observed maximum thickness of 60 feet, and conforms in dip and strike to the structure of the enclosing schists described above. In composition the rock is composed essentially of calcium carbonate with small amounts of magnesium carbonate as shown in the analyses below, made by Dr. Walter B. Ellett, of specimens collected by the writer:

	I Per cent.	II Per cent.	III Per cent.
Insoluble matter........	1.66	0.87	1.10
Alumina } Iron oxide }............	0.24	0.30	0.96
Calcium oxide..........	50.04	52.60	51.00
Magnesium oxide.......	3.28	1.40	1.85
Calcium carbonate......	89.36	93.33	91.07
Magnesium carbonate ...	6.61	2.82	3.73
Barium sulphate........	0.62	0.65	1.62
Copper sulphide.........	trace	trace	0.36

I. White crystalline limestone from Hewitt mine, Campbell county.
II. Same as I.
III. White and pink crystalline limestone from Ramsay mine, Pittsylvania county.

A third important type of rock, intimately associated with the ore and whose fresh equivalent is a limestone schist, is a black manganiferous and ferruginous clay, locally called umber. It is found at every opening made on the belt and its position is next to the limestone, occurring, as a rule, on both sides. Openings made near the outcrop usually penetrate a considerable thickness of the black clay but do not as a rule encounter the limestone. When followed down, however, for a short distance in the direction of the dip, the limestone appears enclosed on either side by the dark clay which apparently thins on depth and ultimately disappears. Like the associated schists, the black clay always contains the foliation planes of the original limy schist from which it was derived.

Leached mica folia and small partially oxidized areas of light green tremolite are found in the black clay of the Pittsylvania county mines. The relations of the clay to the limestone masses and the mica schist, together with its structure and composition, reasonably support the belief that it has been derived by decay from a calcareous schist, which was transitional between the well-defined and differentiated limestone on the one hand, and the mica schist on the other. The kaolinized equivalents of the pegmatitic dike-like forms found cutting the schists, are observed in similar position in the black clay, as shown in figure 46. Much good ore is mined from the black clay, in which it occurs embedded as nodular masses. Figures 46 and 47 make clear the above relations of the clay to the limestone and schist.

Samples of the black clay collected by me from the Bennett mine in Pittsylvania county, and analyzed by Doctor Walter B. Ellett, gave the following results:

	Per cent.
Insoluble residue	14.20
Alumina	4.96
Ferric oxide	32.40
Manganous oxide	19.49
Lime	2.06
Magnesia	trace
Barium oxide	trace
Copper	trace

ASSOCIATED MINERALS.

Calcite in the form of the coarsely crystalline marble, with which the barite occurs, is much the most abundant associate. Pyrite and chalcopyrite are frequently present as thin stringers and as disseminated small grains and crystals in some of the ore, but more especially in the associated limestone. These are usually intermingled, and in several instances a green staining of malachite has been observed from alteration of the chalcopyrite. Manganese and iron oxides are frequent associates, but, as a rule, they are not noticeable in the best grades of the ore. These are usually more abundant and, therefore, more troublesome in the ore mined from near the surface. A small amount of the ore from the Hewitt mine, in Campbell county, is reported to have been highly charged with manganese oxide. Tremolite has been observed in both the black clay and the marble and in places much biotite accompanies the tremolite in the limestone.

STRUCTURE.

The rocks are all schistose and preserve a general northeast strike with local variations which, so far as measured, range from N. 30° to 55°E. Greater variations are shown in dip. The pure limestone masses are usually more or less massive, becoming decidedly schistose with decreasing purity. In the northern end of the belt near Evington, in Campbell county, at the Saunders-Phillips mines, the schists dip N. 60°-65° W. At the Hewitt mine, which is about 2 miles S.70°W. from the Saunders, the dip is to the southeast and quite steep, affording a distinct synclinal structure as shown in figure 48. Near the southern end of the belt at Toshes, in Pittsylvania county, the openings at the Bennett mine show a variable dip to the southeast, which is much flatter than in the Campbell

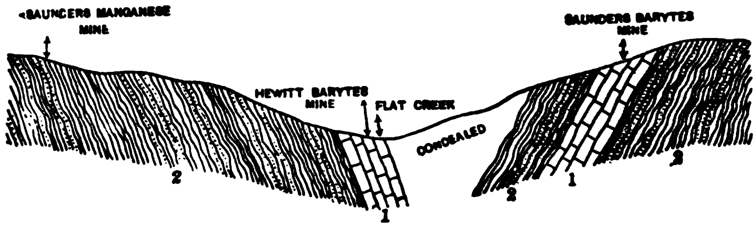

Fig. 48.—Section from Saunders manganese mine to Saunders barite mine, along a northwest-southeast course, near Evington. Length of section about 2 miles. (1) Crystalline limestone; (2) Crystalline schists, chiefly micaceous. (After Watson, Trans. A. I. M. E.)

county area, the probable average being about 20°. Other large mines located nearby and on the same strike as the Bennett, had been abandoned for so long a time, that no reliable measurements were possible. However, outcrops of the schist in the vicinity of the mines show dips conformable with that at the Bennett. As indicated in these measurements the folding has not been of uniform intensity throughout, but at the northeastern end of the belt folding is steeper and of a more closed type, while at the southwestern end it is flatter and of a more open type.

The Louisa County Area.

Barite occurrence and mining in Louisa county are limited to the Walker place, 0.75 mile south of Mechanicsville, and 3 miles south of east from Lindsay, the nearest railway point. The openings comprise a number of test-pits and several shafts, the deepest one of which is between 70 and 80 feet. Mining had been temporarily suspended for several months prior to my visit and the openings were filled with water, which prevented entering them for study of the ore- and rock-relations.

The rocks are metamorphic crystalline schists of probable sedimentary origin. They are very thinly foliated micaceous schists, considerably altered, the foliation-planes of which are so regular and closely spaced as to be called, locally, slates. They strike approximately NE-SW, and observe a general southeast dip, with a probable average of about 45°. Exposures of the rock are rare because of the considerable depth of residual decay, chiefly gray and red clays. Quartz-fragments, both large and small, frequently litter the surface, indicating quartz-veins or vein-like masses interleaved with and cutting across the foliation of the schists. Careful search failed to indicate the presence of limestone and close inquiry further confirmed its absence.

Examination of the ore was necessarily confined to the dumps. The ore is a moderately white grade of coarsely crystallized barite, remarkably free from impurities other than the usual discoloration from the red iron oxide. Several lumps of the ore showed cavities filled with nearly perfect quartz crystals. Drused surfaces of large tabular barite-crystals are abundant. The ore was traced from the surface downward in the openings, observing a general but variable dip toward the southeast. It is reported to be pockety in mode of occurrence, widening and narrowing sharply and frequently, but having a thickness of about 3 feet where worked in the deep shaft.

Evidence is apparently lacking for regarding the ore as a replacement-deposit. It probably represents a filling of an irregular fracture in the crystalline schists, the barium salt of which was probably derived from some mineral or minerals composing the surrounding rocks.

The Bedford County Area.

Barite occurs and has been mined at a number of different points in Bedford county. Several mines near the Campbell county line yielded large quantities of the mineral. In the western part of the county, between Bedford City and Roanoke, a recent operation shows an interesting occurrence of the mineral. The deposit lies about 3 miles northwest from Thaxton, and is reported to have been first opened in 1866, when a small quantity of barite was shipped to Baltimore. It was re-opened again during the fall of 1906. The barite occurs in a completely schistose coarse-grained granite filling a fracture. Some distance away from the fracture the granite is entirely massive and porphyritic.

As nearly as could be determined, the fracture has a N. 10° to 20° E. course, and dips about 60° southeast. An open cut about 20 feet deep has been made along the course of the fracture for a distance of about 450 feet. The granite in the vicinity of the fracture is deeply decayed, although the fracture is distinctly shown at one end of the cut where it carries no barite.

The barite is crystalline, and varies in color from white to deep blue-gray. In places, much galenite in small grains and occasional sphalerite are disseminated through the barite.

THE APPALACHIAN MOUNTAIN REGION.

Introduction.

Barite is found in a number of counties in the middle and northern parts of the Greater Valley, but mining of it in this province has been largely confined to Russell, Smyth, and Tazewell counties in southwest Virginia. Within recent years mining operations have been limited to two of these counties, namely, Tazewell and Russell. Where found in the southwest region it is associated with either the Shenandoah limestone or its residual decay.

General Occurrence.

In southwest Virginia, the barite of the several counties is in association with the Shenandoah limestone or its residual decay. It observes certain minor variations of occurrence from place to place. It fills in part, at least, fractures in the limestone and, in part, it replaces the limestone. In the southeastern part of Wythe county these occurrences in the limestone are fairly well shown. Here the mineral association of barite is with limonite, sphalerite, galenite, and occasional fluorite in certain openings named below, from which iron and zinc ores have been mined. In the Tazewell-Russell area the commoner associates are calcite and limonite, with some siderite, fluorite, and small greenish cherty masses. In addition to its occurrence in the fresh limestone the barite is found as small and large nodules irregularly distributed through the red clay, resulting from the decay of the limestone. (Figure 49.) The variation in local occurrence and in mineral association is brought out in the treatment of the individual areas below.

Wythe County.

In the southern part of the county, near the eastern margin of the Shenandoah limestone, barite is found in association with the metallic ores in some of the zinc and iron mines. No attention has been given to the mining of barite in this locality, nor is it known whether commercially valuable barite occurs. In several of the brown iron-ore pits at Ivanhoe, notably those of the New River Mineral Company and the Painter, barite has been observed in some of the limestone chimneys (pinnacles) as protruding irregular porous or cellular masses, intimately associated at times with sphalerite and galenite. These latter minerals, sulphides, were noted in several instances as enclosures in the barite, and the barite replaces in part the limestone. Northeast of Ivanhoe at the Bertha zinc mines, which have been operated for several years for iron-ore, barite is found in places as loose nodules embedded in the red clay, result-

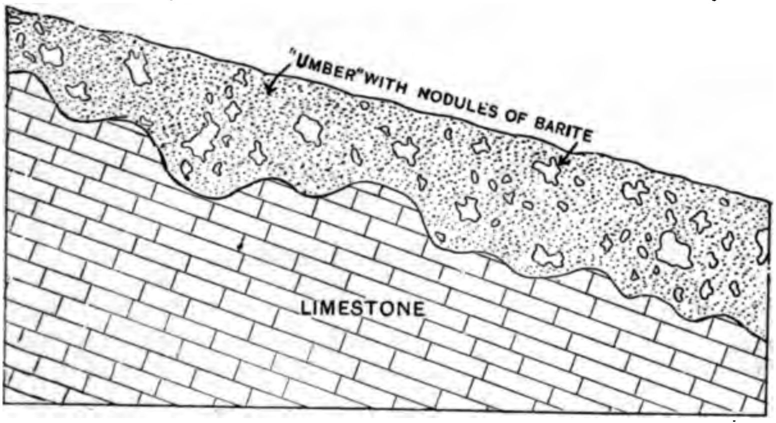

Fig. 49.—Section showing mode of occurrence of barite in clays derived from limestone. Tazewell-Russell counties area. (After Watson, Trans. A. I. M. E.)

ing from the limestone decay. About a half mile northeast of Bertha at the Barren Springs iron-ore pits, barite is again found similarly occurring. The mode of occurrence and the associations of the barite in the above localities suggest the introduction of the barium salt along fracture lines in the limestone and the partial replacement of the limestone by the barite.

Smyth County.

Barite was extensively mined some years ago near Marion, the county-seat of Smyth. The mining and shipping of barite in this county were begun about 1877 by Mr. Goodell, and the work was continued more or less energetically until about 1885. Some mining on a small scale has since been done from time to time.

The mining of barite in Smyth county was largely confined to the west side and at a distance of about 3 miles from Marion, although some ore was mined on the east side of the town. Mining was largely confined to the lumps and nodules of barite embedded in the residual red clays derived from the Valley limestone. In some instances, mining operations extended into the fresh and hard limestone beneath the clays, but nowhere was a greater depth reached in mining than 100 feet. During the fall of 1906, 2 car-loads of barite were mined and shipped from the W. M. Copenhaver property on the west side of Marion. During the period of active operations in this county the barite was chiefly milled and prepared for market in Marion. A smaller mill was operated both on the east and west sides of Marion.

Washington County.

About 4.5 miles northwest of Glade Spring and on the north side of and about a half mile from the Saltville branch of the Norfolk and Western Railway, barite occurs in the red clay derived from the Valley limestone on the Buchanan, McNew, and White places. No prospecting nor work for barite has been done in this county.

Russell and Tazewell Counties.

Russell and Tazewell counties are the largest producers of barite, at present, in the State. Extensive deposits of the mineral are found in both counties. In its geographical distribution the mineral is limited chiefly to the southern slope of Kent Ridge and its prolongation both northeastward and southwestward along the valley of Clinch river, extending from near North Tazewell on the northeast to near Lebanon on the southwest, a distance of more than 30 miles. Map, figure 50, shows the most productive portion of the belt. Barite has been mined at numerous points along this northeast-southwest belt, the principal ones being near North Tazewell; 3 miles south of Richlands; 3 miles from Honaker on the Clinch river; and on the southwestern end of the belt in the vicinity of Lebanon.

The barite is found throughout this belt in the upper portion of the Knox dolomite and its residual decay. Sections AA and BB, figure 50, show the structural relations of the Knox dolomite and the adjacent rocks on the northwest and southeast, near Sword Creek and Richlands in Tazewell county. The barite occurs as small and large lumps of irregular shapes assembled in the residual clay of the limestone, and in pocket form and vein-like bodies filling spaces in the limestone, and in part replacing the limestone.

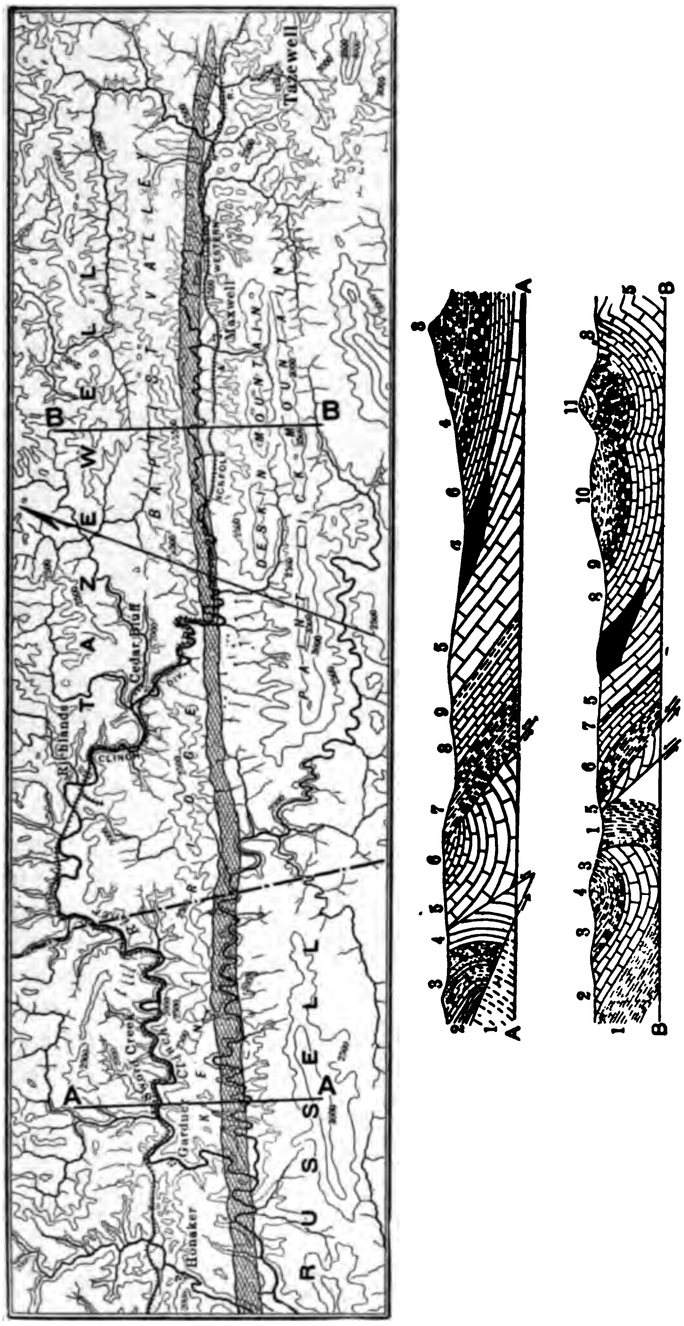

Fig. 50.—Map and structure sections of the Russell-Tazewell counties barite area. Cross-lined belt through middle of map is barite. (Based on the Tazewell folio, U. S. Geol. Survey). Solid black areas in sections are barite.

[illegible] Marion, although some ore [illegible] the town. Mining was largely confined to the [illegible] deposits of barite embedded in the residual clay derived from [illegible] limestone. In some instances mining operations extended [illegible] limestone beneath the clay, but nowhere was a greater depth reached in mining than 100 feet. During the fall of 1906, several tons of barite were mined and shipped from the W. M. Copenhaver property on the west side of Marion. During the period of active operations [illegible] the barite was chiefly mined and prepared for market at Marion [illegible] mill was operated both on the east and west sides of Marion.

Washington County

[illegible] northwest of Glade Spring and on the north side of [illegible] about [illegible] mile from the Saltville branch of the Norfolk and Western [illegible] barite occurs in the red clay derived from the Valley limestone on the Buchanan, McNew, and White places. No prospecting nor work for barite has been done in this county.

Russell and Tazewell Counties

Russell and Tazewell counties are the largest producers of barite at present in the State. Extensive deposits of the mineral are found in both counties. In its geographical distribution the mineral is limited chiefly to the southeast slope of Kent Ridge and its prolongation both northeastward and southwestward along the valley of Clinch River, extending from near North Tazewell on the northeast to near Lebanon on the southwest, a distance of more than 30 miles. Map, figure 56, shows the most productive portion of the belt. Barite has been mined at numerous points along this northeast-southwest belt, the principal ones being near North Tazewell, 3 miles south of Richlands, 3 miles from Honaker on the Clinch river, and on the southwestern end of the belt in the vicinity of Lebanon.

The barite is found throughout this belt in the upper portion of the [illegible] and its residual decay. Sections AA and BB, figure [illegible], show the [illegible] relations of the [illegible] formation and the adjacent rocks [illegible] near Swords Creek and Richlands in Tazewell county. The barite occurs as small and large [illegible] of irregular [illegible] of the limestone, and in pocket form and [illegible] spaces in the limestone, and in part replacing the limestone.

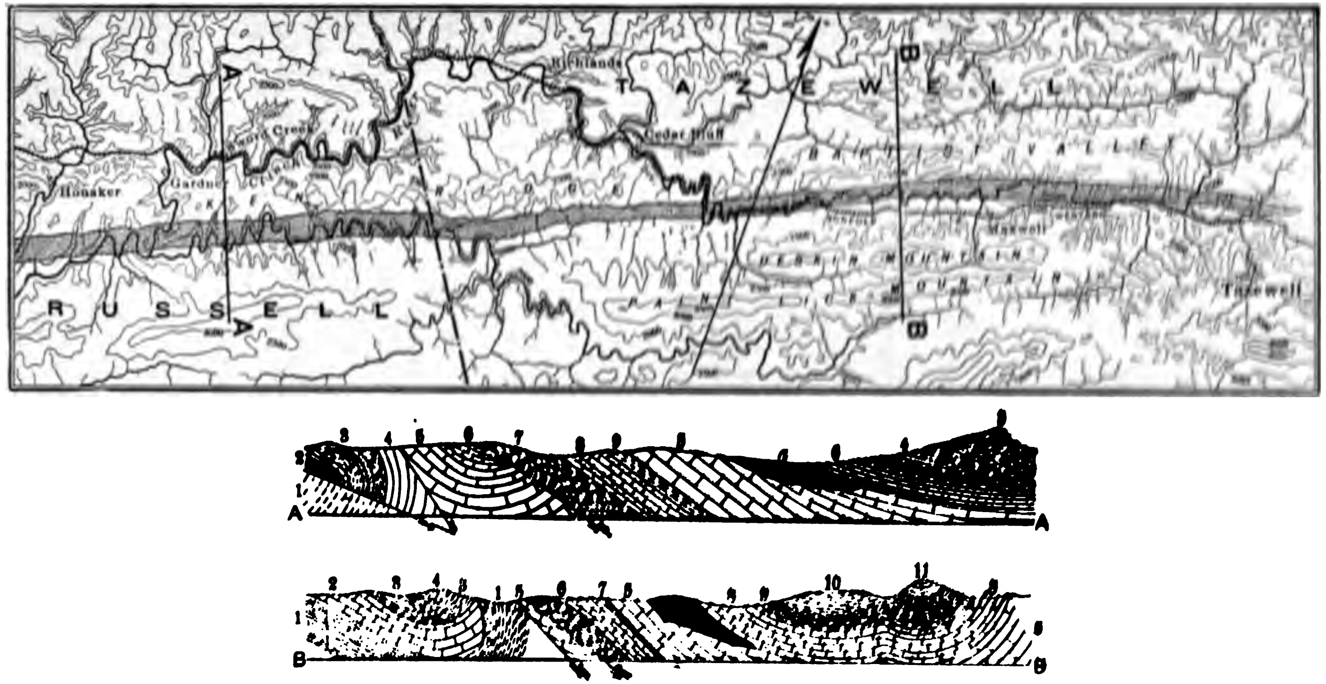

Fig. 50.—Map and structure sections of the Russell-Tazewell counties barite area. Cross-lined belt through middle of map is barite. (Based on the Tazewell folio, U. S. Geol. Survey). Solid black areas in sections are barite.

mills and are well equipped. Plate L is a view of the milling plant of the Pittsburg Baryta and Milling Corporation at Richlands. This plant is very commodious, completely equipped with modern machinery, and is one of the best modern barite mills in the country.

Methods of Mining.

As noted above in the description of the barite mines, now or formerly operated in the different sections of Virginia, the mining is all surface work with no deep mining in any part of the State. The greatest depth yet reached in any of the Virginia mines is a shaft recently operated at the Hewitt mine, in Campbell county, which is 160 feet. In the crystalline area, east of the Blue Ridge, the ore is first located by surface indication and is won by vertical timbered shafts and drifts, which follow the direction of the ore bodies. The machinery employed is simple, light and inexpensive. In the limestone of the southwest Virginia region the mining is shallow and largely by open pit work. In mining the ore in the fresh limestone, blasting becomes necessary for breaking it down.

Preparation.

For removal of the impurities from the better grades of merchantable ore, washing and bleaching, and occasionally jigging, are the only operations necessary. The common impurities in the best grades of ore include iron and manganese oxides, limestone, clay, and sand. Higgin's description in the *Engineering News* for 1905 of bleaching barite, in preparing it for market, is here given in full as summarized by Pratt in the Mineral Resources of the United States for 1904:

"In bleaching the barytes, the crushed mineral is placed in wooden tanks lined with sheet lead and holding from 5 to 25 tons of mineral. The tanks used are either circular or rectangular, the former being preferable for the reason that the steaming can be more uniformly done. The best size is 4½ feet high and 8 feet in diameter. With a tank of this size, one steam inlet is required. The most satisfactory tanks are made of stout, well-seasoned cypress wood, which are well braced on the outside and lined on the inside with heavy sheet lead. A lead coil of pipe one-half to 2 inches in diameter is constructed in such a manner that either steam or water can be supplied through the perforations which are best located at an angle of about 45° to the vertical diameter of the pipe rather than directly on top of the pipe. With the perforations in this position there is less chance of the holes becoming clogged up by fines dropping into them. In charging the tanks the barytes is added to a depth of about 3 feet and then the dilute sulphuric acid solution, which is used as the solvent, is run in. Steam is admitted by means of the coiled lead pipe, which is closed at one end and provided with small perforations from 6 to 8 inches apart. The steam escaping from these perforations agitates and heats the mixture, which requires from six to eighty hours to bleach, depending entirely on the amount of iron contained in the barytes. After drawing off the acid, the cleaned mineral is discharged either by sluicing through a specially constructed spout or else by shovelling over the side of the tank and is transferred to a washer in which the last traces of the acid and clay material are removed. The cleaned mineral is then dried either on large pans or by means of some one of the patented rotary driers."

"In this bleaching process the manganese dioxide is not removed and the barytes that contains this impurity has to be ground to paste on a 40-mesh screen and then mixed with nitrate of soda, salt, and sulphuric acid in the proper proportions. This mixture is then heated in a specially constructed furnace by which process the iron and manganese are converted into chlorides, which, being very soluble in water, can be completely removed by washing, the barytes being allowed to settle in a series of tanks, generally three in number."

"The next step in the preparation of the barytes for market is reducing it first to the size of fine sand by means of rolls and then to an impalpable powder by means of buhrstones, after which it is ready to be packed for shipment."

Uses.

The principal use made of barite at present is as a white pigment. It was formerly used as an adulterant of white lead but it is now recognized that barite alone makes a good pigment. At the present time, therefore, barite is put on the market as a pigment in competition with white lead and other white pigments. It has a permanent white color and is not effected by weather or by gases which cause in some cases white lead to blacken. According to Pratt, barite can be used to advantage in combination with either white lead or zinc white. Any pronounced increase in the consumption of white pigments will produce a corresponding increase in barite; and as barite is more and more replacing the other white pigments, there is a noticeable increase in the production of barite from these causes. Pratt states that of the total production of barite, about four-fifths are used in the manufacture of white pigment.

A further use made of barite is for giving weight and body to certain kinds of cloth and paper. The use of barite in the manufacture of barium compounds for chemical purposes is increasing.

General view of the Pittsburg Baryta and Milling Corporation's plant, Richlands.

BARITE MILL IN VIRGINIA.

Production.

›roduction of crude barite in Virginia from 1901 to 1905 is as

Year	Quantity Short tons	Value $
1901	10,270	31,260
1902	12,400	39,700
1903	5,700	20,400
1904	11,214	31,452
1905	6,468	27,838

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ineral Resources of the United States from 1883 to date; Mineral from 1892 to date.

2. GYPSUM.

General Properties.

iically, gypsum is a hydrous calcium sulphate corresponding to ula $CaSO_4.2H_2O$. When pure, natural gypsum is usually white ssive, and pearly when crystallized. It is often gray, brown, red, ı black from impurities. Ordinarily the impurities are organic matter, ferruginous and aluminous or clayey matter, and the carbonates of lime and magnesia.

The hardness of gypsum varies from 1.5 to 2.0; specific gravity, 2.3. The softness of the mineral, which is such that it can be readily scratched with the finger-nail, serves to distinguish it from the other minerals which it resembles. Three principal varieties of gypsum are usually recognized: (1) The crystallized, foliated and transparent variety, known as selenite; (2) the fine fibrous and pearly or opalescent variety, known as satin spar; and (3) the common massive, fine-granular variety, known as gypsum. When of white color and sufficiently compact or fine-grained for carving and sculpturing, it is known as alabaster.

Origin and Occurrence.

In commercial quantities, gypsum is always associated with stratified rocks, when it is usually regarded as a chemical deposit, resulting from the evaporation of inland sea and lake waters. The gypsum beds usually occur interstratified with shales and limestones and in many places beds of rock salt. In southwest Virginia the gypsum deposits are associated with gray and purple clays in shales and shaly limestones of Lower Carboniferous (Mississippian) age. It may also be formed through the oxidation of sulphides and the action of the liberated sulphuric acid on limestone; or through the action of solutions of metallic sulphates on calcium carbonate (limestone); through the hydration of anhydrite; and through the action of sulphurous vapors from volcanoes on lime-bearing rocks.

General Geologic Relations of the Southwest Virginia Deposits.

The gypsum and salt beds of southwest Virginia are intimately associated, and are confined to a narrow southwest-northeast valley of the North Fork of the Holston river, extending from Plasterco on the southwest to within 3 miles west of Chatham Hill post-office on the northeast, a distance of about 16 miles. Plates XXXIII, XXXIV, and LI, views taken at Plasterco and Saltville, give a general idea of the outline and surface character of the southwest end of the valley.

The ridges known as Pine and Little Brushy Mountains bound the valley on the northwest sides and are composed of rocks which range in age from Silurian through Devonian to Lower Carboniferous. Near the middle portion of the valley the road follows for some distance close to, on and over, thin-bedded sandstones and siliceous shales of Carboniferous age, which

Fig. 1.—View of the southwest end of the Saltville valley at Plasterco, showing gypsum masses (white) mined by the Buena Vista Plaster and Mining Company.

Fig. 2.—The Buena Vista Plaster and Mining Company's plant, Plasterco, Washington county.

GYPSUM MINES AND MILL, WASHINGTON COUNTY, VIRGINIA.

form the basal slope of the ridges. These rocks, dipping at angles varying from 23° to 45° southeast, underlie the Greenbrier limestone. This limestone forms a narrow belt extending from and along the basal slope of the ridges to the southeast side of the river where it is cut off by a fault, which has brought up the Cambro-Ordovician limestone. As mapped by Professor Stevenson, this fault, designated the Saltville fault, extends from the southwestern end of the area, passing within a short distance to the southeast of Plasterco and Saltville, in a general northeast direction several miles north of Chatham Hill post-office. The rocks on the southeast side of the fault are limestones and blue limy shales which dip to the southeast at angles varying from 21° to 35°, measured along the road extending from Saltville to the limestone quarry of the Mathieson Alkali Works, 3 miles S. 15° E. of the Salt Works plant. A view in this quarry, showing the limestone capped by shales, is given in plate XLVI, figure 2. The accompanying map, plate LII. make plain the above geologic relations.

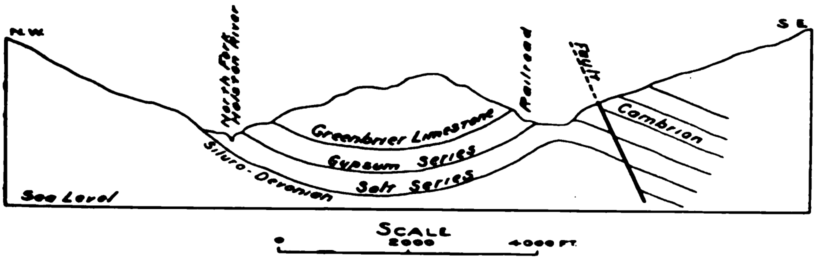


Fig. 51.—Section across Holston and Saltville valleys on a northwest-southeast line midway between Saltville and Plasterco. (After E. C. Eckel.)

Both the gypsum and the salt deposits are limited to the narrow belt on the northwest side of the Saltville fault, included between the fault and the Carboniferous shales and sandstones of the basal slopes of Pine and Little Brushy Mountains. So far as has been made out, this narrow belt is composed of the Greenbrier limestone (Carboniferous) and the beds of gypsum and salt. Figure 51, a section by Eckel across the Holston and Saltville valleys, along a northwest-southeast line between Saltville and Plasterco, shows the relations of the Greenbrier limestone and the gypsum-salt beds.

Mining Developments.

Commercial deposits of gypsum in Virginia occur only in Washington and Smyth counties, in the narrow valley of the North Fork of Holston river described above. Professor Rogers described the occurrence of gypsum in a number of the Coastal Plain counties of eastern Virginia in association with the greensand deposits, but no developments have been made, nor is it certain that commercial gypsum is found.

Within the limits of the Holston and Saltville valley gypsum has been worked at numerous points. The mines and milling plant of the Buena Vista Plaster and Mining Company, situated near the southwest end of the Valley and about 2 miles southwest of Saltville, are the most extensive. The exact date of the discovery and first working of gypsum in this valley is unknown to the writer, but it certainly dates back as far as the early part of the nineteenth century. The location of the principal mines are shown on map, plate LII. Beginning on the northeast end of the belt the principal mines are described in order toward the southwest.

On the *Buchanan place*, about 3 miles west of Chatham Hill post-office, are several openings worked to a depth of less than 50 feet. Several hundred tons of gypsum were mined and crushed for use as land plaster.

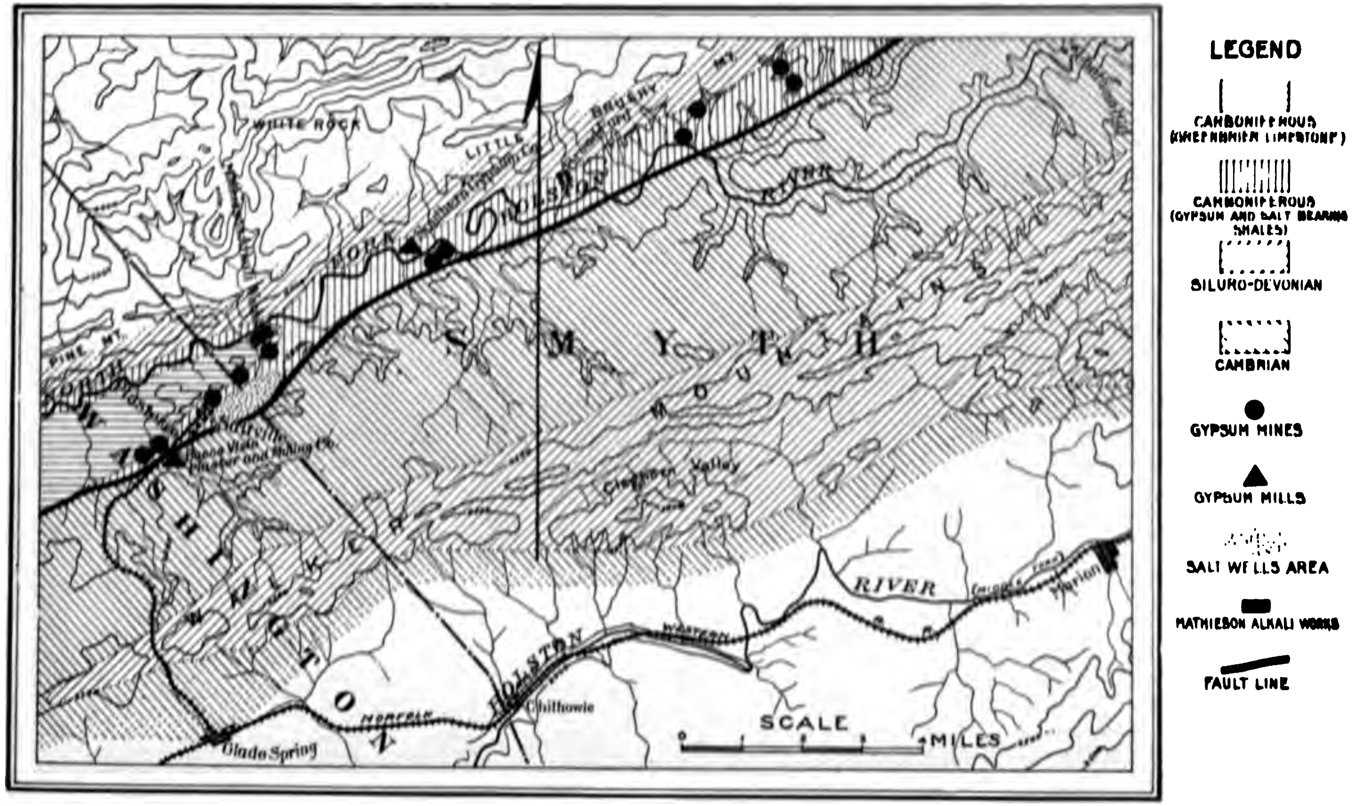
About 8 miles north of west from Saltville a good supply of gypsum has been mined on the *Barnes place*, situated less than one-half mile south of the base of Little Brushy Mountain. This mine was first opened about 15 years ago and was developed by an incline shaft and drifts which were filled with water at the time of my visit in August, 1906. As judged by the large dump pile at the opening the gypsum mined was of good quality. It is quite similar to that mined at Plasterco and it contains very thin leaves of interlaminated gray crystals of the gypsum.

An analysis of the gypsum from the Barnes mine made by Professor M. B. Hardin gave:

	Per cent.
Calcium sulphate	78.60
Water	20.79
Calcium carbonate	0.21
Calcium chloride	trace
Magnesium chloride	trace
Organic matter	0.12
Silica, alumina, etc	0.23
Total	99.95

Gypsum has been worked in the past at a number of places along the North Fork of the Holston river between the Barnes mine and Saltville.

The most extensive one of these is that of the *Southern Gypsum Company, Incorporated*, which began prospecting for gypsum in the valley of the North Fork of the Holston river in the summer of 1906. A drill giving cores 3¼ inches in diameter was used and a very accurate record of the



Map of the salt and gypsum deposits in southwestern Virginia. Based on topographic sheet, U. S. Geol. Survey. Geology partly adopted from Stevenson.

formations passed through was obtained. After nearly a year of drilling, the *Pierson Plaster Bank farm*, 3.5 miles above Saltville, was purchased. Under this farm, the drilling of the company has already demonstrated a very large amount of gypsum, while a considerable portion of the farm remains to be prospected.

The mine of the company is well opened and by July of 1907, the *Southern Gypsum Company*, will be placing gypsum on the market. The full capacity of the mill will be 400 tons per day. Of this about 4/5 will be put upon the market in the form of wall plaster, the remaining 1/5 will be used by Portland cement mills and in the form of land plaster.

Gypsum was worked as recently as 1902 at Saltville, where several large openings were developed. The gypsum mined at Saltville was shipped to Glade Spring, where a part of it was used for land plaster, but most of it was used in the manufacture of Keene's cement. In Volume IV of *The Virginias* for 1883, Major Hotchkiss reports an analysis of the gypsum, made by Thomas Jones from the plaster banks of the Salt Works Company, to be:

	Per cent.
Lime	32.293
Sulphuric acid	46.445
Water	20.856
Magnesia	.151
Iron and aluminum oxides	.149
Siliceous matter	.070
Total	99.964

The mines of the *Buena Vista Plaster and Mining Company* at Plasterco, about 2 miles southwest of Saltville, are much the most extensive in the valley. Between the years 1815 and 1857 a number of borings were made on this property for the purpose of ascertaining (1) the thickness of the gypsum, and (2) the presence of brine or rock salt. The records of 7 of these borings taken from Bulletin No. 213 of the United States Geological Survey are here given:

		Feet.
Well A.	Bored between 1815 and 1820:	
	Red clay	0— 14
	Clay and plaster	14—120
	Pure plaster	160—200
Well B.	Bored in 1847:	
	Red clay	0— 10
	Clay and plaster, buhrstone	10— 30
	Clay and plaster (deep red)	30— 50
	Pure plaster	50— 95
	Impure blue plaster	95—163
	Hard blue slate	163—420

Well C. Bored in 1847:

	Feet.
Red clay	0— 10
Clay and plaster, with brown rocks	10— 70
Pure plaster	70—100
Slate and plaster	100—200
Hard blue plaster	200—360
Red slate	360—480
Gray slate	480—495
Red rocks, a little salty	495—505

Well D. Bored in 1847:

Red clay	0— 10
Clay and plaster	10— 62
Plaster, with a little clay	62—200
Red clay, with a little plaster	200—385
Red clay, alkali, and salt	385—387
Pure plaster	387—590

Well E. Bored in 1847:

Red clay	0— 10
Clay and plaster	10— 16
Impure plaster	16— 50
Pure plaster	50—102
Slate and plaster	102—165
Nearly all plaster	165—210
Blue slate	210—320
Blue slate and plaster	320—390
Yellow soapstone	390—445
Pure plaster	445—490
Red rock, with a little salt	490—505

Well F. Bored in 1853:

Clay	0— 17
Clay and plaster	17— 50
Pure plaster	50— 83
Hard black flint rock	83— 90
Pure plaster	90— 96
Plaster and sulphur balls	96—105
[Record lost]	105—109
Red and yellow soapstone	109—120
Hard blue slate and red, blue, and gray rock	120—359
Yellow and blue slate	359—390
Yellow and blue slate, salty	390—460

Well G. Bored in 1854:

Sand and gravel	0— 20
Blue clay	20— 30
Hard white sand rock	30— 40
Clay and plaster	40— 55
Buhrstone	55— 60

The present mines lie near the southeast side of the valley and are developed by drifts and shafts, the deepest one of which is nearly 200 feet. A depth of 280 feet was reached in one of the old shafts. The material as mined is ground and calcined at the milling plant of the company tc 1906, inclusive, was kindly furnished me by Mr. Wyndham B. Robertson, President of the Buena Vista Plaster and Mining Company.

Year	Quantity short tons	Value $	Year	Quantity short tons	Value $
1890	6,350	20,782	1898	8,378	23,388
1891	5,959	22,574	1899	11,480	32,043
1892	6,991	28,207	1900	11,940	18,111
1893	7,014	24,359	1901	15,236	45,144
1894	8,106	24,431	1902	10,418	
1895	5,800	17,369	1903	14,741	
1896	5,955	17,264	1904	13,784	
1897	6,374	16,899	1905	16,578	
			1906	20,006	

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X. HYDROCARBONS.

I. COAL AND ITS BY-PRODUCTS.

1. COAL.

HISTORICAL.

The first coal mined in the United States was in the Richmond basin, where mines were opened and worked on the James river, near Richmond, as early as 1750. For the next 71 years, or from 1750 to 1822, there are no available records of production from the mines near Richmond; the first year for which figures of production are given is 1822, when 54,000 short tons of coal were mined. In 1824 the production was 67,040 short tons; in 1826, 88,720 tons; and in 1828, 100,280 tons. The production from the Richmond basin continued to increase until 1832, when it began to decline. Shortly after the decline began in the Richmond basin, areas in the northwestern part of the State (now West Virginia) began to produce coal, and until West Virginia was made a separate state in 1863, Virginia was numbered as one of the important coal-producing states, which rank has been restored in recent years by the mining of the large reserves of coal in the southwestern part of the State.

The construction of the Norfolk and Western Railway through southwest Virginia, in 1882, opened up the famous Pocahontas coal district, which lies partly in Virginia and partly in West Virginia. Likewise, the building of the Clinch Valley division of the Norfolk and Western Railway, nine years later, marked the beginning of the development of the Wise county coal district. The developments in these two fields in southwest Virginia, Tazewell county in 1883, and Wise county in 1891, again restored Virginia to importance as a coal producer. Each year since, the production has shown a large increase over that of the preceding year, and out of 31 coal-producing states in 1905, Virginia ranked as fifteenth.

Coal was mined in the Montgomery-Pulaski counties area prior to the Civil War, but not in an extensive way. It is reported that some of the coal used in the bunkers of the *Merrimac* (Virginia), in her fight with the *Monitor* in Hampton Roads, came from the Price Mountain mines in Montgomery county. For a period of 30 years after the Civil War, the only mining carried on in this field was to supply a local market. For

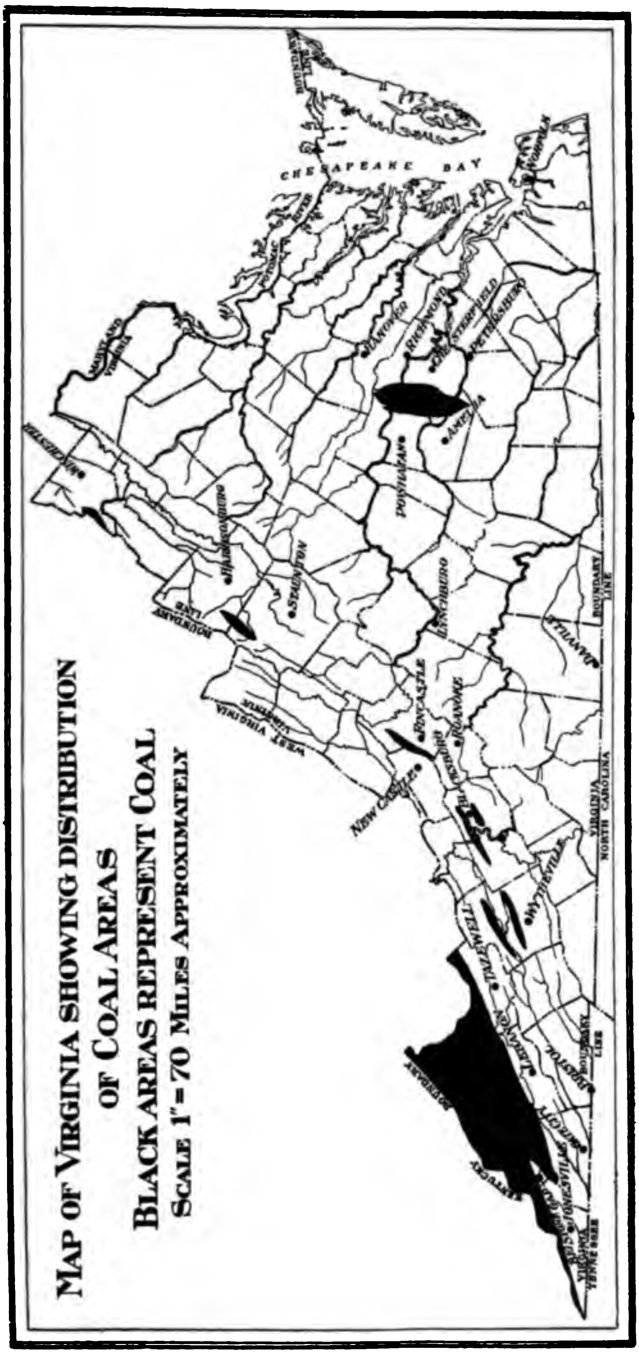


Fig. 52.—Map of Virginia showing coal areas.

a number of years past large developments have been made, more extensive and systematic mining has been carried on in accordance with modern methods, and a steady increase in output over that of the local market has been indicated yearly.

The present annual production of coal in Virginia is about 4,500,000 short tons valued at approximately $4,000,000.

DISTRIBUTION OF THE COAL.

The geographic distribution of coal in Virginia is shown on the accompanying map, figure 52. As shown on this map, coal is found and has been extensively mined in two of the three larger physiographic provinces of the State, namely, the Mountain province and the Piedmont province. Of these, the deposits of the Mountain province are the only producing ones at present, although recent developments in the Piedmont province will again restore this area to the rank of a producer at an early date.

The distribution of the Virginia areas, which have produced or are producing coal, is as follows:

I. The Coal Deposits of the Piedmont province. Includes the Richmond Coal Basin, which covers parts of the following five counties: Henrico, Chesterfield, Powhatan, Goochland, and Amelia. The Farmville area, which covers parts of Prince Edward, Cumberland, and Buckingham counties.

II. The Coal Deposits of the Mountain province, which include a number of separate areas stretching from the northwestern corner of the State southwestward near and beyond the west side of the Great Valley.

(1) The Frederick County Area. Includes the Mountain Falls district in the southwestern portion of the county and near the West Virginia line.

(2) The Augusta County Area. Includes the North River district in the northwest corner of Augusta county and the contiguous part of Rockingham county.

(3) The Botetourt County Area. Includes the southwest corner of Botetourt county.

(4) The Montgomery-Pulaski Counties Area. Includes Price and Brush Mountains in Montgomery county, and Cloyd and Little Walker Mountains in Pulaski county.

(5) The Bland-Wythe Counties Area. Includes a small area in the southern part of Bland county and in the northern part of Wythe county.

(6) The Southwest Virginia Area. Forms the southeastern portion of the Kanawha basin, and comprises the Pocahontas or Flat-Top and the Big Stone Gap coal fields of the following counties: Tazewell, Russell, Scott, Buchanan, Wise, and Lee. Of these Wise and Tazewell counties are the most important producers at present.

Geologically, the distribution of the Virginia coals is not the same for all the areas enumerated above. They are comprised in two of the larger geologic time divisions: (a) The Mesozoic (Jura-Trias or Newark) coals, to which the Richmond basin and the Farmville area coals belong; and (b) the Paleozoic (Carboniferous) coals, to which all the deposits of the Mountain province belong. Of the several coal areas enumerated above in the Mountain province, the deposits of the Mountain Falls district in Frederick county; the North River area of Augusta county; the North Mountain area of Botetourt county; the Montgomery-Pulaski counties area; and the Bland-Wythe counties area, are of Lower Carboniferous (Mississippian) age. The remaining areas of this province and vastly the most important ones in the State are of Upper Carboniferous (Pennsylvanian) age.

The coals of Virginia are separately treated below by areas as grouped above.

THE PIEDMONT PROVINCE.

Numerous areas of Mesozoic rocks, of large and small extent, are distributed over the Piedmont province, east of the Blue Ridge. In a number of the Mesozoic areas, beds of coal occur, but only in one of these areas has the coal proved to be of sufficient thickness and extent to be of much commercial value, namely, the Richmond basin, near the middle eastern margin of the Piedmont region. Some coal has been mined in a smaller, similar area in Prince Edward county, but to a very limited extent; and thin seams of coal, not of workable grade, are known in at least one other of these areas.

The Richmond Coal Basin.

POSITION AND EXTENT OF THE BASIN.

The Richmond coal area, known also as the Richmond coal basin, lies within but near the eastern margin of the Piedmont plateau, on either side of the James river. The total length of the area is 33 miles, and its maximum width is 9.5 miles, comprising a total area of about 190 square miles. It covers parts of five counties, which are Henrico, Chesterfield, Goochland, Powhatan, and Amelia. The position and limits of the basin are shown on the accompanying map, plate LIII.

This area is important, economically as well as scientifically, for it contains the only free-burning coal located immediately adjacent to tidewater in the eastern portion of the United States.

HISTORICAL.

The first coal mined in the United States is said to have been from the Richmond basin in Virginia. In his *"Story of American Coals,"* Mr. W. J. Nicolls states that coal mines were opened and worked on the James river, near Richmond, in 1750, and for a number of years not only Richmond, but Philadelphia and New York, obtained supplies of coal from these mines. According to Parker, this antedates by 19 years the first reliable record of the use of anthracite coal in Pennsylvania. There is, however, no record of the amount of coal produced prior to 1822, when, according to Taylor in his *"Statistics of Coal,"* 54,000 short tons were mined. Records of coal production in Virginia that are available date from 1822, and the annual production from 1822 to 1906, inclusive, is given in the table on page 375.

GENERAL GEOLOGY OF THE BASIN.

The rocks bordering and underlying the Richmond basin are granites and gneisses of the mica type, and are characteristically dominant rocks over many parts of the Virginia Piedmont region. They are older than the rocks filling the basin and a marked difference in attitude and structure is shown in the rocks within and without the basin. The basin rocks are composed principally of sandstones and shales with beds of coal. The rocks are quite fossiliferous in places, both plant and animal remains occurring. The series of sedimentary rocks are penetrated by basic, igneous dikes, the whole, both sedimentary and igneous rocks, being of Newark (Mesozoic) age. Professors Shaler and Woodworth give the following table of formations of the Richmond basin rocks:

attributed to the basin can probably be traced largely to the downward drag of the strata on the west side, perhaps aided by lateral pressure and folding.

The Richmond basin rocks, in common with the Newark areas northward, are intersected by dikes and sills of diabase. On the eastern border of the basin these rocks have long been known because of the association with them of natural coke in several of the coal mines. The prevailing direction of the dikes is northwest-southeast, with some trending east-west.

THE COAL BEDS OF THE BASIN.

From the published accounts of sections in the mines opened in the basin, 3 and sometimes 5 beds of coal occur, separated by beds of sandstone and shale. The uppermost bed or seam has usually been found to be the thickest. Estimates show considerable variation in the thickness of this bed. varying from 30 and 40 feet in the old workings about Midlothian to 5 and 8 feet in other places. According to Professors Shaler and Woodworth, from the vicinity of Midlothian northward to Gayton (Edge Hill or Carbon Hill of the old reports) this uppermost bed is wholly or partly converted into coke, from the proximity of igneous rocks. Sir Charles Lyell states, that at Dover. on the western margin, was an upper bed of coal 16 feet thick, and 2 thick beds below.

The true coals of this field are bituminous, the character of which is somewhat variable, as indicated in the analyses below. Ordinarily the quality of the coal is excellent, but occasional thin seams of calcite and pyrite have formed along the joint-planes, cutting the coal in places. In such cases the removal of the calcite and pyrite is desirable and can be easily effected by breaking and washing the coal, when an excellent fuel should be obtained. As proved by nearly a century of constant use, the quality of this coal is entirely satisfactory for many purposes.

Extent of the coal beds.—Concerning the extent of the coal beds in the Richmond basin, I quote in full from the excellent report of Professors Shaler and Woodworth, based on a detailed geological survey of the area and published in the Nineteenth Annual Report of the United States Geological Survey for 1897-98.

"As to the area of the basin underlain by the coal beds, the evidence may be stated as follows: On the eastern margin, where the beds are best placed to be exposed in natural sections, and where they have been most extensively worked in former years, there is a fair presumption that the deposits are substantially continuous. Where, as is shown on the map, the coal beds have not been found, as is the case in two considerable sections of the eastern border, the failure of the slight explorations to disclose them may be fairly explained by the existence of faults which

Analyses of coal from the Richmond basin.

South of James River.

Name of Pit (Eastern Outcrop)	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Analyst
Clover Hill (Coxe's Mine)	1.339	30.984	56.831	10.132	0.514	Prof. Johnson
Clover Hill (Coxe's Mine)	.....	29.12	65.52	5.36	......	W. B. Rogers
Clover Hill (Coxe's Mine)	.....	38.50	55.00	6.50	......	G. W. Andrews
Stone Henge	.....	36.50	58.70	4.80	......	W. B. Rogers
Creek Company Shaft	1.450	26.788	60.30	8.57	2.89.	Prof. Johnson
Mills and Reed Creek Shaft	.....	38.60	57.80	3.60	......	W. B. Rogers
Greenhole Shaft	.....	31.17	67.83	2.00	......	W. B. Rogers
Midlothian, average	2.455	29.738	53.012	14.737	.058	Prof. Johnson
Midlothian, new shaft	0.670	31.208	56.40	9.44	2.286	Prof. Johnson
Midlothian, screened	1.785	34.295	54.063	9.655	.202	Prof. Johnson
Midlothian, 900-foot shaft	1.172	27.278	61.083	10.467	......	Prof. Johnson
Midlothian	2.000	31.62	58.26	7.67	......	Silliman & Hubbard
Midlothian	.....	31.60	61.10	7.10	......	J. H. Alexander
Midlothian, grove shaft, screened	1.03	38.23	54.27	6.47	1.52	A. S. McCreath
Midlothian, average	1.05	36.49	46.702	15.758	2.23	A. S. McCreath
Maidenhead	.....	32.83	63.97	3.20	.....	W. B. Rogers
English Co., old shaft	.....	35.82	53.36	10.82	.....	W. B. Rogers
English Co., middle bench	.....	28.40	66.50	5.10	.....	W. B. Rogers
English, Co., top bench	.....	28.40	61.68	9.52	.....	W. B. Rogers
Chesterfield Mining Co	1.896	28.719	58.704	8.634	1.957	Prof. Johnson
Willis Pit (Ætna shaft)	......	28.80	66.60	4.60	.....	Clemson
Western Outcrop						
Powhatan Pits	......	32.33	59.87	7.80	.....	W. B. Rogers
Scott's Pit	......	33.70	60.86	5.66	.....	W. B. Rogers

North of James River.

Name of Pit (Eastern Outcrop)	Moisture	Volatile Matter	Fixed Carbon	Ash	Sulphur	Analyst
Carbon Hill, upper seam	1.40	20.60	60.80	17.20	....	O. J. Heinrich
Carbon Hill, second seam	0.40	18.60	71.00	10.00	....	O. J. Heinrich
Carbon Hill, carbonite	1.57	9.64	79.93	8.86	....	O. J. Heinrich
Carbon Hill, average	1.785	23.959	59.976	14.28	...	Prof. Johnson
Carbon Hill, natural coke	1.116	11.977	75.081	11.826	....	Prof. Johuson
Western Outcrop						
Anderson's Pits (Dover)	.....	28.30	66.78	4.92	....	W. B. Rogers
Anderson's Pits (Dover)	.....	26.00	64.20	9.80	....	Clemson
T. M. Randolph	.....	30.50	66.15	3.35	....	W. B. Rogers
Coalbrookdale	.....	29.00	66.48	4.52	....	W. B. Rogers
Coalbrookdale, 1st seam	.....	24.00	70.80	5.20	....	W B. Rogers
Coalbrookdale, 2d seam	.....	22.83	54.97	22.20	....	W. B. Rogers
Coalbrookdale, 3d seam	.....	24.70	65.50	9.80	....	W. B. Rogers
Coalbrookdale, 4th seam	.....	21.33	56.07	22.60	....	W. B. Rogers
Cranches, upper seam	.....	30.00	64.60	5.40	....	W. B. Rogers
Waterloo	.....	26.80	55.20	18.00	...	W. B. Rogers
Deep Run Basin	.....	26.16	69.86	5.00	....	W. B. Rogers

have thrown the beds down or up, so that the shallow pits which were sunk did not pass through the deep surface rubble. So far as has been learned, there were no indications in the old workings that the coals were fading out in the directions of these portions or the margin where they have not yet been found. In the blank north of the Clover Hill mines the streams run so near the position of the outcrop that exploration has been discouraged by the difficulty which would evidently be encountered from surface water.

"On the western margin the coals are practically unknown from a point about 2 miles south of the James River, at the Old Dominion pits, to the southern extremity of the basin, though there are traces of the dark shales which are probably associated with it. In this part of the border the failure to discover the beds may well be due to the abrupt down-faulting which is known to exist along this line. At only one point, viz., in the stream bed of Turkey Branch, has it been possible to obtain a tolerably continuous section of the beds on the western margin of the field. This failed to reveal the coal-bearing beds, but there is reason to believe that they may have been thrown down by an unobserved fault traversing a portion of the line where the strata were not disclosed, or that they are to be found under a slight cover of alluvium.

"As to the extension of the coal beds beneath the central parts of the area, the evidence in hand is insufficient to warrant a definite statement. The conditions may be briefly set forth as follows: The tolerably complete if not perfect continuity of the beds on the eastern margin and at either end of the basin appears to afford fair evidence that the coal beds have a continuous habit. It has been suggested that the coals, though continuous along the margin of the basin, may be lacking in the central parts of its area. But it should be noted that the present outcrop line is not to be regarded as the original border of the coal-bearing strata. That line was probably miles east of its present position. The existing face is, in effect, a chance north-and-south section of the deposits. There is no evident reason based on the character of this outcrop why a like exhibition of coal beds should not be had if the face were carried 1, 2, or 3 miles westward.

"The failure to find the coal beds in the Sinking shaft and in the drill hole in its bottom has been considered as evidence that these beds were lacking at a point about 1 mile from its margin. This failure to attain the coal is to be explained in the light of the information obtained in the Salisbury boring. The depth at the Sinking shaft was altogether insufficient to traverse the barren strata, the drill most likely not penetrating to within 200 feet of the level where the coal beds might be looked for. The Salisbury drill hole, on the other hand, has shown the coal-bearing rocks at a distance of a mile from the eastern main outcrop, at a depth of about 2,350 feet below the surface.

"When all the evidence is weighed, it leads to the conclusion that the central portions of the area most likely contain coal beds in something like the measure that they are exhibited in the margin. The measure of the probability of such occurrence is rather greater as regards that portion of the field which lies to the east of a line drawn from the Clover Hill pits, near the southern end of the basin, to the Old Dominion mines, on the western margin about 2 miles south of the James River, than it is concerning the field west of that line. This is for the reason that outcrops have not been found along the western margin south of the Old Dominion property, though, as before noted, their failure to occur may be accounted for by accidents of faulting. Leaving out of the reckoning the southwestern portion as possibly lacking the coal-bearing beds, there remains an area of about 150 square miles where the deposits may reasonably be expected to occur.

"Although the information obtained from the existing and the old workings show the coal to vary greatly in thickness, and some of the beds much in quality, it is a not unreasonable estimate that the average thickness of the workable material is 12 feet. Allowing for occasional strips of coal which have been crushed by faulting and for loss in treatment in the breaker, the yield per acre may be roughly estimated at 1,000 tons per foot in depth, or a total of 12,000 tons. The total area which is reckoned as most probably coal-bearing (150 square miles by 640 acres) equals 96,000 acres, which, on the basis of yield above adopted, would give a total content of 1,152,000,000 tons. This reckoning, it should be said, rests altogether on probabilities. . . . .

"In none of the mines does it appear that less than two beds of workable thickness [of coal] are encountered. In other instances there is reason to believe that three, four, and at Clover Hill even five beds of economic value were found. Although all these beds thicken here and thin there and probably at points unite or separate, the coal-bearing character of the section in which they lie is probably maintained in a tolerably continuous manner."

Depth of the coal.—In regard to the question as to the depth at which the coal lies, Professors Shaler and Woodworth say: "In the present condition of our knowledge of the basin it will be safe to assume that at the distance of a mile from the eastern outcrop the coal-bearing section lies at a depth of about 2,500 feet below the surface. Farther toward the interior of the field the depth at which it will be found will probably be somewhat greater. It is not impossible that at some points the faulting has carried these deposits more than 4,000 feet below the present surface. From what has been learned of the conditions, it seems unlikely that the section in which the coals belong is at any point as deep as 5,000 feet."

Mines.

The Richmond coal basin has been developed by numerous mines, many of which have been extensively worked with a large total production of coal. Considerable depths have been reached in some of these. Examination of the map, plate LIII, shows the distribution of the mines to be along the eastern border of the basin, and along the west border in the northern part of the area in the vicinity, and north and south, of the James river. No mines have yet been opened in the more central portions of the basin. The principal mines are further grouped about certain geographic centers along the border portions of the basin.

On the eastern border, beginning with the southernmost ones, the principal mines are grouped about Winterpock; in the vicinity of Coalboro; Midlothian, including the mines of the outlying basins Blackheath, Cunliffe, etc.; to the north of and between Midlothian and the James river, the Salle and Burfoot pits; and Gayton (Edge Hill or Carbon Hill of the old reports), including the outlying Deep Run basin. In the northern portion of the basin and along the west border the principal mines are in the vicinity of Manakin on the north and south sides of the James river; and about two miles south of west from Huguenot.

In addition to these, many smaller openings have been made along the border portions of the basin and drillings have been put down in places, which, in some cases, reached a depth of more than 2,000 feet.

Operations in the Richmond basin during 1905 and 1906 were confined to Winterpock and Midlothian, in Chesterfield county, and were largely in the nature of development work preparatory to shipping. The Gayton mines north of the James river in Henrico county were closed down several years ago. Since closing down, these mines have changed hands and as yet work has not been resumed. At Winterpock a new incline was under way during the summer of 1905. At Midlothian the only mining of coal during the past two years was limited to that for the company's use. The developments at Midlothian during the past two years comprise a new incline 1,020 feet long by 16 feet wide and 7 feet high on a 33° pitch, to coal 8 feet thick. The coal has actually been proved in this incline for 1,300 feet and laterally for 700 feet each way. One and a quarter miles of trackage and a tipple will be completed by the close of 1906, when the shipment of coal from this property will begin. The future prospects of this property are very encouraging. The property is under the control of the James River Coal Corporation.

THE APPALACHIAN MOUNTAIN PROVINCE.

Lower Carboniferous (Mississippian) Coals.

The coals of Rogers' formation No. X (Vespertine) extend, as isolated areas, nearly entirely across the State, in a northeast-southwest direction, west of the Blue Ridge. So far as known the Lower Carboniferous coals in Virginia include the following fields:

(1) The Mountain Falls District in Frederick County.
(2) The North River Area in Augusta County.
(3) The North Mountain Area in Botetourt County.
(4) The Montgomery-Pulaski Counties Area.
(5) The Bland-Wythe Counties Area.

These are separately described below in the order here named.

The Mountain Falls District.

Frederick county.—Very little is known as yet in a definite way of the geology of this region. In his *"Reprint of the Virginias,"* page 99, Professor Rogers mentions the occurrence of coal seams in Frederick, Shenandoah, and Rockingham counties along with those of Augusta, Botetourt, and Montgomery counties. In each of these counties, with the exception of the first two, the coal-bearing horizon is known as formation No. X (Vespertine) or. Mississippian. The inference is, therefore, that the coal in Frederick county is of the same age.

In the first four counties, Frederick, Shenandoah, Rockingham, and Augusta, the coal is nearly identical, and according to Professor Rogers the seams vary in thickness from 3 to 7 feet. The dipping west into Little North Mountain, near Coal Run, in Rockingham county, is said to be about 4 feet thick.

Two operations have produced some coal during the past few years near Mountain Falls, in the southwestern part of Frederick county, near the West Virginia line. One of these was reported idle during 1905.

The North River Coal Field.

Augusta county.—In the northwest corner of Augusta county and the contiguous part, southwest corner, of Rockingham county is a small area of Lower Carboniferous (Mississippian) rocks which, to a limited extent, are coal-bearing near the top. The formation is mapped by Darton as the Pocono sandstone with thin coal beds and shale in the upper portion. The field is known as the North River coal field and it is west of Narrow (Little North) Mountain.

The coal is of the semi-anthracite variety and it has been mined to a limited extent in North River Gap, in Augusta county. The supply has been found sufficient for local use. The beds are thin and the coal is often crushed, but it is reported not difficult to obtain small supplies. Darton states that attempts have been made to find thicker beds by excavations and deep diamond-drill borings, but without success.

Hotchkiss gives the following analyses of the coal made by Booth, Garrett and Blair of Philadelphia, from the Augusta county area:

Constituents	I Per ct.	II Per ct.	III Per ct.	IV Per ct.	V Per ct.	VI Per ct.	VII Per ct.
Carbon	89.47	89.02	87.65	86.35	88.09	87.40	85.85
Volatile matter	6.00	6.42	7.58	7.27	6.64	6.10	6.20
Water	0.40	0.50	0.80	0.80	0.35	0.45	0.60
Ash	4.13	4.06	3.97	5.58	4.92	6.05	7.35

I and IV—Opening on Briery Branch about 100 feet above the base of Narrow Mountain.
II—Little Coal Run, from end of a 100-foot drift in an 18-inch bed, and 5.5 miles southwest of III.
III—Near Briery Branch at foot of Narrow Mountain from a drift 5 or 6 feet in a 4-foot bed.
V—Half a mile southwest of II, from a bed 4 to 5 feet thick and 13 feet lower.
VI and VII—From the Scheffer drift in a 6-foot bed, North River Gap, near II and V.

The North Mountain Coal Field.

Botetourt county.—The North Mountain coal field, known by some as the Katawba, Caldwell, or Brushy Mountain field, is located along the Botetourt-Craig counties boundary, in the southwest corner of Botetourt county. The coal is of Lower Carboniferous age and has been used locally for a long time. The coals have had greater or less local value and were considerably mined prior to 1864 for local use. They will probably never furnish a basis for large mining enterprises, as the areas are limited, the beds are crushed and broken, and are cut by faulting.

A sample of this coal collected by Mr. O. J. Heinrich on Stone Coal Run, in Botetourt county, gave on analysis:

	Per cent.
Carbon	78.0
Volatile matter	12 2
Sulphur	trace
Ash	9.8

The coal is reported to be a semi-bituminous variety, averaging 12 to 14 per cent. volatile matter, 75 to 80 per cent. fixed carbon, and 5 to 9 per cent. ash. It is practically free from sulphur and burns to a white ash. According to Heinrich two principal seams were developed; the lower about 5 feet thick with 2 feet of coal, the upper from 10 to 12 feet thick with 6 to 10 feet of coal. The seams are best developed on Stone Coal Run.

The Montgomery-Pulaski Counties Field.

Of the numerous Lower Carboniferous coal areas known in Virginia, the Montgomery-Pulaski field is much the most important one, and it is practically the only producing area at present. The area is located 30 to 50 miles west of the city of Roanoke. Map, figure 54, shows the location of the principal mines in this area.

In the Montgomery county portion of the area the mines are opened along the south slope of Brush Mountain and on the slopes of a parallel ridge locally known as Price Mountain, distant some 3 to 4 miles south from Brush Mountain. In Pulaski county developments are made on the slopes of Cloyd and Little Walker Mountains, which are a continuation southwestward of Brush Mountain in Montgomery county. The coal area lies near the northern border of the two counties and is crossed by New river, which is the dividing line between the counties.

The total estimated acreage of the Montgomery county portion of the field is about 7,000 acres. The extent of the Pulaski part of the field is not certain but it is probably nearly equal to the Montgomery field. It extends from New river to within 6 miles northwest of the town of Pulaski, which includes the developments thus far made.

Coal was mined in this field prior to the Civil War but not in an extensive way. It is reported that some of the coal used in the bunkers of the *Merrimac* (Virginia), in her fight with the *Monitor* in Hampton Roads, came from the Price Mountain mines. For a period of 30 years after the Civil War the only mining carried on in this field was to supply a local market. For a number of years past large developments have been made, more extensive and systematic mining has been carried on in accordance with modern methods, and a steady increase in output over that of the local market has been indicated yearly.

The coal seams occur in strata of Lower Carboniferous (Mississippian) age. The rock series consists of a variable thickness of sandstone, conglomerate, and shale, dipping at angles varying from 20° to 40°. On

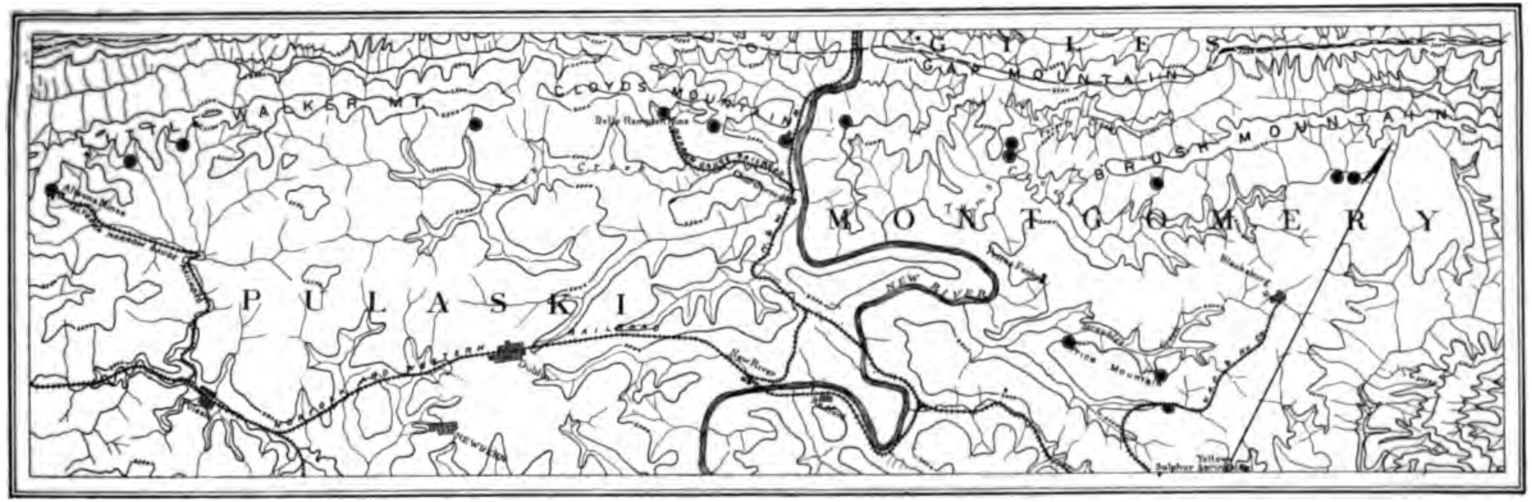


Fig. 54.—Map showing location of principal mines in the Montgomery-Pulaski counties coal field. Mines indicated by heavy dots. Based on the Christiansburg and Dublin topographic sheets, U. S. Geol. Survey. Scale, 1/4 inch = 1 mile, approximately. Contour interval, 500 feet.

Merrimac coal mines and breaker. Virginia Anthracite Coal Company, near Christiansburg, Montgomery county, Virginia.

ANTHRACITE COAL MINES AND BREAKER.

Price Mountain 5 coal seams are indicated, only one of which has yet proved to be workable. An average thickness of 4.5 feet of clean coal is mined from this seam. On Brush Mountain two seams yield workable coal which average in thickness 3 and 4.5 feet of clean coal, respectively; they are named the "Little" and "Big" seam. Likewise two seams are worked in the Pulaski portion of the field. The coal is the semi-anthracite variety of excellent quality. That from the Price Mountain mines is harder, and consequently not so free-burning as the coal from Brush Mountain.

Of the various mines operating in the Montgomery-Pulaski field the *Merrimac mines* on Price Mountain, Montgomery county, are probably the largest producers. These mines are owned by the *Virginia Anthracite Coal Company* and are directly on the standard-gauge steam road which connects Blacksburg with the Norfolk and Western Railway at Cambria. A breaker (plate LIV) has recently been completed having a capacity, with the present machinery, of 500 tons per day. By installing duplicate screens and other machinery it is claimed the capacity can be more than doubled. The storage capacity of the breaker is 500 tons. The average run of the breaker at present is 100 cars of coal per month. The present depth of working at these mines is 1,026 feet on a dip of 22°.

During 1905 some half dozen operators were engaged in mining coal in the Brush Mountain area, the principal ones being the *Virginia Anthracite Coal Company,* the *Blacksburg Mining and Manufacturing Company,* and a number of private individuals.

The principal mines working in the Pulaski field during 1905 were the *Altoona, Belle Hampton,* and *Kimball.* The *Kimball mines* are located on New river, and directly on the Norfolk and Western Railway. This property has recently been acquired by the *Pulaski Anthracite Coal Company,* which is making extensive improvements with a promising outlook. A breaker has recently been erected at the mines, and a small one is being built at the *Belle Hampton mine* by the *Belle Hampton Coal Company.* A spur track connects the Belle Hampton mine with the Norfolk and Western Railway. The *Altoona mines,* located 6 miles northwest of Pulaski, are owned and operated by the Bertha Mineral Company at Pulaski. All the coal formerly used by the Bertha Company at its zinc furnaces in Pulaski came from the Altoona mines, but only the "firing" coal or reducing material is obtained there at present. A steam road is operated between the mines and Pulaski.

The following chemical analyses of coal from the Montgomery-Pulaski field afford a general idea of its composition:

Constituents.	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.	VI Per cent.	VII Per cent.
Carbon	73.012	75.618	70.924	72.737	70.924	74.018	80.16
Volatile matter	11.652	11.324	12.870	12.215	12.870	9.675	13.60
Water	1.228	0.816	0.615	0.725	0.615	1.080	0.887
Ash	13.560	11.545	15.110	13.990	15.110	14.550	5.76
Sulphur	0.548	0.697	0.481	0.333	0.481	0.682	——

Constituents.	VIII Per cent.	IX Per cent.	X Per cent.	XI Per cent.	XII Per cent.	XIII Per cent.
Carbon	79.97	74.24	72.737	74.013	69.66	71.86
Volatile matter	9.82	11.00	12.215	9.675 }	14.93	13.14
Water	0.74	1.16	0.725	1.080 }		
Ash	8.91	13.53	13.990	14.550 }	15.41	15.00
Sulphur	——	——	0.333	0.682 }		

I to V—Brush Mountain mines, Montgomery county, A. S. McCreath, analyst.
VI—Price Mountain mines, Montgomery county, A. S. McCreath, analyst.
VII—Wilson drift, Price Mountain, Montgomery county, Dr. W. B. Ellett, analyst.
VIII—Merrimac mine, Price Mountain, Montgomery county, W. T. Young, analyst.
IX—Kipps mine, Price Mountain, Montgomery county, Dr. W. B. Ellett, analyst.
X and XI—William Meyers' lands, east slope of Price Mountain, Montgomery county, A. S. McCreath, analyst.
XII and XIII—Belle Hampton mine, Pulaski county, H. H. Hill, analyst.

The Bland-Wythe Counties Field.

A small coal field of Lower Carboniferous (Mississippian) or Pocono age is found in the southern portion of Bland county and in the northern portion of Wythe county. The coal seams appear in the Price sandstone in the vicinity of Bland court-house, Sharon Springs, and near the southwestern corner of Bland county; and near and to the south of Little Walker Mountain in Wythe county, on Reed creek. As a rule the seams are small and much broken by partings and the coals are generally high in the percentage of ash. The rocks are usually highly tilted and are more or less crushed.

The coals have attracted considerable attention from time to time and attempts have been made to develop them, but thus far without success.

The following analyses of the coal from the Wythe county portion of the field made by A. S. McCreath, afford some idea of its character:

Constituents.	I Per cent.	II Per cent.
Carbon	55.615	59.427
Volatile matter	16.264	17.853
Water	0.466	0.620
Ash	26.660	20.525
Sulphur	0.995	1.575

I—Seven miles northwest of Wytheville from a 3-foot bed. Little Walker Mountain, near the level of Stony creek or Reed creek.
II—From near the same place as I. Coal from 2-foot bed that had been exposed to the weather for a month.

The Carboniferous (Pennsylvanian) Coals.

LOCATION AND IMPORTANCE.

The southwest Virginia coal field is located in the extreme southwestern part of the State, on the west side of the Great Valley, and occupying the eastern and southeastern portions of the Cumberland plateau region in Virginia. It forms the southwestern part of the Kanawha basin, and comprises the following counties: Tazewell, Russell, Scott, Buchanan, Wise, Dickenson, and Lee. Of these, Wise and Tazewell counties are the two most important producers at present. The other counties contain very large coal reserves which, in places, are rapidly undergoing development. The present era of railroad construction in this part of Virginia will witness, in the immediate future, extensive developments and mining of the enormous reserves of excellent coal hitherto undeveloped because of lack of railroad facilities.

The southwest Virginia coal field is vastly the largest, most productive, and most important in the State. Indeed, it is due to this field that Virginia is entitled to rank among the principal coal-producing states in the United States. It is estimated that the area of coal-bearing formations in this field comprise 1,850 square miles, with probably 80 per cent. of it productive.

The two principal coal fields in the southwest Virginia area thus far developed are (a) The Pocahontas or Flat Top Coal Field, and (b) The Big Stone Gap Coal Field. These are separately described below in the order here named.

Geologic Relations.

THE AGE OF THE COAL-BEARING ROCKS.

The coal-bearing rocks of the southwest Virginia field belong to the Coal Measures division of the Carboniferous. Probably most, if not all, of the coal-bearing rocks in this field correspond in age to the Pottsville series, the lowest subdivision of the Pennsylvania section. In the Pocahontas or Flat Top coal field, situated in the northeastern part of the Virginia field, the Pocahontas formation of Campbell is the basal member of the series, and to the southwest in the Big Stone Gap field the Lee formation forms the basal member. The subdivision in southwest Virginia is separated by a probable thickness of coal-bearing rocks of from 2,800 to 3,000 and more feet.

Stratigraphy.

The Carboniferous formations in southwest Virginia, as mapped in the Pocahontas, Tazewell, Bristol, and Estillville quadrangles by the U. S. Geological Survey, are separately given below in descending order, together with the thickness and character of each formation. In these tables is given the original classification of Professor Rogers of the Virginia Carboniferous, with the present classification of the U. S. Geological Survey.

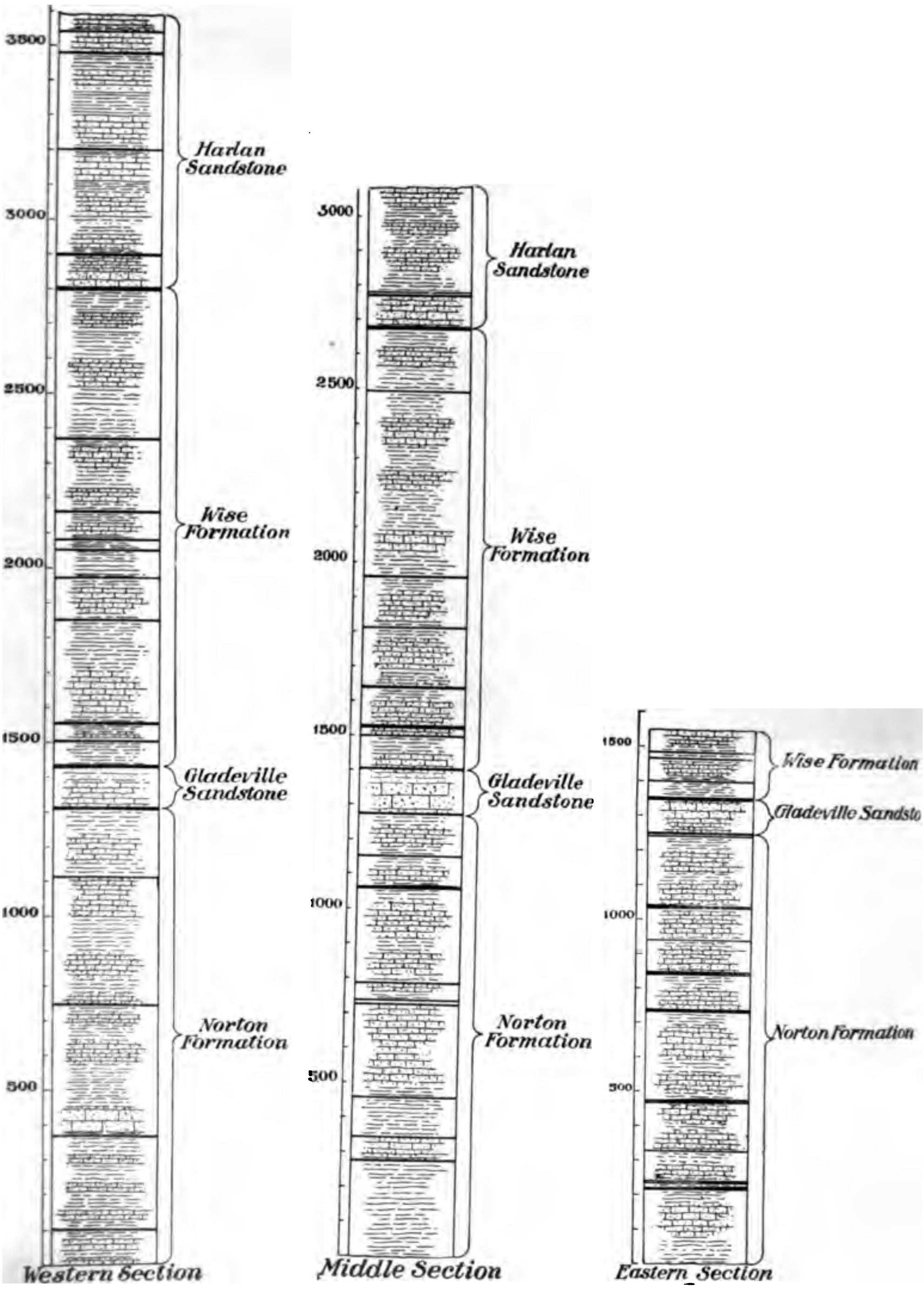
The four quadrangles cover parts of the following counties in Virginia, which contain coal-bearing rocks: The Pocahontas quadrangle, includes a part of Tazewell county; the Tazewell quadrangle, includes parts of Tazewell, Buchanan, and Russell counties; the Bristol quadrangle, includes parts of Russell, Wise, Scott, and Dickenson counties; and the Estillville quadrangle, includes parts of Lee, Wise, and Scott counties.

Pocahontas Quadrangle.

Rogers	U. S. Geological Survey	Thickness in feet	Character
No. XII Great conglomerate.	Sewell formation.	100+	Sandy shale
	Raleigh sandstone	80	Coarse sandstone in heavy beds
	Quinnimont shale	300	Shale, sandstone, and coal
	Clark formation	380	Sandstone at top; shale, sandstone, and coal at bottom
	Pocahontas formation	360	Shale, sandstone, and coal
No. XI Greenbrier shale.	Bluestone formation	800	Shale, sandstone, impure limeston
	Princeton conglomerate	40	Coarse sandstone or conglomerate
	Hinton formation	1250-1300	Shale and sandstone
	Bluefield shale	1250-1350	Sandstone and calcareous shale
No. XI Greenbrier limestone.	Greenbrier limestone	1500	Blue limestone
No. X Montgomery grits.	Price sandstone	200-300	Shales, sandstones, and coal seams

Tazewell Quadrangle.

Rogers	U. S. Geological Survey	Thickness in feet	Character
No. XIII Lower coal group.	Tellowa formation.	500	Sandstone, shale and coal
	Sequoyah formation	450	Sandstone, shale and coal
No. XII Great conglomerate.	Dotson sandstone	180	Coarse sandstone, with shale at
	Bearwallow conglom'ate	60	Coarse conglomerate or sandsto
	Dismal formation	490	Sandstone, shale, and coal
	(Dismal conglomerate Lentil)	0-120	Coarse conglomerate in western of area
	Raleigh sandstone	100	Coarse sandstone, sometimes glomeratic
	Welch formation	700	Sandstone, shale, and coal
	Pocahontas formation	360	Sandstone, shale, and coal
No. XI Greenbrier shale.	Bluestone formation	700-800	Shale, sandstone, impure limes
	Princeton conglomerate	20- 40	Fine conglomerate
	Hinton formation	1150-1250	Shale, sandstone, impure limes
	Bluefield shale	1150-1250	Shale, impure limestone at the
No. XI Greenbrier limestone.	Greenbrier limestone	900-1000	Blue limestone
No. X Montgomery grits.	Price sandstone	0-200	Sandstone and shale



Generalized sections from different portions of the Big Stone Gap coal field, showing important coal horizons. (After M. R. Campbell, Bul. 111, U. S. G. S.)

The Sewell formation of the Pocahontas quadrangle includes the Dotson, Bearwallow, and Dismal formations of the Tazewell quadrangle. The Quinnimont and Clark formations are included in the Welch.

Bristol Quadrangle.

Rogers		U. S. Geological Survey	Thickness in feet	Character
No. XII	Great conglomerate.	Wise formation	100+	Shale, sandstone, and coal
		Gladeville sandstone	100	Coarse sandstone, sometimes conglomeratic
		Norton formation	1200-1300	Shale, sandstone, and coal
		Lee formation	1500±	Sandstone, conglomerate, shale, coal
No. XI	Greenbrier shale.	Pennington shale	1040-1100	Shale, occasional sandstone, and impure limestone
	Greenbrier limestone.	Newman limestone	1000±	Blue limestone

Estillville Quadrangle.

Rogers		U. S. Geological Survey	Thickness in feet	Character
No. XII	Great conglomerate.	Harlan sandstone	880	Coarse sandstone, shale, and thin coal seams
		Wise formation	1260	Shale, sandstone, and coal
		Gladeville sandstone	120	Coarse sandstone, sometimes conglomeratic
		Norton formation	1270	Shale, sandstone, and coal
		Lee conglomerate	1240-1590	Sandstone, conglomerate, shale, coal
No. XI	Greenbrier shale.	Pennington shale	1040-1100	Shale and sandstone
	Greenbrier limestone.	Newman limestone	700- 930	Blue limestone

As is observed above in the tables of Carboniferous formations, the coal-bearing strata of the southwest Virginia field consist of beds of conglomerate or coarse sandstone, shale, and numerous seams of coal.

Beneath this group of coal-bearing strata and to the southeast of the Pocahontas field, in the southern portion of Bland county and the northern part of Wythe county, is a coal-bearing series of rocks, principally the Price sandstone, of Lower Carboniferous or Mississippian age. Areas belonging to this horizon are found, as described above, at intervals along the western side of the Great Valley in Virginia as far north as Frederick county. These are described above under coals of Mississippian age.

On plate LV, are given three generalized sections from the eastern, middle, and western portions of the Big Stone Gap coal field, showing important horizons. These sections, adopted from Campbell, show four well-marked coal horizons.

Stru

On plate LVI are given 4 struc
from different places in the southw
from these and from the position o
figure 52, the strata forming the c
greatly folded rocks which form the
disturbance. As would naturally b
more disturbance along the eastern
west. In general the beds are more
exceptions gentle northwesterly dips,
figures 1, 2, 3, and 4.

In the Pocahontas field a fault
southeastern border. Traces of the
found in isolated places to the eas
greater eastern extension of the field
to thicken toward the east.

The Big Stone Gap coal field,
the coal basin, is marked by a belt o
forms the transition from the nearly
plateau on the west to the highly co
the east. The most pronounced str
Powell valley anticline, which has its
Gap field. It is an unsymmetrical ant
is almost vertical, while its southeas
axis and gradually merges into the
Middlesboro syncline, the most econ
Big Stone Gap field, has suffered con
in the form of folds and flexures.

These structural features have a
development of the field.

Character

The fuel value of a coal is d
steam boiler tests, and by results
large number of analyses made of
field, a few of those which seemed
ones accessible to the writer are given

Analyses of coal from the Tazewell area (Tazewell folio).

ure ent.	Volatile Matter Per cent.	Fixed Carbon Per cent.	Ash Per cent.	Sulphur Per cent.	Total Per cent.
9	16.00	70.99	12.72	0.62	100.62
2	22.36	70.35	6.67	0.91	100.91
2	27.19	59.88	12.51	1.30	101.30
9	25.29	64.24	10.08	1.17	101.17
8	25.91	64.23	9.20	1.19	101.19
2	32.86	48.83	9.89	0.51	100.51
9	22.55	60.72	10.84	0.55	100.55
5	25.61	68.54	5.70	0.94	100.93
3	29.68	61.75	7.99	0.79	100.79
4	24.65	63.77	9.34	0.65	100.55
2	22.88	65.24	11.36	0.73	100.73
8	18.45	62.93	16.16	0.54	100.54
1	19.32	70.42	10.05	0.72	100.72
0	22.09	71.78	5.63	0.62	100.62
3	18.80	54.54	24.83	0.54	100.54
3	30.08	55.90	13.36	0.74	100.74
7	33.31	59.22	6.70	0.65	100.65
4	24.20	71.63	4.03	0.85	100.85
7	30.79	66.52	2.12	0.68	100.68

Creath reports, as an average of eight samples taken by himself the Pocahontas, No. III seam, in the Pocahontas field, the results in column I below. Column II is an analysis of the same coal from the *West mine* of the *Pocahontas Collieries Company*, at Poca-, made by Professor Hite of the West Virginia Geological Survey.

Constituents	I Per cent.	II Per cent.
Moisture	.699	.21
Volatile matter	18.756	19.62
Fixed carbon	73.406	76.61
Ash	6.388	3.56
Sulphur	1.752	1.69
Phosphorus	—	.006

nalyses of coal from the Big Stone Gap field (Estillville folio).

	Water Per cent.	Volatile Matter Per cent.	Fixed Carbon Per cent.	Sulphur Per cent.	Ash Per cent.	Total Per cent.	Chemist
	1.716	43.069	48.252	0.738	6.225	100.00	McCreath
	2.234	35.571	58.016	0.749	3.430	100.00	McCreath
	2.260	37.270	57.661	0.539	2.270	100.00	McCreath
	1.508	38.602	48.393	3.077	8.420	100.00	McCreath
	1.206	41.539	48.274	3.527	5.460	100.00	McCreath
	1.154	35.346	60.107	0.643	2.750	100.06	McCreath
	0.924	35.971	58.436	0.579	4.090	100.00	McCreath
	1.400	33.660	58.365	0.705	5.870	100.00	McCreath
	1.464	36.266	59.741	0.799	1.730	100.00	McCreath
	2.008	31.437	57.704	0.651	8.200	100.00	McCreath
	1.096	34.684	58.143	0.662	5.415	100.00	McCreath
	0.600	35.795	57.428	0.652	5.525	100.00	McCreath
	1.480	31.97	62.85	0.68	3.70	100.68	Potter
	2.02	32.18	60.66	0.90	5.14	100.90	Potter
	2.22	29.56	59.66	—	8.56	100.00	Potter
	1.090	34.145	59.879	1.081	3.805	100.00	McCreath
I	0.840	33.720	60.006	0.709	4.725	100.00	McCreath
I	0.798	34.022	61.411	0.619	3.150	100.00	McCreath

The name, stratigraphic position, and location of the seams yielding the analyses given on preceding page are appended below in tabular form. The numbers in the first column on the left of the two tables are the same:

No.	Name of Seam	Stratigraphic Position	Location
I	Cannel	110 feet above Gladeville sandstone	Preacher creek
II		80 feet above Gladeville sandstone	Sang Trace creek
III		On top of the Gladeville sandstone	Clover Fork
IV		Under Gladeville sandstone (?)	Carroll opening, on Jones creek
V		Under Gladeville sandstone (?)	Bailey opening, on Jones creek
VI	Imboden	180 feet below Gladeville sandstone	Little Looney creek
VII	Imboden	180 feet below Gladeville sandstone	Little Looney creek
VIII	Imboden	180 feet below Gladeville sandstone	Little Looney creek
IX	Imboden (?)	180 feet below Gladeville sandstone	Pigeon creek
X	Imboden	180 feet below Gladeville sandstone	Mud Lick creek
XI	Imboden	180 feet below Gladeville sandstone	Preacher creek
XII	Upper Banner	800 feet above Lee conglomerate	3 miles E. of Tacoma
XIII	Upper Banner	800 feet above Lee conglomerate	Near Tacoma
XIV	Upper Banner	800 feet above Lee conglomerate	Near Tacoma
XV	Lower Banner	600 feet above Lee conglomerate	Old Greeno-Bodine mine, Tacoma
XVI	Lower Banner	600 feet above Lee conglomerate	Toms creek, 4 miles northeast of Tacoma
XVII	Kennedy	425 feet above Lee conglomerate	Old Greeno-Bodine mine, Tacoma
XVIII	Kennedy	425 feet above Lee conglomerate	Banner, 6 miles E. of Tacoma

McCreath and d'Invilliers in their report entitled "*Mineral Resources of the Upper Cumberland Valley, Southeastern Kentucky and Southwestern Virginia,*" give the following analyses of coal collected by them from the Crab Orchard district in Virginia:

Analyses of coal from the Crab Orchard district in Virginia (McCreath and d' Invilliers.)

Locality.	Water Per cent.	Volatile Matter Per cent.	Fixed Carbon Per cent.	Sulphur Per cent.	Ash Per cent.
Big Crab Orchard creek, McConnell opening	3.122	35.798	52.374	.565	8.146
Big Crab Orchard creek, Wilson opening	2.692	38.723	51.847	2.008	4.730
Sugar Hollow, upper bed, A. C. Morris	2.356	36.314	57.820	1.685	2.825
Sugar Hollow, lower bed, A. C. Morris	2.692	36.933	55.233	.947	4.195
Sugar Hollow, R. Mullen's coal	1.568	38.332	57.865	.525	1.710
Wolf Harbor creek, M. Zion's coal	1.662	38.533	53.329	2.096	4.380
Puckett's creek, LeRoy Kirk's coal	2.162	36.573	48.453	2.632	10.180
Puckett's creek, Cooper bank	.978	39.442	47.224	3.771	8.585
Puckett's creek, J. D. Pennington's coal	1.734	39.071	57.059	.436	1.700
Near Big Branch, E. L. Parson's coal	3.572	31.913	48.240	.615	15.660
Bailey's Trace, Newman's coal	1.586	33.229	51.045	.535	13.605
Ely's creek, N. Woodward's coal	2.472	37.403	56.389	.586	3.150

The Pocahontas or Flat-Top Coal Field.

INTRODUCTORY STATEMENT.

The construction of the Norfolk and Western Railway in 1882 opened up the famous Pocahontas coal district, which comprises Tazewell and Buchanan counties, in Virginia, and McDowell, Wyoming, and Mercer counties, in West Virginia. The district includes about 450 square miles of rough mountain land. The first mine is reported to have been opened in 1882, at the village of Pocahontas, Tazewell county, Virginia, from which the area derived its name. As described below, there are a number of workable seams of coal in the district, but the principal one worked at present is the great Pocahontas vein, No. III, which is 11 feet, 3 inches thick.

The superior quality of the Pocahontas coal has long established it as the best steam coal in the world. As such it has foremost rank, and it is used on the ocean steamers of the principal nations. It produces an excellent coke, but, as a rule, the lump coal is placed directly upon the market for general purposes, while the slack and fine coal go direct to the ovens for coking.

The general purity of the Pocahontas coals is remarkable; picked samples frequently run less than 1 per cent. of ash. These coals possess in an eminent degree three qualities of marked recognition: (1) Superior steaming qualities; (2) relatively smokeless qualities; and (3) superior coking qualities.

OPERATIONS.

The largest operations in the Pocahontas field are controlled by the *Pocahontas Collieries Company*. This company is opening up a new mine at Boissevain, which, after completion, will be followed by other new development work. In the latter part of 1906, 4 mines were operating at Pocahontas, producing from 4,000 to 6,000 tons of coal per day. One of these, the *West mine,* has the reputation of being the largest bituminous coal mine in the world. The coal worked here is the Pocahontas, No. III seam, which is 10 feet thick and unusually clean, with practically no partings and an excellent top. (See plate LVII.) The Pocahontas Company is engaged in opening up its new plant at Boissevain, 3 miles west of Pocahontas. Two other plants, located 3 miles west of Boissevain, are reported will open up in the near future. Each operation is expected to produce from 3,000 to 4,000 tons of coal per day. These new mines are located in the valley of Laurel creek and will be reached by a new railroad now under construction from Pocahontas westward.

In addition to the Pocahontas Collieries Company, the other operators in the Pocahontas field are: *J. S. Browning,* the *Town Hill Coal Company,* the *Domestic Coal Company,* and the *Coal Creek Coal Company.*

THE COAL.

Introduction.—In the Pocahontas or Flat-Top coal field, coal has been found in each of the horizons of the Carboniferous above the Bluestone formation, excepting the Raleigh sandstone and the Bearwallow conglomerate, which attain thicknesses of 100 and 60 feet, respectively. In the Tazewell quadrangle, covering parts of Tazewell and Buchanan counties in Virginia, the coal-bearing formations are 6 in number, including in ascending order the Pocahontas, Welch, Dismal, Dotson, Sequoyah, and Tellowa formations. In the adjacent Pocahontas quadrangle on the east the coal-bearing horizons include the Pocahontas, Clark, Quinnimont, and Sewell formations. Not all the coals of the upper formations are within the Virginia portion of the field, but so far as known they are represented across the line in West Virginia.

A large number of coal-beds are found within the total vertical limits of these formations. Some of these are thin, but at least 6 workable beds have been opened in places. Not all of these are workable, however, at any one point, and in places only 1 is worked.

The coals may be conveniently described by formations, which are as follows, beginning with the oldest: (1) Coals of the Pocahontas formation; (2) coals of the Welch (Clark and Quinnimont of the Pocahontas quadrangle) formation; (3) coals of the Dismal (Sewell in part of the Pocahontas quadrangle) formation; (4) coals of the Sequoyah formation; and (5) coals of the Tellowa formation.

The geological section for Tazewell and eastern Buchanan counties, Virginia, and western McDowell county, West Virginia, as compiled by Stevenson from Campbell's studies, is as follows:


1
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12

The relations of the lower beds in northeastern Tazewell county are shown in the following section reported by McCreath:

		Feet.	Inches
1.	Concealed measures	40	0
2.	*Coal 7*	2	0
3.	Concealed	20	0
4.	*Coal 6*	1	6
5.	Concealed	80	0
6.	*Coal 5* and dirt	4	6
7.	Concealed	91	0
8.	*Coal 4*	2	0
9.	Concealed	90	0
10.	Sandy fireclay	6	0
11.	*Coal 3*, Pocahontas	11	3
12.	Fireclay	6	0
13.	Shales and sandstone	61	0
14.	*Coal 2* and shale	4	0
15.	Concealed	12	2
16.	Gray sandstone	15	4
17.	*Coal 1*	1	0
18.	Sandstone, some shale	67	10
19.	Sandstone, *coal* streaks	8	8
20.	Shale and sandstone	294	9

Coals of the Pocahontas formation.—This formation, which averages probably 360 feet in thickness, carries several beds of coal, the most important one of which, in this and in succeeding formations, is the great Pocahontas, No. III seam. The lowest seam in this formation is partially exposed near the mouth of Vall creek just across the line in West Virginia, showing in that part of the seam exposed a thickness of 2 feet 8 inches. Sixty feet below the Pocahontas, No. III seam is a second seam which measures from 2 feet 6 inches to 3 feet 8 inches in thickness, as exposed along Tug river and Adkins branch in West Virginia.

The most important seam of the area and the one which has been developed to the greatest extent is the Pocahontas or No. III seam. It shows a general dip to the northwest, which is irregular, varying from 100 feet in 3 or 4 miles in some places to as much as 200 feet in 1 mile. There are developed in the seam, in addition to the general dip, numerous gentle undulations. It varies in thickness from 4 to 10 feet, and attains its maximum thickness at the original place of opening on Coal Creek, at Pocahontas. According to Campbell it diminished in thickness from this point in all directions, but most rapidly toward the northeast. The Flat-Top Coal Land Association gives the following measurements of the Pocahontas seam at various places: at the mouth of Harmon branch, 8 feet; 1 mile below, 8 feet 7 inches; at Tug River post-office, 9 feet; and at each of four openings on Sand Lick creek, 8 feet. These measurements are all in West Virginia.

Near the point on Long Branch in West Virginia, where the seam passes beneath the water level, the thickness of the seam is reported to be 10 feet 11 inches. On Big creek in the vicinity of Squirejim, the thickness is 4 feet 6 inches; and at the mouth of Cucumber creek it is 6 feet 3 inches. Campbell reports the seam exposed at water level 1¼ miles above the mouth of Big creek on Jacob Fork, but it rises rapidly above water level, from this point southward until at Cucumber creek it is 180 feet above water level. Again on Dry Fork, 1½ miles below the mouth of Keewee creek, the seam rises above water level, exposing a thickness of 3 feet 8 inches. Near the mouth of Vall creek its thickness increases to 4 feet 7 inches. Nearly opposite Sayersville on Beech creek the seam (probably Pocahontas) has a thickness of 6 feet 3 inches. Higher up on the same creek an opening exposes a thickness of 4 feet 9 inches. West of this point the seam is reported to be below water level, unless it is exposed, as suggested by Campbell, in the upturned rocks along the edge of the basin.

Coals of the Welch (Clark and Quinnimont) formation.—The Welch formation carries a greater number of workable coal beds than any other in the area. At Horsepen, north of Tazewell, several large seams occur which range in position from 250 to 440 feet above the Pocahontas or No. III seam. The seams contained within this interval of 290 feet have been grouped and named by Campbell the Horsepen group. There are 4 principal seams in the formation, the lowest one of which, the Lower Horsepen seam, is 150 feet above the Pocahontas or No. III seam. Back of the schoolhouse at Horsepen this seam has a thickness of 4 feet 9 inches. The seam is best developed above Richlands where it has been opened up, but it is extremely variable. West of Big creek the downward pitch of the anticline carries the seam below water level.

One of the best seams of this group is found 120 feet above the Lower Horsepen seam or 270 feet above the Pocahontas, No. III seam. Campbell calls it the War creek coal, where it is well shown on War creek and in the vicinity of Perryville, West Virginia. It is reported opened at 7 or 8 places on War creek and Dry Fork on the West Virginia side, and it holds a constant thickness of from 4 feet 4 inches to 5 feet.

The Middle Horsepen seam is 239 feet above the Lower Horsepen seam and 110 feet above the War creek seam. It shows 4 feet of clear coal at Horsepen. It is found 2.5 miles above Harman, on the eastern fork of the creek, and it is 130 feet above water level. It has been opened above Richlands on Big creek but was afterwards found to be too thin for working. Campbell states that it passes below water level before reaching Coal creek.

At Horsepen is a heavy seam 60 feet above the Middle Horsepen or last described seam, called the Upper Horsepen seam, having a thickness of 8 feet. Four miles east of Horsepen at Smith Store this seam is 9 feet thick. It has been opened at a number of places on Indian creek showing a thickness of from 4 to 6 feet. It grows thinner toward the north and at Perryville, West Virginia, it has a reported thickness of about only 2 feet, and further to the northeast at Welch the thickness is given as 20.5 inches.

About 100 feet above the Upper Horsepen seam is still another seam, which 2 miles south of Bearwallow shows 2 feet of clear coal. Campbell reports 2 probable additional coals above the last mentioned seam, but their occurrence, extent and thickness are somewhat uncertain.

Coals of the Dismal formation.—The coal which appears over a considerable part of the area in the Dismal formation, according to Campbell, is probably not a continuous seam but a general horizon, in which the seams vary slightly in their stratigraphic position. This coal horizon reaches its greatest development on Dismal creek, where it is reported to range in thickness from 10 to 14 feet. At the head of Dismal creek and near the Bearwallow triangulation station, the seam has a thickness of 4 feet 6 inches. It is reported to have its greatest development 5 miles above McNiel's Store. It shows again at a number of places south of Sandy Ridge; on Big Town Hill creek, near its mouth; near the sharp bend in Middle creek; and on Laurel creek, where it varies in thickness from 4 to 5 feet.

According to Campbell, a coal seam in the lower portion of the Dismal conglomerate has been opened in the ridge between Big Town Hill and Mud Lick creeks, showing a thickness of 3 feet 5 inches; and again on the ridge between Indian and Middle creeks its thickness is 4 feet.

Coals in the Sequoyah and Tellowa formations.—Coal seams appear in both of these formations. Those in the Sequoyah formation are not known to be of great commercial value. Those of the Tellowa formation occur beyond Virginia on Tug river in West Virginia.

The Big Stone Gap Coal Field.

LOCATION AND IMPORTANCE.

The Big Stone Gap coal field is located in southwestern Virginia and southeastern Kentucky. In Virginia it embraces parts of Wise, Lee, and Scott counties, and in Kentucky, parts of Harlan and Letcher counties. Its southern and eastern boundaries are irregular, being largely the

Fig. 1.—General view of Clinchfield Coal Company's incline at Dante.

Fig. 2.—General view of the Cranes Nest Coal and Coke Company's tipple, Toms Creek.

COAL INCLINE AND TIPPLE, BIG STONE GAP COAL FIELD, VIRGINIA.

southern margin of the coal measures. As developed at present the field has an approximate area of 540 square miles in Virginia and Kentucky. The area is a part of a long and narrow basin which extends northeast and southwest, and is bounded on either side by sharp and rocky ridges. The natural passageway in and out of this field is Big Stone Gap in Wise county, from which the field received its name. Several lines of railroad utilize this passageway which forms one of the principal outlets from the field.

The building of the Clinch Valley division of the Norfolk and Western Railway in 1891, marked the beginning of developments in the Big Stone Gap coal field. Although opened up nearly 10 years after the famous Pocahontas field, it is much the largest producer of coal and coke, and Wise county is, at present, the largest coal- and coke-producing county in the State. It is estimated that the field produces about 80 per cent. of the Virginia coke output.

THE COAL.

There are 8 workable seams of coal in the district, ranging in thickness from 3.5 to 12 feet, and included within a vertical distance of about 1,200 feet. Of these the 4 highest have their greatest development in the western part of the district. Deep cutting by the streams and light dip of the strata are conducive to economic mining over much of the field.

Campbell divides the field into four separate basins, as follows: (1) The Crab Orchard basin, which includes all the territory in Lee county lying north of Stone Mountain, known as Crab Orchard; (2) the Imboden basin, so named because of the great development of the famous Imboden coal seam, which includes the area drained by the Powell river through Big Stone Gap; (3) the Guest river basin, comprising the region east of Norton drained by Guest river, the principal stream; (4) the Kentucky basin, which lies wholly in Kentucky and forms a part of the Big Stone Gap field. For convenience the field is divided below into the eastern portion and the western portion, and separately discussed.

In the Big Stone Gap field, Campbell divides the measures in descending order, into the following formations:

	Thickness in feet.
Wise formation	1,276
Gladeville sandstone	120
Norton formation	1,280
Lee formation	1.530

Of these the Norton is the principal coal-bearing formation. Two sections measured by Campbell, one in the extreme eastern part of Wise county, the other in the western part of the same county, show the relations of the principal horizons of the Norton formation. Section No. II includes 530 feet of the Norton, the Gladeville sandstone, and some higher beds.

Section No. I. Extreme eastern part of Wise county:

		Feet.	Inches		Feet.	Inches
1.	Gladeville sandstone					
2.	Interval	150	0			
3.	*Imboden coal bed*	4	5			
4.	Interval	250	0			
5.	*Upper Banner coal bed*	3	0	to	7	0
6.	Interval	100	0			
7.	*Lower Banner coal bed*	1	6	to	4	4
8.	Interval	225	0	to	285	0
9.	*Kennedy coal bed*	1	0	to	9	0
10.	Interval	340	0			
11.	*Tacoma coal bed*	3	4	to	4	4
12.	Interval	90	0			
13.	*Jawbone coal bed*	4	4	to	8	8
14.	Interval to Lee formation	150	0			

Section No. II. Western part of Wise county:

		Feet.	Inches		Feet.	Inches
1.	Sandstone	45	6			
2.	*"Cannel bed"*	6	6			
3.	Thin bedded sandstone	29	0			
4.	*Upper Splint bed*	1	6			
5.	Concealed	58	6			
6.	Shale	16	6			
7.	Sandy shale	13	6			
8.	*Lower Splint bed*	2	0			
9.	Gladeville sandstone	122	0			
10.	*Coal bed*	2	0			
11.	Shale and concealed	11	0			
12.	*Kelly coal bed*	1	6			
13.	Interval	75	0			
14.	*Imboden coal bed*	6	7	to	13	1
15.	Concealed	70	0			
16.	Sandstone	20	0			
17.	*Coal* and clay	4	8			
18.	Shale	10	0			
19.	Sandstone	105	0			
20.	Shale	110	0			
21.	*Coal bed*	0	8			
22.	Sandstone	10	0			

OPERATIONS.

The principal operations in the Big Stone Gap coal field are given below in tabular form:

Name of Operation.	Post-office.
Banner Coal Company	Norton,
Barrowman Coal Company	Banner,
Bear Creek Coal and Coke Company	Tacoma,
Blockwood Coal and Coke Company	Blockwood,
Bond Coal Company	Wise,
Bruce Coal and Coke Company	Coeburn,
Carbon Coal and Coke Company	Norton,
Clinchfield Coal Company	Dante,
Cranes Nest Coal and Coke Company	Georgel,
Dawson Coal and Coke Company	Fink,
Domestic Coal Company	Raven,
Guest River Coal and Coke Company	Esserville,
Imboden Coke Company	Imboden,
Intermont Coal and Iron Company	Big Stone Gap,
Nickles Coal and Coke Company	Tacoma,
Norton Coal Company	Norton,
Raven Collieries Company	Raven,
Raven Fuel Company	"
Raven Red Ash Coal Company	"
Richlands Coal Company	Coldron,
Russell Creek Coal and Coke Company	Virginia City,
Seaboard Coal Company	Seaboard,
Spruce Pine Coal Company	Norton,
Stone Gap Colliery Company	Glamorgan,
Stonega Coal and Coke Company	Stonega,
St. Paul Coal and Coke Company	St. Paul,
Swords Creek Coal and Coke Company	Swords Creek,
Tacoma Coal and Coke Company	Tacoma,
The Colonial Coal and Coke Company	Dorchester,
Town Hill Coal Company	Richlands,
Virginia Iron, Coal and Coke Company	Georgel,
Virginia Iron, Coal and Coke Company	Banner,
Wise Coal and Coke Company	Dorchester,

THE EASTERN PORTION OF THE FIELD.

Introduction.—Reference to section No. 1 above, on page 366, will make clear the relations between the different coals in this portion of the field, which occur in the Norton formation. There are six coal horizons in the Norton formation which afford promise of workable seams at some point within the field. Named in descending order, these are designated by Campbell as follows:

(1) Edwards Seam.
(2) Upper Banner Seam.
(3) Lower Banner Seam.
(4) Kennedy Seam.
(5) Imboden Seam (?) so-called.
(6) Jawbone Seam.

These are found in different horizons in different parts of the field. Usually the lower ones are confined to the eastern portion of the field, including the Kennedy, so-called Imboden, and Jawbone seams, and the higher ones to the western, including the Edwards, Upper Banner, and Lower Banner seams. The coals of the higher group are reported to be remarkably regular in thickness and composition, while those of the lower group are considered quite variable.

The Edwards seam.—This is the highest seam of coal in the Norton formation, and it is found in several outcrops near the summits of the highest hills in the northern part of the field. It is found about 150 feet below the base of the Gladeville sandstone, and 250 feet above the next highest or Upper Banner coal seam. It is exposed on the ridge west of Big Tom creek and on Sandy Ridge near the head of the Left Fork of Russell creek. At the former locality, an opening shows a thickness of 4 feet 5 inches of clean coal, and at the latter the thickness is practically the same, including a small shale parting near the top.

The Upper Banner seam.—The Upper Banner seam is found 400 feet below the Gladeville sandstone and 250 feet below the Edwards seam. On account of its thickness and persistence it is reported to be the most important seam in the field and is a coking coal of great excellence. Campbell describes a constant feature of the seam to be a contained small sandstone parting which varies from 1 to 3 inches in thickness. In the Guest river and Tom creek portions of the field, in the vicinity of Tacoma, numerous openings are made on the seam showing a thickness ranging from 4 feet to 7 feet 10 inches. East of Big Tom creek developments are less extensive than in the type locality and the seam does not hold quite the same thickness. At several openings a reported thickness of 5 and 6 feet are given.

A section of the Upper Banner seam measured at the mine east of Tacoma is reported as follows:

	Feet.	Inches
Coal	2	9
Slate parting, some coal	2	10
Coal	2	5
Sandstone parting	0	1
Coal	2	0
Total	10	1

The Lower Banner seam.—This seam is found at approximately 100 feet below the Upper Banner seam. It is reported to be fully as persistent as the upper one but not so thick. In the Big Tom creek portion of the

General view of Seaboard Coal Company's tipple at Seaboard.

COAL TIPPLE, BIG STONE GAP COAL FIELD, VIRGINIA.

field this seam shows a thickness of from 3 to 4 feet, but further eastward on Big Laurel Run and between Lick creek and Austin's Gap the thickness is increased to 52 inches, and 6 feet 2 inches, respectively. From the Left Fork of Russell creek eastward, considerable variation in the thickness of the seam is shown, but it is reported on the whole as making a fine showing. At the Greno-Bodine mines the seam is reported to be 4 feet to 4 feet 10 inches thick. The following section was measured by Campbell on Little Looney creek:

	Feet.	Inches
Coal	1	0
Shale	2	0
Coal	1	8
Total	4	8

The seams described above are the most important ones developed in the vicinity of Tacoma.

The Kennedy seam.—This seam, the uppermost one of the lower group of coals, occurs at a distance of from 225 to 285 feet below the Lower Banner seam. Outcrops of the seam occur along the valley of Guest river as far as Coeburn. It has been opened a short distance east of Banner Station; on the Left and Middle Forks of Russell creek; on Lick creek at the foot of Austin's Gap; and a few openings have been made on the seam farther eastward. Judging from the openings made on the seam it shows much irregularity in thickness, ranging from 2 feet 8 inches to 10 feet. Greater extremes than these are reported.

The Imboden (?) seam, so-called.—The position of the Imboden seam has been shown by Campbell to be 180 feet below the Gladeville sandstone. He states that if this is correct the Imboden seam corresponds very closely, if it is not identical, with the horizon of the Edwards seam described above. The approximate interval between the Kennedy and the so-called Imboden seams is doubtfully given at about 340 feet. The so-called Imboden seam has been prospected a mile east of Tacoma, and small seams at about this horizon are reported at a number of places along the railroad between Tacoma and Coeburn; also east of Little Tom tunnel. It has been opened on Bull Run under the high trestle of the Norfolk and Western Railway where it shows a thickness of 40 inches of coal. It is reported opened again on Russell creek directly above the mine near Virginia City.

The Jawbone seam.—This is the lowest workable bed of coal known in the Norton formation. It is probably 150 feet above the base of the formation, and at the mine near Virginia City it is reported to be 90 feet below the so-called Imboden seam. The seam derives its name from Jawbone Hollow, a small tributary of Bull Run, where it was first opened. Here the coal is said to be irregularly bedded and containing a large parting of bony coal near the middle. The seam has been opened about 1 mile above the mouth of Dry Fork on the east side of Bull Run; and it has been considerably developed on the Right Fork of Russell creek. Numerous openings have been made on the seam in the valley of Bull Run.

A coal found about 200 feet above the Lee conglomerate at Tacoma apparently splits into two seams farther east, one of which shows a thickness of from 8 to 10 feet on Russell creek and is mined as the Jawbone seam. Campbell gives the following section exposed in the creek at Tacoma:

	Feet.	Inches
Coal	0	2
Shale	0	3
Coal	0	7
Knife-edge parting		
Coal	1	8
Dirty coal	0	8
Coal	1	6
Total	4	10

COALS IN THE VICINITY OF BIG STONE GAP AND THE WESTERN PORTION OF THE FIELD.

Introduction.—In the western or Big Stone Gap portion of the field, the principal coals are found below the Gladeville sandstone in the Norton formation, as in the eastern field already described. Of the numerous coals known to exist in the Norton formation in this portion of the field two are more conspicuously developed than the others, namely, the Imboden and the Kelly seams. The Imboden seam is stratigraphically below the Kelly, its position being fixed at 180 feet below the Gladeville sandstone. The Imboden seam is the most famous and important of all the coals known in the field.

As may be seen from section No. II, on page 266, measured in the western part of Wise county, three coal horizons are recognized above the Gladeville sandstone, designated as follows, in ascending order:

(1) Lower Splint bed.
(2) Upper Splint bed.
(3) Cannel bed.

These coals occur in the Wise formation, which, according to Campbell, has an estimated thickness of 1,276 feet. Other coals are reported to occur

Fig. 1.—General view of Stonega coal mining camp.

Fig. 2.—General view, showing tipple, crusher, and part of coke ovens, at Stonega.

COAL MINING PLANT, TIPPLE, CRUSHER, AND COKE OVENS, BIG STONE GAP COAL FIELD, VIRGINIA.

above the Cannel bed, but as yet very little is known of them in the Virginia portion of the field.

The Imboden seam.—The Imboden seam is the most prominent one of the numerous coals in this field. It can be continuously traced from Norton to the Lee county line, and it is found at a vertical distance of 180 feet below the Gladeville sandstone. If this position is correct, the Imboden seam, according to Campbell, is found at about the same horizon as the Edwards seam in the eastern portion of the field, described above. In the vicinity of Lee county the thickness of the Imboden seam is given as 30 inches; in a small branch to the eastward it shows a thickness of 4 feet 6 inches; and still farther east is a section doubtfully indentified as the Imboden. It is:

	Feet.	Inches
Coal	1	0
Shale	5	8
Coal	2	0
Shale	0	6
Coal	3	6
Total	12	8

In the mine on Little Looney creek the Imboden seam varies in thickness from 5 to 9 feet. The entire thickness of 5 feet is solid coal. The following sections measured by Campbell at different places serve to show the variation in thickness and character of the Imboden seam:

Preacher creek:

	Feet.	Inches
Sandstone roof		
Coal	11	0
Bony coal	0	3
Coal	1	8
Clay	0	2
Sandstone floor		
Total	13	1

Mud Lick creek:

	Feet.	Inches
Coal	1	10
Knife-edge parting		
Coal	1	4
Bony coal	0	1
Coal	0	6
Bony coal	0	6
Coal	2	4
Total	6	7

Mouth of Whitley Fork:

	Feet.	Inches
Coal	1	6
Shale	1	4
Coal	2	2½
Dirty coal	1	1
Coal	1	1½
Shale carrying sulphur	0	5
Coal	3	2½
Total	10	10½

Powell river, north of Norton:

	Feet.	Inches
Coal	4	0
Shale	0	2
Coal	4	0
Total	8	2

From the section at the mouth of Whitley Fork, the seam thins to Block creek, where it is about 4 feet 2 inches thick.

One mile northeast of Norton:

	Feet.	Inches
Coal	2	10
Clay	1	0
Coal	0	3
Clay	0	6
Coal	1	10
Clay	0	8
Coal	1	10
Total	8	11

Guest river at the bend east of Norton:

	Feet.	Inches
Coal	2	8
Clay	0	8
Coal	0	2
Clay	0	4
Coal	1	6
Dirty coal	0	2
Coal	0	5
Shale	0	6
Coal	2	8
Shale	0	1
Coal	0	4
Total	9	6

The Imboden seam is a fine body of coal and it produces an excellent coke. Campbell states that the finest showing of coal in the field occurs on the headwaters of a small stream flowing south into Powell river, between Roaring Fork and Bearpen creek. It is the Imboden seam having a thickness of 16 feet, 13 feet of which is without a parting.

The Kelly seam.—From 50 to 75 feet above the Imboden seam is the Kelly coal, which attains considerable thickness in places. Its greatest development is probably on Roaring Fork, where it shows a thickness of 7 feet 3 inches. The section here is:

	Feet.	Inches
Shaly coal	1	3
Coal	6	0
Total	7	3

It is reported to be less than 1 foot thick at Pioneer on Callihan creek, and, according to Campbell, it is generally variable throughout the field.

Seam just beneath the Gladeville sandstone.—So far as I am aware, this seam has not received a definite name. It occurs at the top of the Norton formation, just beneath the Gladeville sandstone on Powell river, north of Norton, and it has a reported thickness of 3 feet. Throughout the valley of Callihan creek, it is reported to have a thickness of about 2 feet, but in Lee county it forms a workable seam. The opening near Morris Gap shows a thickness of 6 feet 8 inches; on Jones creek 5 feet; and on Big Looney creek 5 feet 5 inches.

Coals of the Wise formation.—Of the numerous coals found in the Wise formation and above the Gladeville sandstone, there are at least 3 which are of importance. These are the Lower Flint, Upper Flint, and Cannel beds.

According to Campbell they have their greatest importance in the Kentucky portion of the field, although a goodly thickness of the beds is shown in places on the Virginia side. The uppermost one of the three, the Cannel bed, which is a persistent seam and is found at about 120 feet about the sandstone, shows the following section on the Virginia side:

	Feet.	Inches
Cannel shale	0	4
Cannel coal	2	0
Shale	0	4
Shaly coal	0	4
Shale	0	5
Coal	0	5
Shale	0	4
Coal	3	4
Total	7	6

Methods of Mining.

In the Pocahontas field the method of mining formerly used was the double-entry system with rooms driven opposite each other and at right-angles to the main entries. The main entries were 10 feet wide with a pillar of coal 50 feet wide between them. The rooms leading out from the entries on either side were spaced about 60 feet apart between centers; were driven 18 to 20 feet wide, supported by a pillar between them from 40 to 42 feet wide. After the mine was blocked out, systematic robbing of the pillars begun.

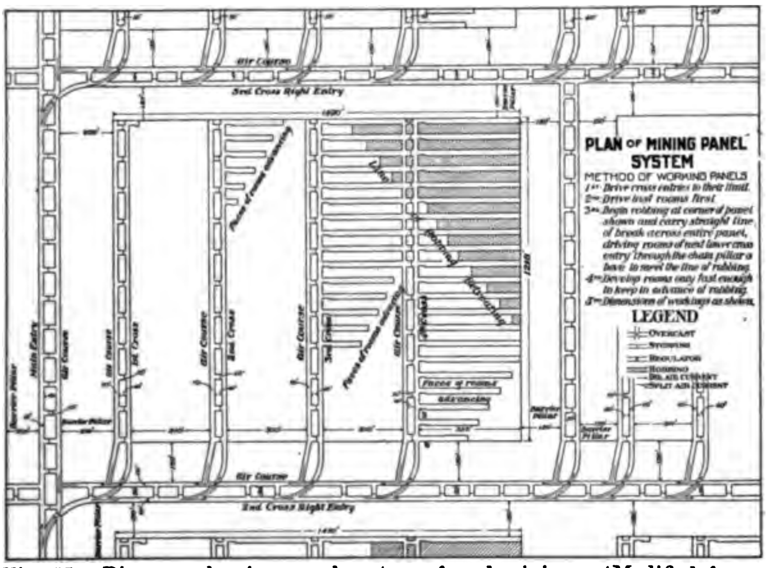

Fig. 55.—Diagram showing panel system of coal mining. (Modified from Geo. L. Fowler.)

At present the panel system of mining is employed with 15 to 25 rooms to each panel and systematically robbing all pillars that have been left. (Figure 55.) The panel system, a modification of the double-entry system, is said to have been introduced in order to avoid the waste of coal due to squeezing, following the robbing of pillars under the double-entry system. The rooms are driven opposite each other and at right-angles to the main entries. The method of mining at the Baby and West mines of the Pocahontas Collieries Company is entirely on the panel system, with 25 rooms to the panel. Large barrier pillars are left to protect haulways, and overcasts carry the air from each panel to the main return airway.

Ventilating fans of 300,000 to 500,000 cubic feet of air per minute are used, and are driven either by steam or by electric motors. Tracks are laid in the rooms from the main entries, and the cars are hauled out by either electric or steam locomotives.

At the new mines now opening up at Boissevain, 3 miles west of Pocahontas, the system of mining will be varied in accordance with the structure of the vein. It is reported that three systems will be used: (1) Where the dip of the seam is less than 5 per cent.; (2) where the dip is between 5 and 20 per cent.; and (3) where it is greater than 20 per cent.

In the Big Stone Gap field the method of mining employed is the room-and-pillar system, with the underground haulage by mules and electric locomotives. Ventilating furnaces are in use at many of the mines, and exhaust fans are used as the mines become more extensively worked.

Production.

Coal production of Virginia from 1822 to 1906, inclusive.

	Quantity (Short tons)	Year	Quantity (Short tons)
	54.000	1864	40,000
	60,000	1865	40,000
	67,040	1866	40,000
	75,000	1867	50,000
	88,720	1868	59,051
	94,000	1869	65,000
	100,080	1870	61,803
	100.000	1871	70,000
	102,800	1872	69,440
	118,000	1873	67,200
	132,000	1874	70,000
	125,000	1875	60,000
	124,000	1876	55,000
	120,000	1877	50,000
	134,000	1878	50,000
	160,000	1879	45,000
	300,000	1880	43,079
	396,000	1881	50,000
	424,894	1882	112,000
	379,600	1883	252,000
	373,640	1884	336,000
	370,000	1885	567,000
	365,000	1886	684,951
	350,000	1887	825,263
	340,000	1888	1,073,000
	325,000	1889	865,786
	318,000	1890	784,011
	315.000	1891	736,399
	310,000	1892	675,205
	310,000	1893	820,339
	325.000	1894	1,299,083
	350,000	1895	1,368,324
	370,000	1896	1,254,723
	380,782	1897	1,528,302
	352.687	1898	1,815,274
	363,605	1899	2,105,791
	377,690	1900	2,393,754
	359,055	1901	2,725,873
	473,660	1902	3,182,993
	445,165	1903	3,451,307
	445,124	1904	3,583,914
	40,000	1905	4,275,761
		1906	4,275,815

Coal production in Virginia by counties from 1900 to 1905.

(Short Tons).

County.	1900	1901	1902	1903	1904	1905
Montgomery......	9,814	11,177	12,786	20,288	21,628	———
Tazewell...........	970,863	776,568	723,753	840,195	871,720	961,380
Wise	1,363,570	1,918,693	2,422,417	2,563,285	2,514,133	2,990,698
Chesterfield... } Henrico.. ..... }	40,178	11,760	16,206	18,084	2,100	———
Pulaski.......... } Russell......... }	9,326	7,675	7,831	9,255	174,033	323,073
Small mines			200	300	300	120
Total............	2,393,754	2,725,873	3,182,993	3,451,307	3,583,914	4,275,271
Total values...	$2,123,222	$2,353,989	$2,543,595	$3,302,149	$2,921,911	$3,777,325

*Includes Lee and Montgomery Counties.

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2. CARBONITE (NATURAL COKE).

Carbonite, natural coke, occurs in the Richmond coal basin and is a modification of the normal coal due to the heat of intruded localized masses of igneous rocks (diabase). It has been mined especially on the east side of the basin at Carbon Hill and Midlothian.

The natural coke varies much in quality and texture, ranging from a dense, amorphous graphitic-looking material to that which in general aspect, especially in the prismatic form of the masses, resembles the non-compact varieties produced in modern ovens. From the origin of the coke and the differences in the original composition of the coal from which it has been derived, it is irregular in distribution and variable in quantity. Data are lacking upon which to base an estimate of the proportion of the coal of the basin which has been coked by the igneous masses. According to Woodworth probably less than one-fifth of the coal has undergone this change to coke.

Sufficient tests of its economic value have not been made, although the coke has long been in use as a domestic fuel and it is highly esteemed locally. It is denser than artificial coke and has more nearly the quality of anthracite coal. Adequate tests have not been made to ascertain its fitness for metallurgical work.

Samples of the coke were analyzed by R. B. Riggs in the laboratory of the U. S. Geological Survey with the following results:

	Per cent.
Carbon	67.13
Volatile matter	18.35
Ash	12.86
Water	1.66
Total	100.00
Sulphur	4.70

Samples of the carbonite from the Jewett and Brother's Colliery on the east side of the basin were separated into two portions, a dull and a lustrous portion, and separately analyzed by Doctor Drown with the following results:

	Dull Portion Per cent.	Lustrous Portion Per cent.
Carbon	79.33	81.52
Volatile matter	15.47	11.10
Ash	3.20	6.68
Loss at 100° C	2.00	0.69
Total	100.00	100.00
Sulphur	4.08	1.60
Specific gravity	1.375	1.350

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3. COKE.

The rapid development of the excellent coking-coal fields in southwestern Virginia during the last few years has made Virginia one of the prominent coke-producing states. The State now ranks fourth among the coke producers. Prior to 1895 there were only two coke-making establishments in Virginia, with a production of less than 200,000 tons per year. The number of establishments increased to 7 in 1901, and the total number of coke ovens increased from 832 in 1896 to 2,775 in 1901, with a total production of more than 900,000 short tons. Construction and development work progressed rapidly during 1902, the number of establishments was doubled, and at the close of the year 2,974 ovens were built and 1,208 were building, with a production increased to 1,124,572 short tons.

In 1903, 2 more establishments were added, making the total number 16, with a total of 4,251 ovens, and the production further increased to 1,176,439 short tons. In 1904, there was an increase of 94 completed ovens, the number of establishments remaining the same as in 1903, while the production declined to 1,101,716 short tons. Two establishments, having a total of 107 ovens, were reported idle during the year 1904. One of these was the Newton-Chambers ovens at Pocahontas in Tazewell county.

The product in 1905 amounted to 1,499,481 short tons, an increase of 36.1 per cent. over 1904. The value, $2,869,452, increased 62 per cent. over 1904. The number of ovens increased to 4,549 in 1905.

The remarkable increase in coke-production in Virginia during the last few years has resulted from the development of the Wise county coal fields on the Clinch Valley division of the Norfolk and Western Railway.

Fig. 1.—General view of Osaka No. 1 coal tipple.

Fig. 2.—General view of double batteries of coke ovens at Osaka.

COAL TIPPLE AND COKE OVENS, BIG STONE GAP COAL FIELD, VIRGINIA.

With the development of the enormous coal reserves in the adjacent southwest Virginia counties should follow, in the very near future, a greatly increased coke-making output from the State.

All the coal used in coke-making in Virginia up to 1895 was unwashed. Washing slack coal began in 1896, and in 1898 the amount of washed slack coal used amounted to more than 210,000 short tons.

Analyses of Virginia Coke.

Analyses of coke made from the southwestern Virginia coals.

Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Phosphorus	Analyst
Coke made from the Pocahontas or Flat Top Coal						
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
0.29	0.59	93.84	5.28	0.357	0.018	H. Froehling, Richmond, Va.
0.09	1.10	93.67	5.14	0.620	0.0035	Prof. Hite, Morgantown, W.Va.
0.664	1.059	92.816	4.913	0.548	———	A. S. McCreath, Harrisburg, Pa.
0.680	1.74	92.92	4.66	0.619	0.002	Western Steel Co., St. Louis, Mo.
———	3.28	91.37	5.25	0.72	0.007	Joliet Steel Co., Chicago, Ill.
0.347	0.757	92.55	5.749	0.597	———	A. I. M. E., Boston, Mass.
2.16		91.39	6.45	(By-Product Coke)		Dora Furnace Co., Pulaski, Va.
Coke made from the Big Stone Gap Coal						
0.35	———	91.36	8.29	0.68	0.034	Made from Scott Co., Va., coal

An analysis of the ash given in the first analysis of the above table, from the coke of the Pocahontas or Flat Top coal field, gave Doctor Froehling the following results:

	Per cent.
Silica	2.780
Alumina	1.009
Iron oxide	.881
Lime	.341
Magnesia	.016
Phosphoric oxide	.018
Sulphur trioxide	.158
Potash	.068
Maganese oxide	trace
Total	5.271

Analyses of coke made from coal in the Big Stone Gap field, Wise county.

Name of producer.	Fixed carbon.	Volatile matter.	Ash.	Sulphur.	Phosphorus	Analyst.
	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	
Colonial Coal & Coke Co...	88.37	1.43	10.20	0.82	———	F. W. Ganer.
Colonial Coal & Coke Co...	88.14	1.56	10.30	0.89	———	F. W. Ganer.
Wise Coal & Coke Co.....	88.75	1.45	9.80	0.73	———	F. W. Ganer.
Wise Coal & Coke Co	88.41	1.43	10.16	0.83	———	F. W. Ganer.
Norton Coal Co...........	94.45	1.60	3.95	0.75	———	R. W. Durrett.
Norton Coal Co...........	93.43	1.75	5.44	0.726	0.034	Booth, Garrett & Blair.

The character of the coal used in the manufacture of coke in Virginia since 1890 is shown in the following table:

Character of coal used in the manufacture of coke in Virginia, 1890-1905.

(Short Tons.)

Year.	Run of mine.		Slack.		Total.
	Unwashed.	Washed.	Unwashed.	Washed.	
1890	98,215	0	153,468	0	251,683
1891	107,498	0	177,615	0	285,113
1892	106,010	0	120,507	0	226,517
1893	107,498	0	86,561	0	194,059
1894	103,874	0	176,650	0	280,524
1895	114,802	0	295,935	0	410,737
1896	70,756	0	370,624	13,584	454,964
1897	286,158	0	227,363	61,021	574,542
1898	405,399	0	237,474	210,099	852,972
1899	612,267	0	225,118	157,250	994,635
1900	620,207	0	463,620	0	1,083,827
1901	869,203	0	531,028	0	1,400,231
1902	1,018,148	0	697,962	0	1,716,110
1903	857,332	0	1,002,893	0	1,860,225
1904	1,213,226	44,222	379,457	0	1,636,905
1905	1,096,656	0	1,087,713	0	2,184,369

The following are the statistics of the manufacture of coke in Virginia from 1883 to 1906:

Fig. 1.—General view of coke ovens, lower batteries, at Stonega.

Fig. 2.—General view of coke ovens, upper batteries, at Imboden.

COKE OVENS, BIG STONE GAP COAL FIELD, VIRGINIA.

Statistics of the manufacture of coke in Virginia, 1883-1903.

Year.	Establishments.	Ovens.		Coal used.	Coke produced.	Total value coke at ovens.	Value of coke at ovens per ton.	Yield of coal in coke.
		Built.	Building.	*Short tons.*	*Short tons.*			*Per ct.*
1883	1	200	0	39,000	25,340	$ 44,345	$1.75	65
1884	1	200	0	99,000	63,600	111,300	1.75	64.3
1885	1	200	0	81,899	49,139	85,993	1.75	60
1886	2	350	100	200,018	122,352	305,880	2.50	61.2
1887	2	350	300	235,841	166,947	417,368	2.50	70.8
1888	2	550	0	230,529	140,199	260.000	1.74	64.7
1889	2	550	250	238,793	146,528	325,861	2.22	61
1890	2	550	250	251,683	165,847	278,724	1.68	66
1891	2	550	250	285,113	167,516	265,107	1.58	58.8
1892	2	594	206	226,517	147,912	322,486	2.18	65.3
1893	2	594	206	194,059	125,092	282,898	2.26	64.5
1894	2	736	100	280,524	180,091	295,747	1.64	64.2
1895	5	832	350	410.737	244,738	322,564	1.32	59.6
1896	7	1,138	101	454,964	268,081	404,573	1.509	58.9
1897	6	1,453	110	574,542	354,067	495,864	1.40	61.6
1898	6	*1,564	0	852,972	531,161	699,781	1.317	62
1899	6	*1,588	429	994,635	618,707	1,071,284	1.73	62.2
1900	7	*2,331	300	1,083,827	685,156	1,464,556	2.137	63.2
1901	7	*2,775	0	1,400,231	907,130	1,483,670	1.635	64.7
1902	14	*2,974	1,208	1,716,110	1,124,572	2,322,228	2.065	65.5
1903	16	*4,251	142	1,860,225	1,176,439	2,724,047	2.315	63.2
1904	16	*4,345	68	1,636,905	1,101,716	1,772,717	1.609	67.3
1905	16	*4,549	0	2,184,369	1,499,481	2,869,452	1.913	68 6

*Includes 56 Newton-Chambers by-product ovens.

In the following table is given the production of coke in Virginia in by-product ovens in 1902 to 1904:

Year.	Quantity. *Short tons.*	Yield per ton of coal. *Per cent.*	Value per ton.	Total value.
1902	36,748	54.8	$2.76	101,538
1903	33,766	60.6	3.30	111,467
1904	27,337	55.5	3.60	98,387

4. GAS, TAR, AND AMMONIA (BY-PRODUCTS OF COKE WORKS).

In the bee-hive form of coke ovens all gases and by-products were allowed to go to waste, a condition which is now being largely remedied by the use of the by-product ovens. This form of oven is coming into greater use, although it is claimed that it does not produce coke with a silvery luster like that from the bee-hive oven, but the structure and quality of the by-product coke is not much inferior to the old bee-hive product.

The following tables, compiled from the recent volumes of the Mineral Resources, show the production and value of gas, tar, and ammonia, produced at by-product coke works and in gas-house retorts in Virginia from 1902-1905.

Under Coke on page 383, is given a table showing the production and value of coke produced in Virginia in by-product ovens from 1902-1905.

Table showing quantity and value of gas produced and sold at by-product coke plants in Virginia from 1902 to 1905.

Year	No. of establishments.	Coal carbonized	Total gas produced	Gas sold for illuminating purposes			Gas sold for fuel purposes			Total gas sold			Quantity of gas unaccounted for
				Quantity	Value	Price per 1000 cu. feet	Quantity	Value	Price per 1000 cu. feet.	Quantity	Value	Av. price per 1000 cubic ft.	
		Short tons	Cubic feet	Cubic feet	$	$	Cubic feet	$	$	Cubic feet	$	$	Cubic feet
1902	14	*66,981	361,328,023	291,187,286	352,512	1.21	31,391,000	33,966	1.082	322,578,286	386,478	1.198	38,749,737
1903	14	*55,723	399,926,480	277,857,260	325,342	1.16	61,438,826	64,374	1.04	339,296,086	389,716	1.15	60,630,394
1904	13	49,247	447,928,210	317,968,979	348,962	1.10	71,726,171	79,797	1.11	389,695,150	428,759	1.10	58,233,060
1905	13	55,657	513,801,470	322,709,181	376,645	1.16	97,711,297	108,723	1.11	420,420,478	485,368	1.15	93,380,992

*Includes 56 Newton-Chambers by-product ovens.

The following table gives the coal-tar production in Virginia from 1902 to 1905:

Year.	Number of establishments.	Quantity. *Gallons.*	Value.	Value per gallon *Cents.*	Yield per ton of coal. *Gallons.*
1902	———	461,317	$20,493	4.40	6.88
1903	14	606,994	25,293	4.16	10.89
1904	———	503,460	18,119	3.60	10.22
1905	13	691,530	21,152	3.06	12.40

In the table below is given the production of ammonia liquor in Virginia and West Virginia at the gas and by-product coke works from 1902 to 1905. The returns do not separate Virginia and West Virginia:

Year.	Coal carbonized. *Short tons*	Ammonia liquor produced. *Gallons.*	Equivalent to anhydrous ammonia (NH_3). *Pounds.*
1902	258,695	1,052,817	1,311,715
1903	219,481	757,136	1,108,472
1904	238,461	1,183,096	1,336,085
1905	176,398	1,073,102	1,002,058

XI. MISCELLANEOUS.

1. GEM MINERALS.

Under this heading are grouped those minerals which are distinguished, when cut and polished, for their beauty, durability, or rarity. The essentials, beauty and durability, are dependent upon color, brilliancy, and hardness of the mineral, which in turn are dependent upon the chemical and physical properties of that particular mineral.

Distribution and Localities.

A variety of minerals of gem grade have been found in the crystalline rocks of the Piedmont province of Virginia. Some counties in this area, which seemingly offer good possibilities for the occurrence of gem materials, have not yet been exploited for this purpose. The known counties which have either produced gem minerals, or contain minerals which might be of desirable gem grade, are Amelia, Amherst, Bedford, Buckingham, Fairfax, Hanover, Nelson, and Spottsylvania. Of these, Amelia county is the best known and has produced the largest variety and quantity of gem minerals. These have come from the mica mines opened in the pegmatite dikes, near Amelia court-house.

Those minerals known to occur in Virginia which have been used or are capable of being used for gem material are separately described below.

Diamond.

The largest diamond discovered in the United States up to 1884 was found by a laboring man at Manchester, Virginia, in 1855, in some earth he was digging. So far as known to the writer this marks the only diamond-find in the State. A writer states that this stone was put into a furnace for melting iron at Richmond, where it remained at red heat for 2 hours and 20 minutes, and when taken out it was found to be uninjured. It was valued in Richmond at that time at $4,000.00 and was later cut at an expense of $1,500.00. Its form was that of a slightly rounded trigonal trisoctohedron, and in the rough it weighed 23¾ karats; after cutting its weight was 11 11-16 karats. In color it was a faint greenish white with perfect transparency, but the refraction was somewhat impaired by a flaw or speck in the interior.

It has been suggested that the stone was brought down by the James river during spring floods from the Virginia gold fields. Exact copies of this gem, in glass, as it was found and as cut were deposited in the United States Mint Museum in Philadelphia, and at the Peabody Museum in New Haven, Connecticut.

Quartz.

Several varieties of quartz are found in Virginia from which a few gems have been cut. These include a greenish colored banded quartz; a milky-white chalcedony; colorless quartz with dark inclusions; and a smoky-brown quartz. These have come from one locality, namely, Fairfax court-house. Gems cut from each variety of the Fairfax court-house quartzes named above are included in the collection of gems in the United States National Museum.

In the cabinet of Tiffany and Company of New York City, is a fine limpid crystal of quartz, one inch long and two-thirds of an inch in diameter, penetrated by fine green crystals of actinolite a half millimeter in diameter, from an unknown Virginia locality.

Amethyst, a variety of quartz, has long been known to students and collectors as occurring in Virginia. A promising locality has recently been opened and some good gem mineral taken out at a point about 2 miles from Lowesville post-office in Amherst county, and about the same distance from the James river. It occurs in pockets connected with a well-marked vein of white quartz, which extends for some miles along the base of the Blue Ridge. It occupies an area of about 11 acres, and the amethyst occurs but a few inches below the surface. The deposit has been only slightly exploited.

Garnet.

Beautiful transparent spessartite, a manganese-aluminum garnet, used as a gem, is found at the mica mines near Amelia court-house, in Amelia county. Irregular masses of the spessartite variety of garnet with crystalline exterior have been obtained from the Amelia court-house mines, which on cutting finished fine gems very similar in color and luster to the essonite or hyacinth of Ceylon. The cut stones varied from 1 to 100 karats in weight.

According to Kunz, George W. Fiss, of Philadelphia, found some of the most beautiful natural gems of microscopic yellow garnets from the mica mines of Amelia county. In his *"Descriptive Catalogue of the Collections of Gems in the United States National Museum,"* Tassin lists 9 gems cut from the Amelia county spessartite with the following weights: 39.13, 7.26, 2.38, 2.60, 1.10, 11.51, 8.89, 9.32, and 5.65 karats.

Analyses of the Amelia county spassartite by Bradbury and Clarke are given on page 288.

Andradite.

A calcium-iron garnet, usually of black color, has also been reported from the Amelia county mines. *Topazolite*, a sub-variety of andradite, having the color and transparency of topaz, also occurs in the same mines, near Amelia court-house.

Beryl.

Beryls of large and small size in more or less perfect crystals are found in the mica mines of Amelia county. Beryl of pure white color has been noted from these mines. An analysis made by Baker of the Amelia county beryl gave:

	Per cent.
Silica	65.24
Alumina	17.05
Ferric oxide	2.20
Beryllium oxide	12.64
Lime	0.57
Soda	0.68
Water	2.70
Total	101.08
Specific gravity	2.702

Apatite.

Crystals of apatite are found in association with the mica, beryl, etc., in the Amelia county mica mines. Some of the apatite crystals are of very large size. An analysis made by Rowan of a specimen of apatite from the Amelia county locality gave:

	Per cent.
Lime	53.94
Phosphoric acid	41.06
Alumina	0.19
Ferric oxide	0.81
Fluorine	3.30
Chlorine	trace
Ignition	0.81
Insoluble residue	0.63
Total	100.74
Specific gravity	3.161

Allanite.

Allanite is known in Bedford, Amelia, Amherst, and Nelson counties, Virginia. It occurs in considerable quantity in Amherst county, where it is found in large masses and crystals, very compact and black in color, and would form a black metallic gem stone. It is found in large masses in the Amelia county mica mines.

Analyses of allanite from Amelia, Bedford, and Nelson counties, gave:

	Bedford County. Per cent.	Amelia County. Per cent.	Nelson County. Per cent.
Silica	26.70	32.35	30.04
Alumina	6.34	16.42	16.10
Ferric oxide	3.21	4.49	5.06
Cerium oxide	33.76	11.14	11.61
Didimium oxide	16.34	6.91	5.39
Lanthanum oxide	1.03	3.47	4.11
Ferrous oxide	4.76	10.48	9.89
Erbium oxide	0.52	——	——
Manganous oxide	trace	1.12	trace
Lime	2.81	11.47	13.02
Magnesia	0.54	——	1.11
Soda	0.49	0.46 (Soda and Potash)	0.28
Potash	0.55		0.02
Water	1.99	2.31	2.56
Tin oxide	——	——	0.17
Total	99.04	100.62	99.36

Kyanite.

This mineral, a silicate of aluminum, is found at Willis Mountain, in Buckingham county; in the vicinity of the old mica mine near Hewlett's, in Hanover county; and 2 miles north of Chancellorsville, in Spottsylvania county. As yet no really fine gems have been produced from any of the American kyanite.

Fluorite (Chlorophane).

One of the most remarkable varieties of this mineral, chlorophane, is found at the mica mines in Amelia county. It fluoresces by the heat of the hand, thus affording a fluorescent gem stone, but not hard enough for any kind of wear.

Kunz says of the Amelia county chlorophane: "It is a fact of much interest that the variety of fluorspar found at Amelia, Va., has been found extremely sensitive to heat, so that it becomes distinctly luminous by the warmth of the hand, and that it also shows a triboluminescence so marked that the slightest friction will cause it to emit a phosphorescent light. A spectroscopic examination by Humphreys of the Amelia county chlorophane showed that yttrium was present and ytterbium in some."

For other occurrence of fluorite in Virginia see page 215.

Feldspar.

The numerous pegmatite dikes found penetrating the metamorphic rocks of the crystalline or Piedmont region, east of the Blue Ridge, frequently contain feldspar of gem grade. The most noted locality in Virginia where feldspar of gem grade is found, and which has produced moonstones in some quantity, is that of the mica mines near Amelia court-house, in Amelia county. Three species of feldspar from the Amelia court-house mines have yielded gems. These are the green-colored potash feldspar, microcline, and the soda and soda-lime feldspars, albite and oligoclase.

Microcline, variety *amazonstone,* is found near Amelia court-house of rich green color. An elliptical girdle, a small tray, and two small balls, cut from amazonstone of the Virginia locality, are in the collection of gems in the United States National Museum.

Albite and *Oligoclase,* variety *moonstone,* occurs near Amelia court-house, varying from colorless to white, opaque, with fine change of color. A goodly number of moonstones from the Amelia county mines, of double and single cabochon cut, elliptical girdle, are in the gem collections of the United States National Museum.

The finest examples of moonstone from an American locality, very closely resembling the Ceylon in quality and transparency, are found at Amelia court-house. Analyses of both the amazonstone and the moonstone from the Amelia county mines are given on page 277.

Microlite.

The rare mineral, microlite, which is essentially a calcium pyrotantalate containing niobium, fluorine, and a number of bases in small amount, is found in Virginia, only at the Amelia county mica mines, in association with beryl, spessartite, fluorite, etc. The microlite occurs in the Virginia locality in fine crystals up to 1 inch in diameter, and in imperfect crystals up to 4 pounds in weight.

Where the mineral has been found at other localities it was opaque or at best translucent and not of value as a gem stone. At the Virginia locality, however, some of it is of sufficient transparency to be highly prized as a gem, the color varying from an essonite red to that of a rich spinel yellow, and remarkably brilliant. It is remarkable for its density, having a specific gravity higher than that of any known gem, being about 6.

An analysis of the Amelia county microlite yielded Professor Dunnington the following results:

	Per cent.	
Ta_2O_5	68.43	
Nb_2O_5	7.74	
WO_3	0.30	
SnO_2	1.05	
CaO	11.80	
MgO	1.01	
BeO	0.34	
UO_3	1.59	
Y_2O_3	0.23	
$(Ce, Di)_2O_3$	0.17	
Fe_2O_3	0.29	
Al_2O_3	0.13	
Na_2O	2.86	
K_2O	0.29	
H_2O	1.17	
F	2.85	
Total	100.25	
Specific gravity	5.656	(Dunnington)
Specific gravity	6.13	(Hidden)

Columbite.

Columbite, a niobate and tantalate of iron and manganese, occurs in the Amelia county mica mines with microlite in fine splendent crystals. An analysis of the columbite from Amelia county gave Professor Dunnington:

	Per cent.
Nb_2O_5	31.40
Ta_2O_5	53.41
SnO_2	trace
FeO	5.07
MnO	3.05
CaO	1.27
MgO	0.20
Y_2O_3	0.82
Total	95.22
Specific gravity	6.48

Helvite.

This mineral is of yellow color and is found filling cracks in spessartite at the mica mines near Amelia court-house. Sloan and Haines give the following composition of the mineral from the Virginia locality:

	Sloan, B. E. Analyst Per cent.	Haines, R. Analyst Per cent.
SiO_2	25.48	31.42
BeO	12.63	10.97
MnO	39.07	40.56
FeO	2.26	2.99
Mn	8.66	8.59
S	4.96	4.90
Al_2O_3	2.95	0.36
CaO	0.71	——
K_2O	0.43	——
Na_2O	1.01	——
Total	98.16	99.79

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2. SAND.

Sand, suitable for the three principal uses made of it, is found in commercial quantity in Virginia. This includes sand used for glass manufacture, molding, and building purposes. The principal production of

Virginia sand up to the present time is utilized in molding and for building purposes. Although commercial deposits of glass sand occur, there has been no production, as yet, for this purpose, in Virginia.

Glass Sand.

A purer sand is required in the manufacture of glass than that used for any other purpose. Sand suitable for glass manufacture is found at a number of localities in the State. Deposits of a fine white sand, derived by disintegration from the hard Potsdam sandstone, are found at several places along the eastern edge of the middle Valley region. An extensive deposit occurs at Balcony Falls in Rockbridge county, along the west base of the Blue Ridge. At Stapleton Mills, in Amherst county, is found a deposit of very pure white sand.

In the northern portion of Roanoke county, in Catawba valley, and along Catawba Mountain, about 9 miles north and west of Salem, are deposits of fine white sand, well suited for the manufacture of glass. Preparations are in progress at present by the *Catawba Valley Railway and Mining Company* looking to the development of the Catawba valley sand deposits. A railroad is being graded between Salem and the Norfolk and Western Railway and Catawba Mountain for the purpose of transporting the sand to Salem, where the glass plant will be located. Contract has been let for the building of the glass plant at a cost of $50,000.00.

An analysis of the Catawba valley sand, made by Mr. H. H. Hill, in the Laboratories of the Virginia Polytechnic Institute, gave:

	Per cent.
Silica	96.99
Alumina	.01
Iron oxide	.02
Magnesia	.07
Lime	.80
Soda	1.40
Potash	.20
Water and organic matter	.31
Total	99.80

An exceptionally pure white sand is described by Professor Fontaine as occurring at the foot of the Potsdam mountains, a short distance southeast of Greenville, in Augusta county. The sand was pierced by a well which, after passing through 6 feet of blue clay, passed through 17 feet of Potsdam bowlders and sand. This sand is described as being of extreme whiteness, in large amount, and valuable for glass-making. A sample of moderately coarse and fine white sand, composed almost exclusively of quartz grains, from the vicinity of Waynesboro, gave on analysis 98.57 per cent. of silica. Glass sand is formed in a number of other counties, but the deposits have not received attention.

Molding Sand.

Molding sands to be of value must possess certain physical qualities, the principal ones of which are, according to Mason, elasticity, strength, and a certain degree of fineness. According to Ries, molding sand must be sufficiently fine-grained and aluminous to permit molding into the required form; strong enough to hold its shape; resistant to heat, and porous enough to permit the escape of gases, but not admit the melted metal. An excess of clay and iron in the sands will cause the mold to shrink and crack under the intense heat, and too little will cause it to dry and crumble.

Sands possessing the qualities enumerated above and of superior quality are found in the vicinity of Richmond, and at other localities in the Coastal Plain or Tidewater region of Virginia. That found on the Cowardin place near Richmond is of excellent quality and is extensively used.

During his investigations of the Virginia Coastal Plain clays in the summer of 1905, Dr. Ries studied and collected samples of the molding sand over the same area. The samples were analyzed in the laboratories of the Virginia Polytechnic Institute by J. R. Eoff, Jr., and James H. Gibboney, with the results given below. As indicated below these sands represent localities chiefly in the vicinity of Richmond, Petersburg, and Fredericksburg.

	I Per cent.	II Per cent.	III Per cent.	IV Per cent.	V Per cent.	VI Per cent.
Silica (SiO_2)	81.59	82.08	66.12	82.32	70.24	70.40
Alumina (Al_2O_3)	6.46	7.12	16.54	7.80	16.62	3.80
Iron oxide (Fe_2O_3)	4.94	4.63	4.46	3.98	3.94	14.94
Lime (CaO)	0.14	0.36	0.40	0.54	0.08	0.12
Magnesia (MgO)	0.22	0.35	0.22	0.41	0.09	0.15
Potash (K_2O)	1.19	1.28	2.67	1.64	1.41	1.95
Soda (Na_2O)	0.59	0.41	0.35	0.80	0.74	0.41
Titanic oxide (TiO_2)	1.90	0.30	0.14	0.22	0.46	0.70
Water (H_2O)	1.63	1.66	4.90	0.19	4.16	4.08
Water (moisture)	1.46	1.52	4.15	0.14	2.42	3.77
Total	100.12	99.71	99.95	98.04	100.16	100.32

	VII Per cent.	VIII Per cent.	IX Per cent.	X Per cent.	XI Per cent.
Silica (SiO_2)......	84.40	93.92	85.04	86.24	89.39
Alumina (Al_2O_3)......	7.56	3.22	5.90	6.32	5.94
Iron oxide (Fe_2O_3)......	2.52	1.08	3.18	2.44	1.22
Lime (CaO)......	0.06	0.24	0.06	0.34	0.32
Magnesia (MgO)......	0.21	0.08	0.14	0.10	0.09
Potash (K_2O)......	1.29	0.45	1.65	1.38	2.10
Soda (Na_2O)......	0.65	0.23	0.83	1.13	0.53
Titanic oxide (TiO_2)......	0.44	0.32	0.78	0.02	0.18
Water (H_2O)......	1.99	0.48	1.57	2.94	0.54
Water (moisture)......	1.76	0.18	1.11	1.29	0.19
Total......	100.88	100.20	100.26	102.20	100.50

I. Redford sand from foundry, Manchester, Virginia.
II. Redford yellow sand collected at pit, Manchester, Virginia.
III. Coarse sand, Harbaugh pit, Richmond, Virginia.
IV. Used molding sand, Redford pit, Manchester, Virginia.
V. Sand from near Petersburg, Virginia.
VI. Blandford pit, Petersburg, Virginia.
VII. Armstrong pit, Petersburg, Virginia.
VIII. Sand from near Standard Brick Company, south of Suffolk, Virginia.
IX. Griffith's pit, Fredericksburg, Virginia.
X. Curlis pit, southeast of Lanexa, New Kent county, Virginia.
XI. One mile south of Layton, Essex county, Virginia.

The following physical tests made on the samples of sand from Virginia, shown in the analyses above, by Doctor Heinrich Ries, further serve to show the general character of Virginia Coastal Plain molding sands:

LOCALITY.	*20*	*40*	*60*	*80*	*100*	*100X*	*Clay*
Redford yellow sand collected at pit in Manchester, Virginia..........	1.51	1.26	1.27	0.56	6.27	71.69	16.52
Coarse sand, Harbaugh pit, Richmond	42.48	12.90	6.16	0.85	1.70	8.58	26.44
Used molding sand, Redford pit, Richmond	5.34	14.73	10.41	1.28	14.61	59.37	3.52
Sand from near Petersburg..........	0.73	2.34	8.76	2.21	12.25	14.79	30.54
Blandford pit, Petersburg..........	3.03	1.41	0.97	0.40	2.61	48.32	41.87
Armstrong pit, Petersburg..........	0.09	0.41	2.21	2.67	17.37	53.20	19.02
Sand from near Standard Brick Company, south of Suffolk..........	0.12	0.29	13.00	6.56	38.02	35.18	6.03
Griffith's pit, Fredericksburg..........	0.19	0.19	0.39	0.19	0.98	81.92	15.97
Curlis pit, southeast of Lanexa..........	——	0.01	0.08	0.07	1.11	86.77	19.57
One mile south of Layton..........	6.68	28.13	51.66	3.18	3.75	2.63	2.16

Building Sand.

A much larger amount of sand is consumed for building and construction work than for any other purpose. No special purity is required of a sand for this purpose, loamy sand as well as mixtures of coarse and fine sands as found in the banks being used. Usually when much coarse material is contained in the sand it is screened out before using the sand.

Sand of the character described above and in all respects suitable for building purposes has wide distribution over nearly all parts of the State. It is found in considerable quantity along many of the stream courses in each of the larger divisions of the State.

Production.

Production of sand in Virginia by years for all purposes, for 1904 and 1905.

Year	Molding sand		Engine sand		Building sand		Other purposes		Total	
	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $	Short tons	Value $
1904	64,313	30,943	3,600	1,800	267,264	123,842	4,357	3,482	339,534	160,067
1905	61,246	37,899	4,775	3,580	244,572	96,248	5,272	3,400	315,865	141,127

3. MARLS.

Definition and Properties.

As ordinarily used the term marl is applied to a variety of soft, earthy materials, composed principally of an amorphous form of carbonate of lime. The greensand marl is an exception, being a hydrous silicate of iron and potash. Marls vary much in color according to the amount and kind of impurities which they contain.

When dry the purer forms are invariably of light color, white or cream. The impure forms are usually some shade of an intermediate or dark color. Moisture influences to some extent the color, for the same marl when dry has usually a lighter color than when wet. A marked feature of calcareous marls is their free effervescence in acids, which serves to distinguish them from certain clays and muds which they sometimes resemble.

Origin and Occurrence.

Based on composition marls may be grouped into (a) calcareous or limy marls, and (b) glauconitic or greensand marls. Both classes have wide distribution over parts of Virginia.

The calcareous marls, sometimes known as shell marls, are chiefly formed in bodies of fresh water such as lakes and ponds, and about springs and small streams. They form a considerable part of the filling of many of the extinct fresh water-bodies and are now forming on the bottom of many such bodies of fresh water. They are formed principally from the accumulations of the remains of fresh water algæ, and from calcareous shells of lime-secreting animals. The stonewort *chara* is an effective agent in abstracting the lime from solutions in lake water and forming lacustrine marl. In some cases, as shown by Blatchley and Ashley from the lakes of northern Indiana, calcareous marls may be formed by chemical precipitation.

Glauconitic or greensand marl derives its name from the presence of the green-colored mineral, glauconite, which is essentially a hydrous silicate of iron and potash, and which imparts a green color to the deposit. According to Professor Wm. B. Clark, the mineral glauconite of the greensand marls, occurs as grains which frequently show themselves to be casts of foraminifera and other calcareous organisms; and as pointed out by Murray and Renard it is always associated with terrigenous minerals, particularly orthoclase (feldspar) and muscovite (mica) and similar potash-bearing minerals. The glauconite grains seldom exceed one millimeter in diameter but occasionally they are agglomerated into nodules of much larger size, the cementing substance of which may be phosphatic.

The glauconitic sands have wide distribution through the various geologic formations, and they are forming at present in places on the floors of existing seas, such as along certain parts off the Atlantic coast.

Distribution and Localities.

Marls of both calcareous and greensand types are widely distributed over the Coastal Plain or Tidewater region of Virginia. As early as 1835 Professor Rogers reported marls from the following Coastal Plain counties: Gloucester, Isle of Wight, James City, Lancaster, Middlesex, New Kent, Prince George, Surrey, and York. Since that time large deposits of marl have been noted in nearly all the remaining counties of this area.

Calcareous marls are also developed in places over parts of the Valley region west of the Blue Ridge.

The Coastal Plain Region.

Greensand marls.—So far as known this type of marl is limited to the Coastal Plain region, largely along its inner margin or western portion, where it is exposed along the Potomac, Rappahannock, Pamunkey, and James rivers. It is further found on the interstream areas and has been traced south from the James river almost as far as the State boundary.

According to Professors Rogers and Clark, the Virginia greensands and greensand marls are of Eocene age, and are found in the Pamunkey group, which in Virginia includes the Acquia and Nanjemoy formations. Professors Clark and Miller have described the Acquia formation as consisting of greensands and greensand marls, the latter often holding great quantities of molluscan shells that afford enough cement at times to produce, under proper conditions, a hardened limestone. Likewise, the Nanjemoy formation consists largely of greensands, but contains a larger amount of argillaceous or clayey materials. The combined thickness of these two formations, each measured in different places, is between 200 and 300 feet.

In some of the marl beds of this area the mineral particles of glauconite are so abundant as to impart a pronounced green color to the deposit. Specimens from James City, York, and other counties in the Coastal Plain area, contain as much as 35 per cent. of the greensand or glauconite. The greensand marls are valuable for fertilizer from the amount of potash contained in them and at times for its additional phosphoric acid. Potash is very variable in amount in these marls, varying according to the proportion of the mineral glauconite present, ranging usually from 1 per cent. in the very impure greensands to 8 and 10 per cent. and more in the purer greensands.

The following analyses made by Ellett and Eskridge of the Virginia Experiment Station on samples of marl from Suffolk and Prince George counties, Virginia, serve to show the potash content:

	Waverly Sussex County Per cent.	City Point Prince George County Per cent.	City Point Prince George County Per cent.
Insoluble residue..	45.20	61.15	56.03
Lime	24.38	1.36	1.52
Magnesia	5.22	2.19	0.37
Phosphoric acid...	1.80	0.47	0.05
Potash	4.73	3.85	3.15

Greensands are found further eastward in the Coastal Plain beneath the cover of Miocene and Recent strata, as exposed in the deep well at Fortress Monroe. The Virginia greensand marls have been worked to advantage at a number of places, especially on the James and Pamunkey rivers.

Calcareous marls.—Marls of calcareous composition are extensively developed over all parts of the Coastal Plain, being especially abundant in the Miocene and, in many places, hardly less abundant in the Eocene. These have resulted chiefly from the accumulation of the remains of mollusks and other shell-secreting animals. In addition to their agricultural value, many of these marl beds are large enough and of sufficient quality to be used in mixing for the manufacture of Portland cement.

In color these marls range from white to blue, and are composed chiefly of calcareous matter, some with as much as 97 per cent., and generally the amount exceeds 80 per cent. Professor Rogers mentions particularly extensive beds of pulverulent white marl in Gloucester, New Kent, Prince George, and other counties. In a table given of the Miocene calcareous marls from 9 localities in Gloucester county, Professor Rogers gives the percentage of calcium carbonate present as ranging from 37.1 to 96.8 per cent.; and 3 from New Kent county as ranging from 76.1 per cent. to 93.6 per cent. In places are beds of hard ferruginous marls consisting of shells more or less broken which are rich in calcareous matter; and shell-rock approaching limestone in composition, some of which Professor Rogers found to contain 87 per cent. of carbonate of lime.

At the Normal cliffs, on the Potomac river, shell marl has been dug for shipment and used in the manufacture of artificial fertilizers.

Ellett and Eskridge obtained the following results on analysis of marls from 9 counties in the Coastal Plain:

Locality.	Insoluble residue Per cent.	Lime Per cent.	Magnesia Per cent.	Phosphoric acid Per cent.	Potash Per cent.
Reves. Prince George Co....	59.00	12.88	0.46	0.07	0.63
City Point, Prince George Co.	67.59	20.41	0.35	0.33	0.41
City Point, Prince George Co.	70.51	12.75	0.09	0.17	0.34
City Point, Prince George Co.	28.07	38.15	0.42	0.29	0.50
City Point, Prince George Co.	41.71	27.40	0.06	0.38	0.26
City Point, Prince George Co.	47.26	24.44	0.48	1.50	0.27
City Point, Prince George Co.	39.05	27.96	0.84	0.13	1.02
Old Church, Hanover Co....	45.68	21.73	1.10	0.16	0.45
Lumberton, Sussex Co......	49.09	25.90	0.06	0.18	0.43
Chuckatuck, Nansemond Co..	13.70	40.97	0.23	5.36	0.26
Fort Lee, Henrico Co.......	15.80	26.79	0.45	0.03	0.25
Fort Lee, Henrico Co.......	29.23	35.74	0.66	0.77	0.65
Claremont, Surry Co.......	8.38	45.83	0.53	0.13	0.35
Yorktown, York Co........	47.45	24.77	none	0.03	0.71
Roxbury, Charles City Co...	27.61	35.54	trace	1.24	0.20

The Valley Region.

Large deposits of marl, usually of good quality, are found in many of the Valley counties on the west side of the Blue Ridge. So far as the writer has information, the marls of this region belong entirely to the calcareous type. Some of these have formerly had a limited use as a flux in iron-making, and, in places, they may offer possibilities for use in the manufacture of Portland cement. See pages 159 and 160, under Cement and Cement Materials.

Ellett and Eskridge give the following analyses of marls from the Valley region:

	Frederick County Per cent.	Frederick County Per cent.	Rockbridge County Per cent.	Alleghany County Per cent.
Insoluble residue	2.61	3.65	4.34	5.91
Lime	52.62	52.19	47.87	50.58
Magnesia	0.43	0.44	3.24	0.86
Phosphoric acid	0.06	0.36	0.80	0.23
Potash	0.58	0.23	0.31	0.28

Uses.

The principal use made of marl is as a fertilizer and as an improver of the mechanical or physical condition of certain types of soils. For these purposes its value is proportional, other things being equal, to the amount of phosphoric acid, potash, and lime it contains. The marl beds have been worked at numerous points in the Coastal Plain for local use as fertilizer. Marl is also used in the manufacture of Portland cement, in the manufacture of quicklime, and, in Virginia, it formerly had a limited use as a fluxing material in some of the iron furnaces.

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4. MILLSTONES (BUHRSTONES).

Under this name is included a siliceous conglomerate of quite variable structure, used in the form of flat-circular disks for grinding purposes.

About 5 miles west of Blacksburg in the vicinity of Prices Fork, Montgomery county, a sandstone-conglomerate occurs in Brush Mountain, in which quarries have been opened for a distance of 3 miles. The stone is somewhat variable in color but is usually white or gray. Likewise, variation in the size of pebble is shown. The rock is made up of well rounded pebbles of quartz compactly embedded in a fine siliceous sandstone matrix, the whole forming an exceedingly tough and hard mass. This stone is known on the market as "Brush Mountain" stone. Practically the same variation in the sizes of stone made at the different quarries obtains. The grindstones made from this rock are of excellent quality and they find a ready market. The age of the Brush Mountain stone is Mississippian (Lower Carboniferous) or Vespertine of Rogers.

Siliceous conglomerates similar to the above are found in the crystalline area, east of the Blue Ridge, and are rather abundantly distributed over the Mountain district west of the Blue Ridge, but so far as the writer is aware the Brush Mountain quarries, in Montgomery county, are the only producing ones in the State.

Production.

The value of millstones (buhrstones) produced in Virginia from 1902 to 1905, inclusive, is as follows:

Year	Value
1902	$11,435
1903	9,812
1904	4,759
1905	8,186

PART IV.

METALLIC MINERALS.

I. IRON.

BY R. J. HOLDEN.

Historical.

The first iron ore mined in America of which there is any known record was mined in Virginia in 1609 by the Jamestown colonists. This ore was taken to England where it produced 16 tons of superior metal. The success of this experiment led to the erection of the first American iron works between the years 1619 and 1622 on Falling Creek about 7 miles south of the site of the present city of Richmond. These works were destroyed in the Indian massacre of 1622 before they had been operated. For a century there were no further operations in the manufacture of iron.

The first successful iron industry in the South was established by Governor Spotswood in the pyrite area of Virginia. This was in connection with the Germania, or Rappahannock furnace, which was built about 1714, in Spottsylvania county, near the Rappahannock river. This was not only the first furnace in the South but, outside of New England and New Jersey, it was the first iron furnace in America. About 1727 Governor Spotswood erected another furnace at Fredericksville, in the southwestern corner of Spottsylvania county. About the same time the Accokeek furnace was built by the Principio Company, on the land of Augustine Washington, the father of George Washington, in Stafford county. Another pre-Revolutionary furnace was Old's furnace, near Charlottesville. The limestone limonite ores were early used by Miller's, or Mossy Creek furnace, built about 1760, and by the Poplar Camp furnace, built in 1778, in Wythe county. The Oriskany ores were probably first used by Zane's furnace, in Frederick county, in Revolutionary War time. By 1781 there were 3 furnaces in operation south of the James river in the magnetite area.

In the iron industry transportation facilities are a controlling factor. The early furnaces of the pyrite area were within hauling distance of water transportation on the eastern rivers. Some of the early Valley furnaces operated to supply a local demand only. The furnaces of the Shenandoah area, of which the Zane was the forerunner and which, in the period immediately preceding the Civil War, were leading producers of the State, had outlets in the northward flowing branches of the Potomac. To the early furnaces of the magnetite area, the James river was the highway of traffic. By the close of the 18th century the industry had been established on the James west of the Blue Ridge. By the middle of the 19th century the Oriskany district, located on the head waters of the James and dependent on that stream for an outlet for its product, had come to be the most important center of iron manufacture in the State, a position which it has since maintained. The coming of the railways changed the conditions of iron manufacture. The effect was seen chiefly in three ways. These were, the large extension of the charcoal furnace industry in the 70s and 80s in Wythe county, the building of coke furnaces in the central part of the State in the 80s and, finally, in the shipment of iron ore. In the late 80s there was a great boom in the iron business in the State, which resulted in a period of most active furnace building. In the years 1890 to 1892 there were 10 coke furnaces built in the State, which became active just before the panic of 1893. In the 15 years since that time not a furnace has been built. The building of the Cripple Creek extension of the Norfolk and Western Railway in 1885 and, a decade later, of the Craig Valley Branch of the Chesapeake and Ohio Railway, opened two regions to shipment of iron ore which have since been important contributors to the iron ore production of the State. The recent construction of a branch of the Chesapeake and Ohio Railway southwestward from Covington up the valley of Pott's creek, and the projection of the extension of the Norfolk and Western Railway northeastward from Interior in the same valley, is expected to open up another important area to the shipment of iron ore. Recent discoveries in regard to the size of some of the Oriskany deposits and in regard to new modes of occurrence of this ore have led to larger ideas of the importance of this ore.

Iron Minerals and Ores.

Iron ores are considered commercially for statistical purposes in four classes. These are red hematite, brown hematite, magnetite, and carbonate. These commercial terms correspond roughly, respectively, to the minerals hematite, limonite, magnetite, and siderite. There are other iron minerals from which iron is obtained as a by-product, the most important of which are franklinite, pyrite, and pyrrhotite.

Red hematite corresponds to the mineral hematite (Fe_2O_3), which carries 70 per cent. of metallic iron and 30 per cent. oxygen. This mineral is differentiated from the other iron minerals by its red streak or powder. Its specific gravity is 5.2. The mineral rarely takes on crystal form. The characteristics of the ore vary widely, especially in color and texture. There are three principal varieties, namely, red hematite proper, fossil ore, and specular ore. The red hematite is the most common, constituting the larger portion of the Lake Superior ores. In color it varies from red to brownish red, steel gray or even black. In texture, it is commonly fine-grained and varies in solidity from massive to powdery. The fossil ore is dark red to brownish red in color and is characterized by a fossiliferous or an oölitic structure. The specular ore is usually made up of flattened oval-shaped grains and is characterized by a black or steel gray color with a metallic pearly luster. It is the least important of the varieties of hematite. There are some similar metamorphic hematites that are sometimes classed with the specular ore. These are, the slate ore, which has a dark color and a slaty cleavage, and the micaceous hematite, which is even darker than the slate ore and readily cleaves into thin mica-like sheets. These hematites together include about 85 per cent. of the iron ore mined in the United States.

Brown hematite corresponds to the mineral limonite ($2Fe_2O_3.3H_2O$), which carries 59.8 per cent. metallic iron, 25.7 per cent. oxygen, and 14.5 per cent. water. This mineral is distinguished from the other iron minerals by its yellowish brown streak. Its specific gravity is 3.8. It is never crystalline. The characteristics of the ore vary widely, especially in texture. It is usually massive, but may be powdery. As massive it is commonly porous, not infrequently vesicular, sometimes cavernous and stalactitic, rarely solid. In color it is brown, liver-colored to brownish yellow on the fractured surface, but frequently black and shining on the natural surfaces. Gothite ($Fe_2O_3.H_2O$) and other hydrous oxides carrying less water and more iron than limonite and commonly associated with that mineral are included under the commercial term brown hematite. Brown hematite constitutes about 8 per cent. of the iron ore now mined in the United States and is mined chiefly in Virginia and Alabama.

Magnetite corresponds to the mineral magnetite (Fe_3O_4), which carries 72.4 per cent. metallic iron and 27.6 per cent. oxygen. This mineral is differentiated from the other minerals by its black streak and its magnetic properties. Its specific gravity is 5.2. The ore is usually crystalline and commonly in small octahedral crystals, but may occur massive. In color it is black. Magnetite constitutes about 5 per cent. of the iron ore now mined in the United States.

Carbonate corresponds to the mineral siderite ($FeCO_3$), which carries 48.2 per cent. metallic iron, 37.9 per cent. carbon dioxide, and 13.9 per cent. oxygen. This mineral is differentiated from other iron minerals by its effervescence with hot hydrochloric acid. Its specific gravity is 3.8. The ore rarely occurs in the form of the cleavable mineral siderite but as a fine-grained rock carrying more or less impurities. As such, its color is commonly gray, bluish gray or brown. When exposed to the air and moisture, it readily alters to limonite. Nearly all surface carbonate is considerably altered to limonite. The commercial term carbonate includes these altered products and the material so classed is commonly more limonite than carbonate. This is the least important of the ores of iron and constitutes less than 1 per cent. of the iron ore now mined in the United States.

Franklinite contains zinc and is mined for that metal in New Jersey. The iron left after the extraction of the zinc furnishes considerable of the former metal. The mineral has its crystal form, color and magnetic properties similar to those of magnetite.

The sulphides of iron are extensively used in the manufacture of sulphuric acid. The iron by-product in this manufacture, known as purple ore or "blue billy," is used in iron furnaces the same as iron ore. The most important of these sulphides are pyrite and pyrrhotite. Both of these occur in Virginia and both are mined.

Pyrite, FeS_2, disulphide of iron, contains theoretically 46.6 per cent. of iron and 53.4 per cent. of sulphur. It occurs frequently in crystals, which commonly have the form of cubes or pyritohedrons. Usually it occurs massive. In color it is quite uniformly a pale brass yellow.

Pyrrhotite, $Fe_n S_{n+1}$, a sulphide of iron, contains a variable percentage of iron according to its variable composition. With the formula $Fe_{11}S_{12}$ it carries 61.6 per cent. of iron and 38.4 per cent. of sulphur. It is rarely in crystals, usually massive with a granular texture. Its color is quite constant and is between a bronze yellow and a copper red. On fresh fracture it speedily tarnishes. It is commonly somewhat magnetic.

Impurities of Iron Ore.

The chief impurities of iron ore are silica, lime, alumina, phosphorus, sulphur, manganese and titanium.

Of these silica, lime and alumina may occur in quantity but in the furnace are thrown into the slag. Phosphorus, sulphur, manganese and titanium usually occur in small quantity and in the furnace are eliminated from the iron not at all or only partially and with difficulty.

Silica in large quantity is objectionable in an ore, not only because it reduces the percentage of iron in the ore, but also because it reduces the production of the furnace by filling the furnace not only with silica but also with the lime which is necessary to flux out this silica. Ores carrying as high as 40 per cent. silica are used in small quantity. In the limonite ores of the State the silica usually runs from 10 to 20 per cent.

Lime in small quantity is not objectionable. In large quantity it is objectionable only when present in amount greater than necessary to flux the silica present. Lime is not an associate of limonite ore but sometimes occurs in undesirably high percentages in the fossil hematite.

Alumina is a common associate of iron ores in small percentages. It is usually higher in limonite than in other classes of ores. In many limonite ores much alumina can be removed by washing. Alumina is apt to be particularly high in limonite ores that are associated with a shale residual, and much of this is so intimately mixed with the ore that it cannot be removed by washing. In large quantities alumina causes the furnace to work badly. It is usually present even in washed limonite ores to the amount of 1 or 2 per cent. and may run as high as 6 per cent.

Phosphorus is the controlling impurity which determines the use to which the iron made from the ore shall be put. Phosphorus of the ore goes into the pig iron. In minute quantities this element produces marked effects on both iron and steel. It renders iron and steel "cold short," that is, brittle when cold, but makes molten cast iron more fluid. For foundry iron, phosphorus is desirable in the ore in fractions of 1 per cent. Virginia cres are relatively high in phosphorus and this fact has been largely responsible in determining that the State should produce foundry and basic iron. The limonite ores of the State usually carry from 0.1 to 0.4 per cent. phosphorus. It is an interesting fact that fault deposits are usually high in phosphorus, even to the amount of 2 per cent. or more. Such ores are desirable for mixing with low phosphorus ores to regulate the phosphorus content of foundry iron.

Sulphur renders iron products "hot short," that is, brittle when hot, even where present in small quantity. It is therefore objectionable. However, the furnace coke usually carries so much sulphur that the sulphur in the average ore is negligible. Sulphur is apt to occur in ore as pyrite but in some limonites it occurs as gypsum or barite. When present in small fractions of 1 per cent. sulphur may be neglected.

Manganese usually occurs in iron ores in fractions of 1 per cent. In certain limonite ores it occurs to the amount of several per cent. Limonite ores are now mined in Virginia which carry 6 per cent. manganese. It also occurs in such quantity that the iron is subordinate in amount and the ore is a manganese ore. Manganese is not usually objectionable in fractions of 1 per cent. For the manufacture of foundry iron the Virginia limonites have to be selected that they may not carry too high manganese content. The ores high in manganese are used for basic iron.

Titanium is objectionable in that it interferes with the operation of the furnace. According to Virginia blast furnace practice, when titanium dioxide is present in quantities greater than 1 per cent. it makes the ore objectionable for furnace use. Titanium occurs chiefly in magnetites.

Origin of Iron Ore.

Iron ore originates for the most part by the segregation of iron, leached from rocks relatively lean in that element. The iron is carried in solution by circulating surface or ground waters and eventually precipitated. The precipitation may occur in some body of standing water and the deposit be a bedded deposit analogous to other bedded deposits, or the precipitation may occur on or near the surface of the land. Deposits beneath the land surface may be in cavities or may be replacements of the rock. In either case limestone is apt to be an associate of the ore deposit. This is true in the first case because limestone is one of the most soluble of rocks and therefore one of the most cavernous. In the second case it is true because the lime readily acts chemically upon the iron in solution in such way that the iron of the solution and the lime of the limestone exchange places. In Virginia examples of bedded deposits are seen in the fossil ores of the Alleghany mountains and the hematite of the Blue Ridge, and examples of land deposits are seen in the Oriskany ores. The different kinds of ores and ore minerals may be the result either of original differences in the minerals which arose at the time of the precipitation of the iron from solution, or of subsequent alterations from one form of minerals to another as a result of geological processes.

Classification of Virginia Ores.

The iron ores of Virginia may be grouped according to their character and occurrence into eleven classes. Listed roughly in the order of their importance these are as follows: Oriskany limonite, limestone limonite, Blue

Ridge limonite, fossil hematite, Blue Ridge hematite, pyrite gossan, pyrrhotite gossan, Piedmont magnetite and specular hematite, limestone magnetite, pyrrhotite and titaniferous magnetite. Of these the first five include most of the iron ore now mined in the State. The remainder are mined at present either from only one or two mines, or are of historical importance only, or are of possible future importance.

Oriskany Ore.

The name Oriskany was given to the limonite ore which was formerly supposed to occupy the position of the Oriskany sandstone. The name is here used for those ores to which it was originally applied and also to all other ores which have a similar origin and occur either in the Helderberg, the Oriskany, or the lower part of the Devonian shale.

This ore is the most important of the classes designated above. It was much mined for charcoal furnaces before the Civil War, and is now extensively mined in the Oriskany area. It is found in the Alleghany mountains from one end of the State to the other. It occurs most abundantly in the Oriskany area, chiefly in the counties of Alleghany, Botetourt and Craig. It has been considerably mined in the Great North Mountain area, chiefly in Shenandoah county. Here the ore occurs chiefly in the Devonian shale. It has been mined to a less extent in Massanutten and Draper mountains and also, in a small way, in a number of other localities.

Most of this ore occupies a very definite horizon at the top of the Helderberg. It occurs in subordinate importance in the lower part of the Devonian shale and rarely in the Oriskany. The strata which are associated with the ore, as they usually occur near mines, taken in descending order, may be listed as follows:

Devonian	300+ feet.	Shale, black at the bottom.
Oriskany	0—15 feet.	Calcareous sandstones.
Helderberg	10—60 feet.	Pure thick bedded, soft, fossiliferous limestone.
	20—60 feet.	Cherty limestone.

The ore is found characteristically replacing the upper pure limestone of the Helderberg. In some localities it is found at varying horizons near the base of the Devonian shale. Rarely the Oriskany sandstone is ore-bearing. Underneath the Helderberg chert there may be several score feet of limestone, shaly limestone and sandstone. These latter present considerable variation in different localities. The lower measures have no significance so far as the iron ore is concerned, as there is not a single instance, known to the writer, in which ore is found below the main body of the chert. Underneath the Helderberg there is a thickness of about 500 feet of Clinton and Medina which is mainly quartzite. The quartzite of these horizons is the ridge maker of the Alleghany mountains. Where the mountains are anticlinal, as in the Oriskany area, the ore-bearing rocks appear on the lower slopes on both sides of the mountain and in the valleys.

The iron of these ores was originally disseminated in the Devonian shale. As this shale was eroded the iron was taken in solution, carried down and deposited in any favorable place. Ordinarily this place was the upper portion of the Helderberg limestone. In some cases there was a direct replacement of the limestone by the iron and in other cases the iron was deposited in the space from which the limestone had been removed by solution. The iron rarely occurs in the sandstone in minable quantity. In the shale it has been deposited chiefly parallel to the bedding of steeply inclined strata.

The outcrop of the ore is usually found on the lower slopes of the mountain a few hundred feet above the valley botton. (See figure 56.) Along the base of the mountain on the strike of the formation the ore may appear with more or less development for miles. Continuous ore-bodies with fairly constant thickness have been worked for half a mile. The thickness of any ore-body has been largely controlled by the original thickness of the upper layer of the limestone at that

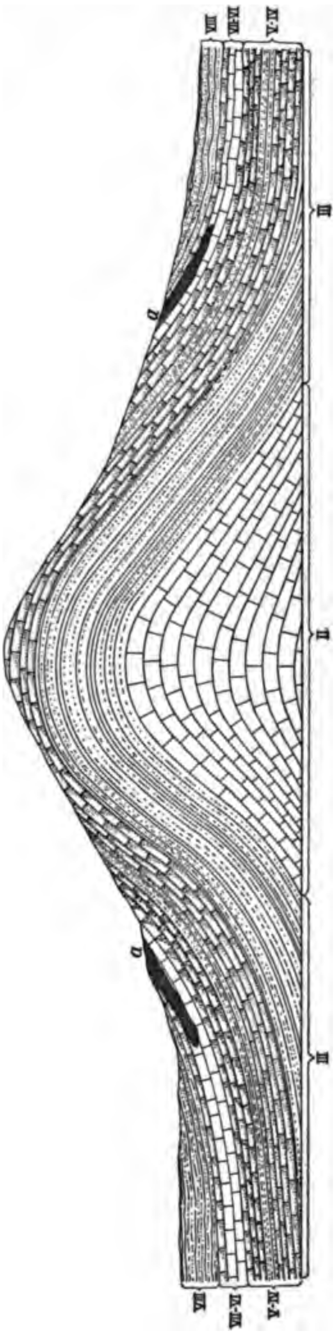

Fig. 56.—Cross section of Alleghany Mountain anticlinal showing relations of Oriskany ore. (a) Oriskany ore. II to VIII refers to Rogers' geologic system.

point. Usually this is replaced to its full width, where replaced at all, and it rarely occurs in thicknesses of a few feet. From 8 to 35 feet are usual thicknesses of the ore-body. Smaller thicknesses are not common except on the borders of the ore-body. Greater thicknesses are not unknown. On the slope of the mountain, that is on the dip of the formation, the extent of the ore-bodies varies between wide limits. The outcrop may be a mere pocket or the ore may extend 700 feet on the slope from the outcrop. Where the outcrop of the limestone horizon is not ore-bearing, ore may occur lower down, generally on a sharp fold of the strata. In some instances there are a number of folds which occupy the lower slopes of the mountains on opposite sides of the valley and the valley between. These may be wholly or partly filled with ore on both trough and crest.

The ore is commonly a continuous mass filling the space, and not lumps of ore in clay. The ore occupies the position in which it was deposited from solution and has the form which it then assumed. It has not been deformed or fractured since it was deposited. The mass is not solid but porous or cavernous. The cavities vary in size from a fraction of an inch up to a foot or more in diameter. These cavities may be vacant but commonly contain water, clay or sand. Less commonly the clay is more abundant and the ore is distributed in it as nodules, irregular masses and stringers. Rarely the associated material is loose sand and the ore consists of stringers in the sand. Where the ore is associated with the shale it may exist either as a surface pocket or as a concentration at some lower depth above an impervious basement or as stringers dipping at high angles with the bedding of the shale. This last occurrence is the most important of the shale occurrences. In this case the stringers may have widths of from a few inches up to 15 feet or more and extend downward 50 to 100 feet. The ore is washed in log washers to remove the clay and not uncommonly is jigged to remove sand and flint. From 50 to 80 per cent. of the material mined is delivered from the washer as washed ore.

The average composition of the Oriskany ores as mined, computed from available analyses, is as follows:

	Per cent.
Metallic iron	43.25
Silica	21.57
Phosphorus	0.38
Manganese	1.29

Limestone Limonite Ores.

The term limestone limonite is here applied to those limonite ores which are associated with the residual decay of a limestone. These ores consist, for the most part, of grains and lumps of limonite scattered through the limestone clay. Such ores are locally known as "limonite." Where limonite ore is more massive and in sheets or larger masses and usually associated with shale, shale residual or other relatively impervious material, the ore is locally known as "mountain ore" to distinguish it from the softer, more porous and usually higher-grade "limonite." The term "mountain ore" would apply to any brown hematite ore which was not the so-called "limonite." The term limestone limonite includes the so-called "limonite" and such of the "mountain ores" as have been obviously inherited from a limestone residual.

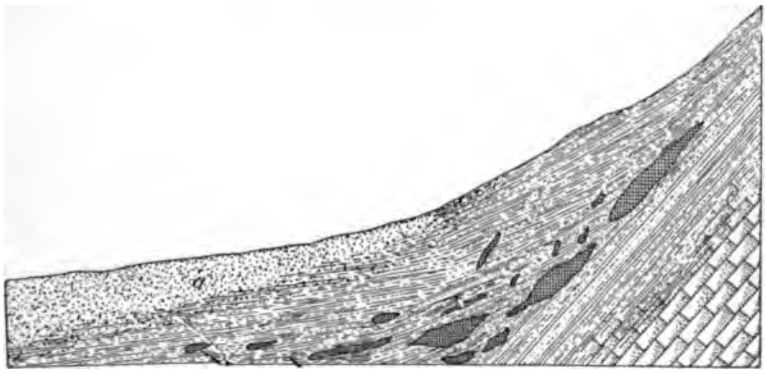

Fig. 57.—Diagram illustrating mode of occurrence of certain "mountain ores" in the New River-Cripple Creek area. (*a*) Residual clay of the Shenandoah limestone. Cross-lined areas represent limonite ore in the Cambrian shale residual. The blocked area in lower left-hand corner represents the Cambrian sandstone.

These ores are well adapted to use in charcoal furnaces and have been mined for that purpose for 150 years. They are now only second in importance to the Oriskany ores and are extensively mined. The chief occurrence of this ore in the State is in the New River-Cripple Creek area. It has been mined most extensively in the counties of Wythe and Pulaski. This is the ore which occurs near the base of the Shenandoah limestone. There are a few other isolated occurrences of the ore of this horizon in the Valley near the Blue Ridge. The ore of the upper horizon of this limestone is nowhere sufficiently developed to form a mining area of consequence but occurs in minable quantity in a number of scattered localities throughout the Valley, particularly in the northern part.

These ores are associated with the Shenandoah limestone and are known with the Greenbrier limestone. The chief occurrence is with the lowest members of the Shenandoah limestone. In the New River-Cripple Creek area where this ore has its greatest development, the lower portion of the Shenandoah limestone is a pure limestone through a thickness of several hundred feet. Under the limestone there is a thin shale and under this a considerable thickness of quartzite. These strata have been deformed considerably by folding and some by faulting. Along the southeast side of the Valley and along several anticlinal valley ridges and other valley anticlinals, the upper limestone measures have been removed by erosion and the lower measures outcrop along the base of the slopes and the crests of the non-ridge-making anticlinals. Where these measures outcrop the residual clay above the limestone is usually ore-bearing. In this area the New river and its branches have cut down 200 to 300 feet below the general level of the limestone surface. The land surface presents a series of oval domes

Fig. 58.—Diagram illustrating relations of the "limonite" in the New River-Cripple Creek area to the lower measures of the Shenandoah limestone. Black cover represents ore-bearing clay. Upper measures are Shenandoah limestone. Thin-lined measures under Shenandoah are Cambrian shales. The mountains are Cambrian sandstones and shales.

and the ore is found mostly on the crests and upper slopes of these hills, several hundred feet above the major streams. Another occurrence of this ore aside from that at the base of the Shenandoah limestone is that which occasionally appears near the top of the same limestone. This ore occurs in widely scattered areas in different parts of the State so that it is not possible to closely correlate the horizons. These occurrences of ore are quite uniformly associated with limestone phases which have a remarkable development of chert. The chert is commonly ridge- or knoll-forming and the ore occurs in the limestone residual on one side of the hill.

The iron of most limestone limonite ores was originally disseminated in the limestone. The ore arose by the removal of great thicknesses of the limestone by solution and the segregation of this iron in the residual clay above the limestone. The final concentration of the iron in the clay was brought about largely by the solution of the iron near the surface of the clay and its deposition lower down. In some cases running water in sink holes, acting as a great natural washer, further concentrated the lumps of ore.

The weathering of the limestone has left behind the more insoluble portions of the rock, the clay, which covers the present rock surface to depths which vary from a few feet up to 80 feet. The limestone weathers very irregularly. (Figure 59.) Commonly these irregularities take the form of pinnacles or steep domes, varying from those which are slender and closely spaced to the larger ones 25 feet in diameter and 50 feet high. (Plate LXXVIII, figure 2.) The clay with the "limonite" ore lies between and over these "horses," forming a cover over their tops which may be 20 feet thick. (Plate LXXVI, figure 2.) The ore occurs at various depths

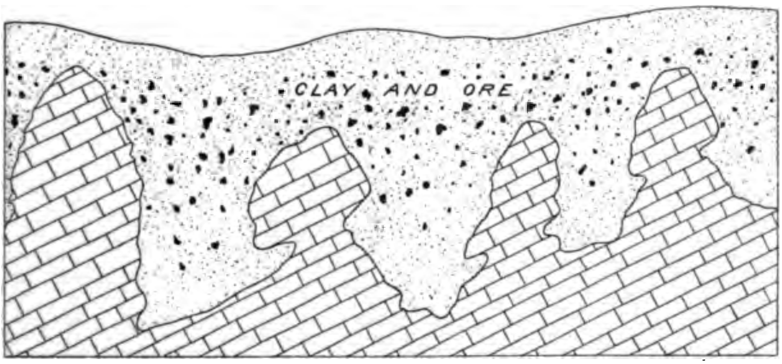

Fig. 59.—Diagram illustrating mode of occurrence of the limestone limonite ore in southwest Virginia.

in the clay. The upper few feet of clay are usually barren. The best concentration usually occurs at depths of from 10 to 20 feet. However, ore may occur well to the bottom of the deep clay. The ore is scattered through the clay in pieces which vary in size from lumps a foot in diameter down to fine particles. The greater portion of the ore is in the smaller size pieces and sometimes is merely a coarse grit in the clay. Where the masses are more than a few inches in diameter they are usually porous with clay in the cavities. The percentage of ore in the clay varies between wide limits. At its best concentration in bodies of any size the ore constitutes about 30 per cent. of the total material of the bank. Where there is less than 4 per cent. it is not usually minable. The clay sometimes carries minable percentages of ore over continuous tracts of many acres. Where the iron has been deposited above a basement which is relatively impervious to water such as is furnished by the shale and quartzite underlying the limestone, the ore is more massive and usually constitutes a much larger percentage of the bank. In such cases the ore is usually in thin seams or lumps, but may constitute masses of 1,000 tons weight. These "mountain ores" are commonly of a lower grade than the "limonite." Along the contact of the limestone and the sandstone there are ores which have characteristics of both the "limonites" and the "mountain ores" and are known as "semi-limonites."

The average composition of these ores is shown in the following table, which is compiled from analyses furnished by the Virginia Iron, Coal and Coke Company, the Pulaski Iron Company, and the New River Mineral Company.

Analyses of iron ores from the New River-Cripple Creek district:

	Limonites[1] Per cent.	Semi-limonites[2] Per cent.	Mountain ores[3] Per cent.	Average[4] Per cent.
Metallic iron	43.76	40.72	37.86	41.99
Silica	13.52	20.12	18.60	16.17
Alumina	1.79	1.81	2.32	1.91
Phosphorus	0.17	0.31	0.40	0.25
Manganese	0.58	0.33	1.49	0.81

(1) Average of 56 analyses from 12 mines.
(2) Average of 15 analyses from 5 mines.
(3) Average of 17 analyses from 4 mines.
(4) Average of all ores from 21 mines.

Blue Ridge Limonite Ore.

This term is used to include all the limonite ore which occurs in the vicinity of the Blue Ridge. Of these there are two classes, the ores which are in the shale and sandstone chiefly at the west base of the Blue Ridge, and the fault deposits chiefly in the sandstone.

This ore was considerably mined for charcoal furnaces and is now mined for shipment at half a dozen operations. These ores occur along the Blue Ridge and have been mined at frequent intervals from Roanoke to Front Royal, a distance of 150 miles. At present the most important operations are in the vicinity of Roanoke, Buena Vista, and Front Royal. Most of the ore thus far mined has come from the west slope of the mountain. Several mines have been located on the east slope of the main western ridge. Portions of the Blue Ridge have a complicated structure and its surface consists of a series of peaks and valleys over areas which are locally 12 miles wide. Some of these areas are known to contain ore but the obstacles to transportation are so great that little has been mined. In parts of the Blue Ridge the strata underlying the Valley limestone are sandstones and not favorable for the formation of ore. In other places, particularly in the southwest, the measures which might bear ore are buried by faulting.

The surface rock of much of the Blue Ridge is composed of two main members of probable Cambrian age, the sandstone and the overlying shale. The Blue Ridge is in general an anticlinal mountain from the crest of which the shales have been eroded. The crest of the mountain is then composed of the sandstone while the shale appears on the flanks. On the west side the shale at the base of the mountain dips northwest at high angles. It is in this that the shale ore of the first kind is found. The fault deposits are higher up on the mountain in the sandstone.

The iron which is now in the ore is believed to have been leached from the shale, carried down and deposited in any favorable place. This applies to all the limonites of the Blue Ridge. In the case of the shale ores it is certain in some, and probable in most cases, that the ore was deposited in

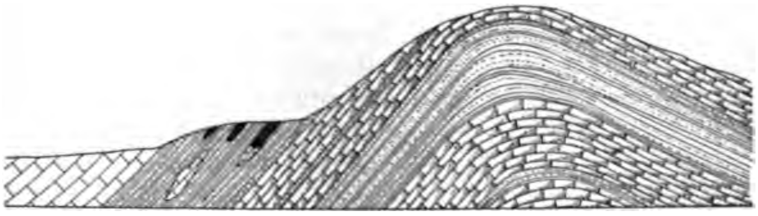

Fig. 60.—Section showing the mode of occurrence of Blue Ridge limonite ore in shale bench.

association with limestone. The ore either replaces the limestone or was deposited in the space from which the limestone had been removed by solution.

On the west side of the mountain the shale commonly forms a bench which is a few hundred feet above the limestone of the Valley and which has a width of a quarter to a half mile. It is in this bench that the shale ore usually occurs. Characteristically the ore-bodies dip north at high angles with the bedding of the shale. The width of the ore-body is quite variable even in short distances, ranging from the thinnest minable seam to a thickness of a score or two feet. The length of the deposits as continuous bodies is quite limited. The greatest known length of continuous working is about a quarter of a mile. The greatest depth to which ore has been mined is about 200 feet. The fault deposits occupy a position along the fault plane of a well marked fault line or are a series of deposits along a general fault and breccia zone. The direction of the fault may be either parallel or transverse to the strike of the bedding. In the case of the deposit along a well marked fault line there may be thicknesses up to 20 feet. The other sandstone deposits are irregular and have a variety of occurrences, but in general they are more compact and have less linear dimensions than the shale ores.

The shale ore, where it occurs in large bodies and is an evident replacement of the limestone, has the same open porous texture characteristic of the Oriskany limestone ore. Where the ore-bodies are thin the ore is apt to be in compact masses of stringers in the decomposed shale. Where the ore is still less abundant it is in the form of lumps, grains and stringers intimately associated with the shale usually in more or less ferruginated beds. The fault deposits are compact black masses of limonite ore. In some instances they have been fractured by dynamic movements subsequent to their deposition. These fault ores are comparatively free from clay and are sent to the furnace as mined without washing. The other sandstone ores may be sandstones which have become highly impregnated with iron or masses of compact massive high grade ore. The composition of the shale ore will vary widely according to the way it is mined. There is much good ore intimately associated with clay that is difficult to mine, without including considerable low grade ore that is difficult to separate from the better ore. The fault deposits are characterized by a high phosphorus content.

The average composition of the Blue Ridge limonite ore as mined, computed from available analyses, is as follows:

	Per cent.
Metallic iron	41.22
Silica	20.61
Phosphorus	0.93
Manganese	0.90

Fossil Hematite.

Fossil hematite is a hematite ore, which occurs as a bedded deposit. It occurs abundantly in the Appalachian mountains and is mined from New York to Alabama. Westward in the flat-lying strata it is mined in Kentucky and Wisconsin. This ore is variously known as fossil, oölitic, Clinton, Rockwood, and dyestone.

This ore was little used in charcoal furnaces. It was first mined for shipment in this State about 1880. It is now mined at Low Moor in the Oriskany area and in a number of operations in the fossil hematite area.

These ores occur in the Clinton stage of the Silurian rocks. The Clinton rocks of Virginia present considerable variation in kind and thickness in different localities. In general they are sandstones or quartzites and shales with a few thin beds of limestone, having a total thickness of from 100 to 900 feet and an average of about 400 feet. Except in the extreme southwestern part of the State, the upper member of the series is a white quartzite while the lower members are mainly thin sandstones, sandy shales, shales, and iron ore. The ore usually occurs interbedded with shale. The Medina rocks underlying the Clinton are usually thick bedded sandstones. These rocks, together with the Clinton, are the main mountain-making strata of the Appalachian mountains in Virginia. As a result of this the fossil ores usually occur well up on the slopes of the mountains. In the Oriskany area the mountains carrying fossil ores are anticlinal and the ores outcrop near the crest of the mountains and dip on both slopes. In the fossil ore area the ore-bearing mountains carry less sandstone measures and are in consequence not so high and, in addition, are mostly monoclinal with the ore beds dipping in one direction. In the Oriskany area one minable bed is known. In the fossil ore area there are three beds which have been mined. These beds have been designated numerically from the lowest up as Nos. 2, 3, and 4. The beds are rarely all workable in the same locality. No. 3 lies stratigraphically above No. 2 from 175 to 225 feet, and No. 4 lies 80 to 90 feet above No. 3. No. 3 has been mined the most extensively and No. 2 the least.

These ore-beds are mined at a minimum thickness of 16 inches and have a maximum thickness of something over 4 feet. Usual thicknesses are from 22 to 36 inches. In minute structure the ore occurs in two main forms, the fossiliferous and the oölitic. In the fossiliferous variety the ore particles consist of small fossils and fossil fragments which have had their calcium carbonate replaced by iron oxide. In the oölitic variety the iron oxide is in the form of concentric layers about some central particle, which is usually a grain of sand or a fossil fragment. In its original condition these concretions and ferruginated fossils were associated with considerable calcium carbonate. Where the lime constituted a considerable percentage of the total material, the rock was a limestone which was thickly set with these iron particles. Where the ore is now above the level of the ground water most of the lime has been leached out. Such leached ore is known as soft ore while the unleached or limy ore is known as hard ore. Up to the present time very little hard ore has been mined in this State. The soft ores of the fossil ore area carry 35 to 45 per cent. of metallic iron and from 15 to 35 per cent. of silica. On the lower levels they are apt to be limy and may carry lime up to 14 per cent. The soft fossil ores of the Oriskany area are of somewhat higher grade carrying about 45 per cent.

of metallic iron. The hard ores offer possiblilities which have not yet been used. Such ores may carry 35 to 55 per cent. calcium carbonate and only 25 per cent. of metallic iron and, if the silica is low, still be usable.

The average composition of the fossil ore as mined in Virginia, computed from available analyses, is as follows:

	Per cent.
Metallic iron	40.84
Silica	21.70
Phosphorus	0.36
Manganese	0.15

Blue Ridge Hematite.

This ore is locally known as specular ore. As the name specular has been applied to a granular black metamorphic hematite, the term specular as applied to this ore is misleading, as it has none of the distinctive characteristics which the specular ore has. This ore was not used in charcoal furnaces. It was first mined for coke furnaces about 1880. It is now mined in a number of operations between Roanoke and Buchanan.

The Blue Ridge hematite ore occupies a definite stratigraphic position in the (topographically) upper end of the great shale formation. It has not yet been definitely determined whether this shale is Cambrian or Ordovician, but it has formerly been regarded as Cambrian. The outcrop of the ore occurs well up on the mountain some 500 to 1,000 feet above the valley. On the Buchanan end the outcrop is on the northwest side of the mountain while farther southwest, near the Grubb mine, it is on the southeast side. The shale enclosing the ore has been intricately folded and portions of the ore-bearing strata occur a quarter of a mile down the mountain from the normal position.

This ore is a bedded deposit, which was formed as a water deposited sediment and later compacted and elevated to its present position, in the same manner as the other associated sedimentary rocks.

The ore bed has been much deformed both by folding and faulting. This has in places resulted in the production of several parallel outcrops. In the view on plate LXVI, figure 1, two of these parallel outcrops are shown. This deformation has altered materially the original thickness of the bed. Where the normal thickness was 3 to 6 feet the limbs of the folds may be thinned to 18 inches or even entirely disappear, while the crests of the folds may be thickened to 12 or 15 feet. The ore-bodies usually dip at high angles. On the strike the ore-bodies are persistent for miles. Surface workings are interrupted by ravines, but with depth they will doubtless be continuous over long distances. On the dip the ore has been mined to a depth of a couple hundred feet. The ore probably extends to as great depths as it will ever pay to mine.

The ore is a massive bed of siliceous hematite between walls of shale. It is considerably fractured; locally, so much so that the ore is removed by dynamite which is inserted in crevices without drilling and the ore removed in angular blocks. The silica is largely present as quartz grains.

The ore carries in metallic iron from 35 to 42 per cent., in silica 20 to 38 per cent. and less than a half of 1 per cent. each of phosphorus and manganese.

The ore is well known at intervals in the counties of Roanoke, Bedford, and Botetourt along a distance of 30 miles. It has been considerably mined near Blue Ridge Springs, and near Buchanan. It is reported to appear at Buena Vista as a ferruginous sandstone and to have been mined near Basic City, 60 miles northeast of Buchanan.

The average composition of the Blue Ridge hematite as mined, computed from available analyses, is as follows:

	Per cent.
Metallic iron	38.94
Silica	35.26
Phosphorus	0.38
Manganese	0.22

Pyrite Gossan.

Pyrite gossan is a limonite which is formed by the oxidation of pyrite. Pyrite is widely distributed east of the Blue Ridge in the main pyrite area, as shown on map, figure 64. It occurs as definite leads and as more or less thickly disseminated pyrite in the schistose rocks. Pyrite is now worked in Louisa county and is used in the manufacture of sulphuric acid. The "blue billy," which arises as a by-product in the manufacture of the acid, is sometimes smelted for its iron. The outcrop of the pyrite is everywhere altered to limonite. This ore was the basis of the first iron industry in Virginia and for 150 years was mined for charcoal furnaces. Except in one or two instances the ore has not been mined by modern methods for shipment.

Pyrrhotite Gossan and Pyrrhotite.

Pyrrhotite gossan is limonite which is formed by the oxidation of pyrrhotite, a sulphide of iron. The pyrrhotite, together with its associated minerals, chiefly chalcopyrite, talc, calcite, hornblende, and quartz, constituting the vein filling, is locally known as "mundic." This gossan was used in bloomery forges and charcoal furnaces for 75 years. It was not satisfactory for wrought iron, but was used successfully for castings. In the two places where the main lead has been reached by railway transportation the gossan has been extensively mined.

These ores occur in Ashe and Alleghany counties, North Carolina, Grayson, Carroll, Floyd, and Franklin counties, Virginia. In the southwestern part of the State the Blue Ridge divides into two ranges. The area between these ranges, including the counties of Floyd, Carroll, and Grayson, constitutes a plateau which rises above the Valley on the northwest and the Piedmont on the southeast. The pyrrhotite leads occur in this plateau and have their strongest development in the northern part of Carroll county, a few miles from and parallel with the northwestern border range. The rocks of this area are of doubtful age. Quite uniformly they are mica schists with the schistosity dipping to the southeast.

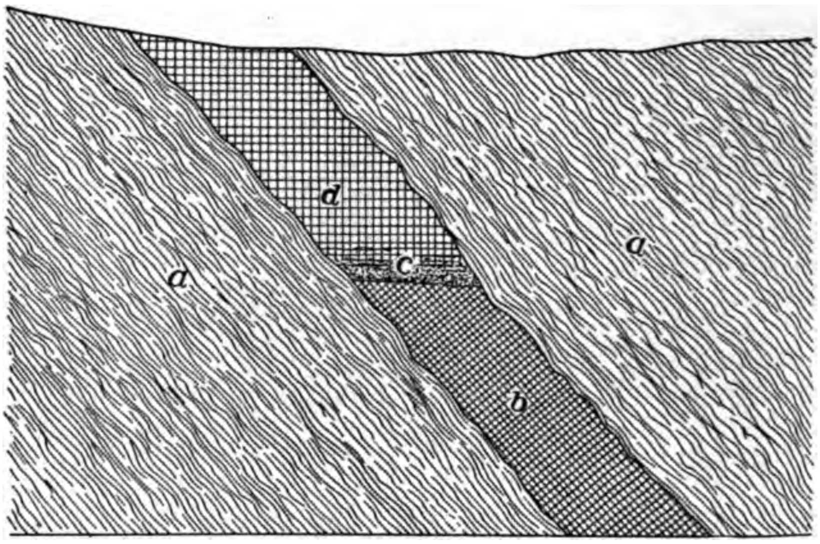

Fig. 61.—Diagrammatic cross-section of the "Great Gossan Lead" in southwest Virginia, showing relations of altered and unaltered pyrrhotite to each other and to the enclosing schists. (*a*) Crystalline schists. (*b*) Pyrrhotite ("mundic"). (*c*) Copper ("smut") ore—secondary concentration.

The pyrrhotite occurs in isolated areas and in more or less regular leads. The leads dip on the average about 35° to the southeast with the schistosity. The width of the lead is quite variable. It may pinch out entirely or have widths as great as 175 feet. Through several hundred yards it may hold a quite constant width of from 10 to 20 feet. For several miles at a stretch it may be fairly continuous and workable. The average width as measured at 18 places where mined for copper is 27 feet with extremes of 6 and 60 feet. Its depth has been proved in two places to be several hundred feet and its probable depth is several times this. The surface of the lead is everywhere weathered. As measured in 20 copper operations this weathering has extended to an average depth of 34 feet, with extremes of 10 and 60 feet. This weathering has produced an oxidation of the sulphides and a removal of some of the material, particularly iron and copper. Further description of this lead as a copper producer is given under Copper on pages 511-517. About one-half of the original material has been oxidized in position to a porous limonite. This is the gossan. In two places the pyrrhotite has been mined for its sulphur content. The "blue billy," which results when pyrrhotite is used in the manufacture of sulphuric acid, has been used to a small extent in iron furnaces as an ore. If a process shall be developed whereby the sulphur is successfully eliminated from this material, this pyrrhotite lead will be one of the greatest deposits of iron ore in the State.

Piedmont Magnetites.

Magnetite occurs in the southern part of the State east of the Blue Ridge among the crystalline schists of the Piedmont. It occurs in three districts along the same general line with somewhat different characteristics in each district. In Franklin and Patrick counties it occurs in leads which are said to attain a width of 12 feet and which are associated with a hornblende schist, the ore-body dipping with the schistosity. This ore was mined for early charcoal furnaces and has since been mined for shipment. In Grayson county there are a number of occurrences of magnetite which are better known on the North Carolina side of the State line. In Pittsylvania county occurs the most extensively mined magnetite. It occurs between walls of crystalline limestone and mica schist in thicknesses up to 12 feet. This was not mined for charcoal furnaces but has been mined for shipment pretty constantly since 1880. On the James river, some 12 miles below Lynchburg, is a magnetite area which in Jefferson's time was a leading iron producing area of the State. About 1880 this region was exploited and some ore shipped. Most of the workings are now closed and little is to be seen of the ore-bodies. Mining was done by open cut and by shaft and tunnel to depths under 200 feet.

The ore is magnetite and specular hematite with limonite in the vicinity, but not usually in immediate association. The associated rocks are chiefly metamorphosed sedimentaries, quartzite, mica and talc schists, and limestone. There are a few scattered trap dikes. In some instances the iron schist overlies quartzite and follows the bedding and is locally an ore. One mine is reported to have produced 10,000 tons of ore. Some of the ore carries phosphorus below the Bessemer limit.

Limestone Magnetite.

Limestone magnetite is the name given to the magnetite and associated iron ores which occur in the Shenandoah limestone. With the magnetite there is associated hematite, limonite, and iron carbonate.

This ore occurs in Giles and Washington counties. It is a secondary deposit in the limestone. In the case of the Washington county deposits the ore is at the extreme top of the Shenandoah limestone and located near the border of an area of Athens shale. The iron of the ore was leached from the shale and deposited in its present position. The magnetite is usually found farther from the surface than the other minerals. In the limestone about these ores in some instances there is iron carbonate which at the surface has been altered to limonite. In some instances the limestone about such deposits has been removed by solution, and lumps of magnetite of a few pounds weight are now found scattered through the clay. About a half dozen of these deposits have been worked. As thus far developed they are small, a few rods wide by 30 feet deep, but with indications on the surface for many rods. Two small mines were operated in 1906. Where the ore is well concentrated the magnetite is the highest grade ore in the State and usually has its phosphorus below the Bessemer limit.

Titaniferous Magnetite.

Titaniferous magnetite occurs in Virginia in several different associations. By present furnace practice it is not usable as an iron ore but offers possibilities for the future. It occurs in the Blue Ridge in a distinct lead which has been prospected in one place and which is reported from a number of places. Near Roseland, Nelson county, and near Vinton, Roanoke county, it has a very different occurrence. The titaniferous rock is made up chiefly of small grains of apatite and ilmenite. It is reported to exist in considerable quantity. These occurrences are described in some detail on pages 232 and 300-301. In Grayson county prospecting has proved the presence of a titaniferous magnetite lead which is better known in the contiguous counties of North Carolina.

Geological Distribution.

Iron ore is associated with the rocks of various geological ages in the State of Virginia. It occurs most abundantly in the strata which are at the top of the Silurian and near the base of the Devonian. It occurs somewhat less abundantly in the rocks of the middle Cambrian age. In other words it occurs near the center and near the base of the geological column, as this is shown in the northwestern half of the State. Of these ores two classes, the fossil hematite and the Blue Ridge hematite, are of the same age as the enclosing rocks. All others originated later than the rocks enclosing them. However, for the purpose of distinguishing a class of ore, the name of the enclosing rock may be used.

The crystalline rocks of the Piedmont, whose age is doubtful, carry some ores of magnetite, specular hematite, and limonite. Beginning with the oldest rocks of *definitely known age* with which iron ores are known to occur, iron ore occurs at several horizons in the *Cambrian*. A small amount of magnetic ore occurs with the *Unicoi sandstone*. Limonite occurs in small quantity with the shale above this sandstone. This latter is of commercial importance in Tennessee and may be of importance in Virginia. The Blue Ridge hematite, a bedded deposit, occurs in strata which have been considered Cambrian. The age of these rocks has not been satisfactorily determined, and there is a possibility that they may be the shales of Rogers' No. III. In the upper Cambrian sandstone there are fault and other deposits of commercial importance. Of these, the fault deposits are now being mined. In the Cambrian shales above the upper sandstone are limonites which are now being mined at several operations. In the lower portion of the Valley limestone which is considered of Cambrian age are limonites of the finest quality and of such quantity as to rank second in importance among the ores of the State. In higher portions of this same limestone there are scattered deposits of some commercial importance which are presumably of Ordovician age. The upper portions of this limestone carries a few small minable deposits of associated magnetite, hematite, limonite, and carbonate. The next higher rocks, No. III of Rogers, are reported to carry ores in a number of places and to have been mined, but such deposits have either not been seen by the writer, or, if seen, have not been confirmed as belonging to this formation. The Upper

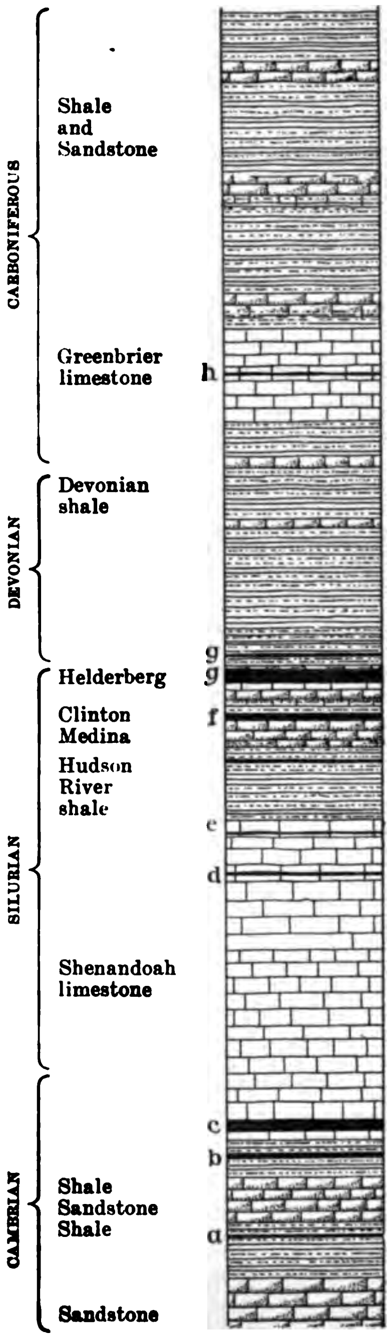

Fig. 62.—Generalized columnar section of the Paleozoic strata in Virginia showing the distribution of iron ores. (*a*) Blue Ridge hematite. (*b*) Blue Ridge limonite. (*c*) Limonite of New River-Cripple Creek area. (*d*) Limonite of the upper Shenandoah limestone measures. (*e*) Limestone magnetite. (*f*) Fossil ore. (*g*) Oriskany ore. (*h*) Greenbrier limestone limonite (not mined).

Silurian rocks carry the most abundant ores. Of these the Medina sandstone, or No. IV, carries little or no commercial ore. The Clinton, or No. V, is an important ore-bearer. In this there occur at several horizons bedded deposits of fossil ore which are now being mined. It is reported that limonites occur in this formation, but although some of these deposits have been seen by the writer, the horizon has not been confirmed as Clinton. The next higher horizon, the Helderberg, or No. VI, is the greatest ore-bearing horizon in the State. This horizon carries the largest part of the so-called Oriskany ore. That part of the formation which carries the ore is the upper part and is limestone. The ore is limonite. The ore is not a bedded deposit although, in occupying the position which was once occupied by the limestone over considerable areas, it has the appearance of a bedded deposit. The Oriskany, No. VII, a sandstone, immediately overlying the Helderberg limestone, locally carries a little ore. The rocks of the Devonian aside from the Oriskany are only rarely ore-bearing. These rocks are almost entirely shales and as such are not favorable for limonite deposits. In a few places Oriskany ore has been deposited in minable quantities in this shale. In one area it has considerable development and is now mined. All of these occurrences are in the lower few hundred feet of the Devonian. It is not known that ore occurs in other horizons of this great shale formation, which attains a thickness of 4,000 feet in the State. Neither the Lower nor Upper Carboniferous is a bearer of any considerable deposit of iron ore. Associated with the Greenbrier limestone there is some limonite that may prove minable, but it is not known that any has yet been mined. With the Coal Measures there is some carbonate of iron. This has been mined in West Virginia in charcoal furnace time, but it is not known that any of this has been mined in Virginia.

Geographical Distribution.

The iron ores are extensively but unevenly distributed over the northwestern half of the State. According to topographic divisions they occur in the Alleghany mountains, the Great Valley, the Blue Ridge, and the northwestern part of the Piedmont plateau. The geographical distribution of the iron ores is dependent on the distribution of outcrops of the strata containing them. In general throughout the Valley from the Blue Ridge to the West Virginia line, from the southeast toward the northwest, the surface rock, beginning with the Cambrian of the Blue Ridge, is of successively younger age up to the Carboniferous in the vicinity of the State line. Figure 63 is a generalized cross section of the northwestern part of the State and is intended to show the effect of the position of the

Fig. 63.—Generalized section across the Valley and Allegheny Mountains regions in Virginia, showing geologic and topographic positions of the iron ore.

ore in the geological column on the geographical distribution across this part of the State. For convenience of discussion the ores are grouped into eight areas. (Figure 64.) These areas will not include all the ores of the State, as there are many scattered deposits. The areas in each case are based on a particular kind of ore but may contain other ores of subordinate importance. These areas may be named as follows: The Piedmont magnetite area, the pyrite area, the great gossan area, the Blue Ridge area, the fossil ore area, the New River-Cripple Creek area, the Great North Mountain area, and the Oriskany area.

The Piedmont magnetite area is a narrow strip about 150 miles long, lying some 15 to 30 miles southeast of the Blue Ridge and parallel to it with its southwest end on the North Carolina line. This is not an area of continuous ferruginous rocks but, on the contrary, it contains considerable intervals which are non-ferruginous. The ore-bearing parts of the area are grouped into four districts: the James river district, the Pittsylvania county district, the Franklin-Patrick counties district, and the Grayson county district. The main ores are magnetites, but there are some specular hematites and minable limonites. The magnetites are of somewhat different nature in the different districts, and are associated with different rocks.

The pyrite area is an area of some 100 miles long, lying some 40 miles southeast of the Blue Ridge with the northeast end touching the Potomac. It is not a well-defined area, but a general territory in which bodies of pyrite occur from which, in charcoal furnace time, the gossan cap was locally mined.

The great gossan area is a narrow belt some 60 miles long, lying in the Floyd-Carroll-Grayson counties plateau region of southwest Virginia, in the northwestern edge of the area of crystalline rocks. The ore is the gossan cap of the pyrrhotite lead.

The Blue Ridge area is a narrow strip of the Blue Ridge 150 miles long, extending from Roanoke to Front Royal. It includes several kinds of ores. These are the bedded hematite, the limonite of the Upper Cambrian sandstone, the limonites of the western base of these mountains, and small quantities of titaniferous magnetite. The first three

Fig. 64.—Sketch map of Virginia showing principal iron-ore areas.

of these are important deposits and are now worked. The first is found chiefly in the 25 miles northeast of Roanoke. The second is found in deposits of commercial importance in a few places along the Blue Ridge. The third occupies quite a definite horizon and occurs at a multitude of places along the line mentioned. The fourth is known in a few places only.

The fossil ore area is a narrow strip some 40 miles long, including the Poor valley, in the counties of Wise and Lee, the extreme southwestern counties of the State. The ore is the bedded fossil ore and occurs in several horizons. It is of commercial importance and is now mined.

The New River-Cripple Creek area is about 30 miles long by 3 miles wide, located in the limestone valley of southwest Virginia, chiefly in the counties of Wythe and Pulaski. The ore is limonite and is associated with the Cambrian limestone and shale. This area is second in importance in the State.

The Great North Mountain area is an area with indefinite boundaries in the northeastern corner of the State along the Virginia-West Virginia line, chiefly in the county of Shenandoah, Virginia. The ore is limonite. It is now worked at one place, but formerly, it was one of the important producing areas of the State.

The Oriskany area is an area about 40 miles long by 10 miles wide, situated about Clifton Forge as a center. The ores are chiefly the Oriskany limonite, but there is also fossil ore. This area is the largest producer of iron ore in the State.

Individual Mines.

In the following description of individual mines it has been attempted to call attention to the iron ore resources of the State and to their distribution in four ways. These are by describing producing mines, by describing abandoned mines, by giving the location of old charcoal furnaces, and by giving the distribution of ore-bearing horizons. In the description of producing mines there is little relation between the amount of description and the importance of the mine. An unimportant mine presenting unique features may be described at greater length than an important one which is one of a class. Abandoned mines are not necessarily exhausted. Better prices for ore, better mining methods and a variety of other reasons may make an abandoned mine profitable to work. A charcoal furnace meant a local mine. In some instances the ore was exhausted, but this is by no means true of all these mines. The Lucy Salina furnace used ore for 40

years from the outcrop of a deposit which has since produced 1,500,000 tons of ore. In the space allotted to iron ores in this publication it is not possible to treat in detail the known ore locations, the mode of occurrence of the ore or the location of reserves. A report which is in course of preparation for the Virginia Geological Survey will treat these in some detail.

Many of the analyses of ores given in the following descriptions have been furnished by the operator of the particular mine to which the analysis refers, and are thought in most instances to show the *mining value* of the ores. An analysis of a sample of hand-washed limonite ore usually shows higher values than the same mine will produce in carload lots, where the ore is dressed by machinery. The analyses quoted below usually show silica or insoluble, metallic iron, phosphorus, and metallic manganese. The word silica, or insoluble, is here used as in the source from which the analysis was taken. Silica here probably means insoluble. Washed limonite ore as received at the furnace usually carries 5 to 10 per cent. of uncombined water. Some of these analyses are given for the natural state, that is, as received at the furnace, while others are given as dried at 212° F. It has not been possible to give all the analyses in the same state. One of these ores dried at 212° F. will carry from 2 to 5 per cent. higher metallic iron than one in the natural state. Comparisons of analyses made in different states should take this difference into account.

COUNTIES WEST OF THE BLUE RIDGE.

These counties produce most of the iron ore now mined in the State. They produce all the limestone limonite, the Oriskany limonite, the fossil ore, the limestone magnetite, the Blue Ridge limonite, and most of the Blue Ridge hematite. While nearly all of these counties have minable iron ore, and there are operating mines in various places, the greater part of the ore now mined comes from the vicinity of Clifton Forge and from the southern part of Wythe county.

Frederick County.

Frederick county has Oriskany ore in the western part of the county. This ore was mined more than a century ago for local charcoal furnace use. Zane's furnace on Cedar creek was active in Jefferson's time. Taylor furnace, 10 miles west of Winchester, was built in 1845. The western part of the county is without railroad facilities and the ores have not been operated in recent years.

Clarke County.

Clarke county has the Cambrian measures of the Blue Ridge on its southern border, while the remainder of the county has for its surface rock the Valley limestone. It is not known that ore has been mined from the Blue Ridge measures, but they are reported to carry ore. There is no record of any furnace ever operating in the county, but ore was mined here for the Shannondale furnace in Jefferson county, West Virginia. The ore is the limestone limonite and occurs in a number of places a short distance west of the Shenandoah river.

Berryville mine.—In recent years this ore has been mined at a point 1½ miles north of Castleman's Ferry and 5 miles east of Berryville.

Warren County.

Warren county has the Cambrian measures of the Blue Ridge on its southeast border, the Shenandoah limestone in the center of the county, and the Silurian shales on the west corner, but no Oriskany measures. Ore has been mined at several places on the west side of the Blue Ridge.

Big Ike mine.—This mine is located a mile or more south of Overall near the Page county line on the west slope of the Blue Ridge. It is a fault deposit of limonite ore in the Cambrian sandstone. It was recently opened and ore hauled in wagons to Overall for shipment.

Happy Creek mine.—This mine is located 2 miles south from Front Royal at the base of small Blue Ridge hills. The ore is limonite associated with Cambrian sandstone. It is washed in a local washer and transported over a narrow-gauge railway to Happy Creek for shipment. In 1907 this mine was shipping about 3 carloads per day. The analyses of samples of 4 carloads of the ore shipped in 1907 as furnished by the operator, H. J. Seibel, Jr., averaged as follows:

Natural State.

	Per cent.
Metallic iron	49.48
Phosphorus	0.59
Manganese	0.75

Shenandoah County.

Shenandoah county has produced Oriskany ores for a century. In the period just before the Civil War this was a leading iron-producing county of the State. These ores are found distributed over the western part of the county and also occur in the southeastern part in Massanutten Mountain. The western part of the county has supported 6 furnaces and the eastern part 2 furnaces. Paddy furnace was located on the Frederick county line. Two Van Buren furnaces were located a few miles southwest of Paddy. Columbia furnace, built 1810, was located west of Edinburg. Liberty furnace was located west of Columbia, 13 miles northwest of Edinburg. The Henrietta was located in the western corner of the county. The Caroline and Fort furnaces were in Massanutten Mountain. A part of the ores of the Henrietta furnace are reported to be carbonate. The mines of Caroline furnace are located on the north slope of the South Mountain, 2 miles west of Kennedy's peak. Columbia and Liberty furnaces drew their ores largely from the same banks, of which there were a number in the mountains within 5 miles of the furnaces. Liberty furnace has produced iron through a period of 80 years and is now producing 25 tons of hot blast charcoal iron per day.

Liberty mines.—The chief mines are located on the slopes of Devil's Hole Mountain. The limonite ore occurs in beds with thicknesses up to 15 feet which dip with the bedding of the nearly vertical Devonian shale and lie a few hundred feet stratigraphically above the Oriskany horizon. A narrow-gauge railway connects the mines and furnace with Edinburg. The composition of the ore as furnished by the operators, the Shenandoah Iron and Coal Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	41.10
Silica	16.32
Phosphorus	0.35
Manganese	3.40

West mine.—This mine of the Van Buren furnace furnished a sample for the Tenth Census report, which gave:

Dried at 212° F.

	Per cent.
Metallic iron	35.78
Phosphorus	0.07

Page County.

The principal surface rock in Page county is the Valley limestone with the Cambrian measures of the Blue Ridge on the southeast border and the Silurian measures of Massanutten Mountain on the northwest border. The ores occur in the Blue Ridge measures, in the Valley limestone, and in the Oriskany. Ores from each of these horizons were mined for charcoal furnaces. While the county has never been a large producer of ore, it has produced quite continuously for 150 years.

The Blue Ridge limonite has been worked chiefly in the southern corner of the county. This ore was mined for the Shenandoah Iron Works charcoal furnace and later for shipment and for the Gem, the present coke furnace at Shenandoah.

Beverley, Kimball, and Shenandoah Iron Works mines.—For the early furnaces ore was mined along the west base of the Blue Ridge a couple of miles east of the railway line from a number of banks of which the Beverley, Kimball, and Shenandoah Iron Works were the most important. Railways extended to the banks and connected with the furnace at Shenandoah.

Boyer mine.—In recent years the Boyer mine, located 1½ miles southeast from the Gem furnace, was much worked. The composition of this ore, taken from the books of the operators, the Alleghany Ore and Iron Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	41.35
Silica	21.95
Phosphorus	0.33
Manganese	0.60

Rileyville mine.—This mine is located 2.5 miles south from Rileyville at the west base of the Blue Ridge. It was operated about 1903 and the ore hauled in wagons to Rileyville. This ore differs from most of the Blue Ridge limonite in that it is associated with sandstone. The composition of the ore, as taken from the books of the Alleghany Ore and Iron Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	37.08
Silica	25.37
Phosphorus	1.82

The Blue Ridge limonite has been mined in a small way at a number of other places in the county.

Titaniferous magnetite is reported as occurring in the valley of Hawksbill creek above Marksville. The ore-body is said to be 6 feet wide and to lie in association with a feldspathic rock. This has been prospected, but it is not known whether it has been mined. The composition of the ore, as sampled by Frederick Prime, Jr., and analyzed by Booth, Garrett and Blair, is as follows:

	Per cent.
Iron	51.44
Titanic oxide	16.76
Phosphorus	0.97

The Valley limestone carries ore which has been mined. The Isabella furnace, which was built about 1760, 1 mile north of Luray, used this ore.

Heiston mine.—This mine is located 5 miles northeast from Luray and 5 miles southeast from Kennedy's peak. The ore is limonite in clay above the limestone. The mine is a pit 300 feet wide by 450 feet long. The ore was mined for the Isabella furnace, but has not been operated for 60 years.

Vaughn mine.—This mine is reported to be located at Vaughn station and to have produced in the 90s 20 tons of limestone limonite ore per day, which was shipped to Pennsylvania.

Catharine furnace, located on Cub run, in Massanutten Mountain, used Oriskany ore. Ore was shown on 3 leads and for several miles on each.

Pit Spring mine.—Since the furnace was blown out this ore was worked in the Pit Spring mine, a mile northwest from the furnace, on the north side of Middle Mountain. The composition of this ore, as taken from the books of the Alleghany Ore and Iron Company, is as follows:

Natural State.

	Per cent.
Metallic iron	40.14
Silica	21.58
Phosphorus	0.36
Manganese	1.06

Rockingham County.

Although this county extends across the Valley from the Blue Ridge to the West Virginia line, it has scarcely an Oriskany horizon. The Valley limestone has been faulted over on to the Carboniferous sediments, burying the Silurian and Devonian measures. Massanutten mountains have their southern end in this county and possibly the old Smith furnace drew its ore from the Oriskany measures of these mountains. The southeastern border of the county carries important ores of the Blue Ridge limonite type. These ores were mined for the Shenandoah furnace No. 2 in the southeastern corner of the county, and for the Mt. Vernon furnace in the southwestern corner.

Fox Mountain mine.—In the southeastern part of the county the chief mine was the Fox Mountain. This was worked for the Shenandoah Iron Works furnace and it was connected with the furnace by a railway. In the 80s this mine was producing 100 tons of ore per day. An analysis of this ore, as given in the Tenth Census report, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron................	41.71
Insoluble	25.48
Phosphorus	0.22

Augusta County.

This county has a geological situation similar to that of Rockingham. However, along the line of the great fault the thrust here was not so great and the limestone has not buried all of the Silurian measures. In the southwestern part of the county gentle folding has brought Oriskany measures to the surface through the Devonian shale. Along the line of the Chesapeake and Ohio Railway, Oriskany ore has been mined at several places.

Buffalo Gap mine.—At Buffalo Gap ore was mined for the local furnaces. An analysis of this ore as given in the Tenth Census is:

Dried at 212° F.

	Per cent.
Metallic iron................	41.95
Phosphorus	0.31

Ferrol mines.—At Ferrol ore was mined for the Ferrol furnace and after this furnace finally blew out the name was a pioneer in producing ore for shipment. An analysis of this ore as given in the Tenth Census is:

Dried at 212° F.

	Per cent.
Metallic iron................	46.76
Phosphorus	0.29

Southwest of Ferrol ore was mined for the Estelline furnace. In the western corner of the county the Oriskany horizon appears in Walker's Mountain and in Sideling hill.

The Valley limestone in this county in several places carries limonite ore in its clay. The first furnace west of the Blue Ridge, the Mossy Creek furnace, built in 1760, probably used these ores. This ore was mined at a number of other places for charcoal furnaces and for shipment.

Fisherville mine.—At Fisherville the ore was recently mined for shipment. It occurs here in the clay of the upper measures of the limestone near the flint horizon.

Spottswood mine.—Near Spottswood there is a similar occurrence of ore which was mined for charcoal furnace.

Lofton mine.—Near Lofton limonite occurs in the limestone clay of the lower limestone measures and was mined for shipment.

Of the Blue Ridge limonite, this county carries a number of deposits. The Mt. Vernon furnace, located in the southeastern part of the county, used this ore for half a century. The Cotopaxi furnace, located in the southern corner of the county, used these ores from a number of banks.

Black Rock mine.—Black Rock mine, located near Cotopaxi Railway siding, formerly operated for charcoal furnaces, has been worked in recent years both by open cut and underground with shaft and tunnels by the Vesuvius Mining Co. This ore sampled by McCreath gave as follows:

	Per cent.
Metallic iron	38.95
Insoluble	28.29
Phosphorus	0.10

Bare Bank mine.—This mine is located on the west slope of Bare Mountain and 3 miles southeast of Greenville station. It was formerly much operated for the Cotopaxi furnace and was opened in 1906 with a good showing of ore.

Crozier mine.—This mine, located 900 feet southwest of Bare bank, formerly operated for charcoal furnace, was prospected in 1906 with a good showing of ore.

Blue Bank mine.—This mine, located 4 miles southwest from the above mines on the end of Cellar Mountain, shows a series of old workings and the ruins of a small washer.

Mine Bank mine.—This mine, located 4 miles up the head waters of South river from Black Rock, was first worked for charcoal furnace and about 1890 was worked for about a year in several cuts. Ore was brought down the mountain by a series of 3 inclines to the washer. A branch railway connected with the Norfolk and Western Railway near Black Rock.

The ore is a manganiferous iron ore and is associated with the Cambrian sandstone. This ore sampled by McCreath gave as follows:

	Per cent.
Metallic iron	41.13
Insoluble	14.83
Phosphorus	0.26
Manganese	8.22

Rockbridge County.

This county has a geological situation similar to that of Rockingham and Augusta. However, the fault which was present on the western side of the limestone in the latter counties is not present here and ore-bearing Oriskany measures are brought to the surface in the first folds west of the limestone. These ores were mined for the California, Mount Hope, Panther Gap, and Bath Iron Works charcoal furnaces. In 1883 the Victoria (Goshen) furnace was built in this area at Goshen to use these ores. This furnace was claimed to be one of the largest in the United States at the time, producing 100 tons of pig metal per day.

Victoria mines.—Twelve miles of narrow-gauge railway brought ore from the Victoria mine on Bratton's run and from mines at Rockbridge Alum Springs. The Victoria mines were chiefly on the south slope of Brushy Mountain. They were a series of open cuts which extended for a couple of miles along the base of the mountain. The ore according to furnace returns was reported to carry 47 per cent. metallic iron.

This county has important Blue Ridge limonite ores. These were mined for the Vesuvius furnace near the Augusta county line, for the Buena Vista furnace at Buena Vista, and for the Glenwood furnace near Balcony Falls.

Buena Vista mines.—These mines were operated by the Jordans for the Buena Vista and Amherst furnaces for 40 years. During this time they were worked by open cut and by shafts and tunnels to a depth of 190 feet. In recent years these mines have been operated by the Buena Vista Iron Company. Mining is now largely carried on by steam shovel. The mines are now equipped with the most substantial and complete ore dressing establishment in the State and are producing several carloads of ore per day. Captain Jordan reports that furnace returns for 10 years showed the ore to yield 53 per cent. of metallic iron. The illustration on plate LXIV, figure 1, shows the present steam shovel operation.

Dixie mine.—The Coalshire (Coldshort) mine of the Vesuvius furnace

Fig. 1.—Buena Vista iron mine. Mining is by steam shovel.

Fig. 2.—Dixie iron mine, a fault deposit, shows operating of air-drill. Light-colored area to left of operators is ore. The track is on ore. Dark areas on both sides of the ore are the sandstone walls.

IRON MINES IN THE BLUE RIDGE REGION, VIRGINIA.

is now operated by the Alleghany Ore and Iron Company under the name of the Dixie mine. This mine is located near Vesuvius on the Augusta county line. It is a fault deposit of limonite ore in the Cambrian sandstone. (Figure 65.) It has been mined for a length of 1,200 feet along the strike of the fault and to a depth of 175 feet and to a width of from 4 to 25 feet. Two miles of tram road connect with the Dixie siding. The illustration on plate LXIV, figure 2, shows a view in this mine. The composition of the ore as furnished by the operators is as follows:

	Per cent.
Metallic iron................	48.50
Insoluble	14.46

Mary Creek mine.—This mine is located 2 miles southwest from Vesuvius on the west slope of the Blue Ridge. The ore is limonite and occurs in shale. This ore was worked for charcoal furnaces and more extensively since at a number of times for shipment.

Buck Hill mine.—This mine is located 3 miles west from the Mary Creek mine. It is limonite ore in clay above limestone. It produced 30,000 tons of ore between 1896 and 1898.

Midvale mine.—This mine is located south of Midvale on the crest of South Mountain. The ore was said to be limonite and to lie in a small syncline of sandstone. J. E. Lane mined 20,000 tons of ore here in 1895 and 1896.

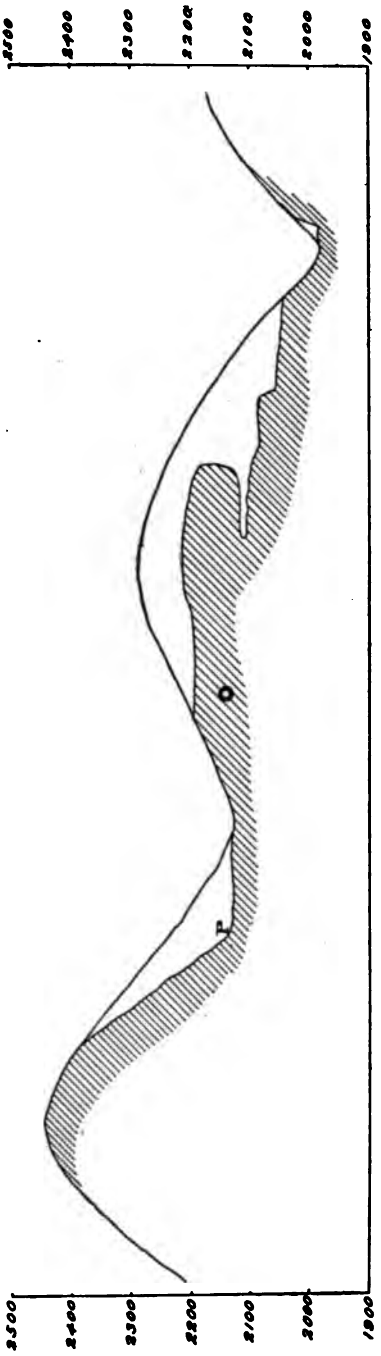

Fig. 65.—Profile of a part of the Blue Ridge along the Dixie mine. White area under profile line shows the amount of ore removed up to 1906. (P) is the point at which photograph was taken, Fig. 2, plate LXIV. (O) Tunnel.

Highland County.

This county lies west of the Valley tier of counties. Its surface is largely Devonian shale with anticlinal folds of the Silurian measures exposed. The county has only small streams and is without a railway. Whether there was ever any operation of iron ore in the county is not known. The county contains abundant outcrops of the Helderberg limestone, but it is not known whether this carries ore in commercial quantity. The Clinton horizon outcrops abundantly on the mountain slopes above the Helderberg limestone. Fossil ore is reported in the slopes west of Sounding Knob.

Bath County.

This county has a geological situation similar to that of Highland. It is traversed by 2 railways in the southern part but otherwise it is without transportation facilities and iron ore has not been developed. Like Highland county it has abundant outcrops of both the Helderberg and Clinton horizons. It is not known whether limonite ore occurs in commercial quantity, but ore is found on McClung's Ridge and on Jack Mountain. Fossil ore with a thickness of 2 feet is reported in the valley east of Warm Spring Mountain.

Alleghany County.

This county has a geological situation similar to that of Highland and Bath counties. It is crossed by the Chesapeake and Ohio Railway and by streams which, in the days before the railway, furnished an outlet for large quantities of charcoal pig iron. The county is largely covered with Devonian shale through which anticlinal mountains and ridges have brought the Oriskany measures to the surface. This county has the greatest number of large mines and is the largest producer of iron ore of any county in the State. The following figures of shipments from this county are taken from the reports of the American Iron and Steel Association.

Year	Iron ore *(long tons)*
1887	150,000
1888	156,126
1893	175,140
1894	142,808
1895	209,619
1901	212,690
1902	199,690
1903	196,126

In charcoal furnace days this county supplied the Dolly Ann, Lucy Salina, Australia, Clifton, and Rumsey furnaces. All of these furnaces except the Clifton were operated by the Jordans. To-day the county has 6 modern coke furnaces which are run largely on ores mined in the county. The Clifton furnace stands in the gap at Iron Gate. It used ores from the southeast side of Rich Patch Mountain near the furnace. These same banks have been operated somewhat since then. The Rumsey Iron Works furnace stood on Dunlaps creek near the present Mud tunnel on the Chesapeake and Ohio Railway.

Rumsey mine.—This mine is located 3 miles southwest from the furnace site at the head of Harmon branch on the southeast slope of Sweet Spring Mountain. It has been operated for a mile along the mountain in various places. A broad-gauge railway connected with the furnace at Covington.

The Dolly Ann furnace was located 3 miles east of Covington between Peters Ridge and Fore Mountain, using ores mined near at hand.

Dolly Ann mine.—This mine has been extensively worked for the last 20 years on the slopes of these two mountains and in the valley between them for a mile or more along the mountains. A broad-gauge railway connects with the furnace at Covington. This is one of the large mines of the district. It produced in 1897, 71,124 long tons of iron ore. The composition of the ore as furnished by the operators, the Low Moor Iron Company, is as follows:

	Per cent.
Metallic iron	44.32
Insoluble	24.15

Iron Mountain mine.—This mine lies in the same valley and extends northeastward for several miles. The ore has been mined chiefly on Fore Mountain on the outcrop of the deposit.

Lucy Salina and Australia furnaces were located on Simpsons creek between Brushy Mountain and North Mountain. They drew their ores from the southeast slope of Brushy Mountain. These mines, now known as the Longdale, have the greatest total production of any mines in the State. The Jordans worked them for 40 years for the charcoal furnaces, and since 1869 they have given the Longdale Iron Company 1,500,000 long tons of ore, producing, in 1889, 80,452 tons. The mines have been worked for a mile along the mountain and on the slope, chiefly underground, for 500 feet. Eleven miles of narrow-gauge railway connect the mines and furnaces with the Chesapeake and Ohio Railway at Longdale station. The composition of the ores as furnished by the operators is as follows:

	Per cent.
Metallic iron	48.20
Insoluble	13.83
Phosphorus	0.42

Fancy Hill mine.—This mine is located north of the Longdale furnaces on the south slope of Mill Mountain. It has been operated in recent years. A narrow-gauge railway connects with the furnaces.

A number of large mines have been developed since charcoal furnace days. These are the *Stack, Low Moor, Rich Patch,* and *Fenwick.*

Stack mine.—This mine is located on the northwest slope of Sweet Spring Mountain 5 miles southwest of Mud tunnel on the Chesapeake and Ohio Railway. This mine was one of the first to be opened for shipment and has been producing for 25 years. It is mined for a half mile along the mountain by open cut, and by underground work for several hundred feet on the slope. A narrow-gauge railway connects with the Chesapeake and Ohio Railway at Backbone. The composition of the ore as furnished by the operators, the Low Moor Iron Company, is as follows:

	Per cent.
Metallic iron	45.67
Insoluble	19.72

Low Moor mine.—This mine is located 2 miles south of Low Moor between Rich Patch and Horse mountains. It was opened about 1878 and has produced steadily until the last few years with a total production of about 1,000,000 tons. Ore was mined on several folds of the formation, located on the lower slopes of the 2 mountains and in the valley between them. A broad-gauge railway connects with the furnace at Low Moor. The composition of the ore as furnished by the operators, the Low Moor Iron Company, is as follows:

	Per cent.
Metallic iron	46.52
Insoluble	17.60

Rich Patch mine.—This mine is located southwest from the Low Moor mine in the same valley. This is one of the more recent mines, being first opened about 1895. It is one of the largest producers in the State, yielding 90,000 tons in 1902. Ore is mined chiefly on one syncline on both sides of the valley. Mining is mostly underground but there is some steam shovel work done. A broad-gauge railway connects with the Chesapeake and Ohio Railway at Low Moor. The composition of a sample of the ore taken from 29 carloads at the Goshen furnace stock pile as furnished by the operators, the Goshen Iron Company, is as follows:

	Per cent.
Metallic iron	42.90
Silica	25.60
Phosphorus	0.33
Manganese	0.78

Potts Valley mine.—This was a small mine, located west of Covington and operated for a few years recently. The composition of the ore as furnished by the operators, the Alleghany Ore and Iron Company, is as follows:

	Per cent.
Metallic iron	41.10
Insoluble	24.41
Manganese	0.69
Phosphorus	0.43

Potts valley lies southwest from Covington between Potts Mountain on the south and Peters and Warm Spring mountains on the north. This valley was known to contain ore many years ago but it had no railway till 1906, when a line was built by the Chesapeake and Ohio Railway. Extensive developments have recently been made by the Low Moor Iron Company at various places in the valley. The valley carries a number of folds of the Oriskany measures and some of these are ore-bearing. The chief developments are at *Bess* and *Double Ridge* mines.

Bess mine.—This mine is on Chisley's Run, 2 miles south from its mouth. This is on one of the valley folds and has a good showing for a large mine.

Double Ridge mine.—This mine is located a couple of miles southwest from the Bess mine on the north slope of Potts Mountain.

Given mine.—Other prospects are the Given bank at the southwest end of Mill Ridge, the Robinson and Bennett on the south slope of Warm Spring Mountain.

Fossil hematite ore has been mined in two places in the county, namely, at Iron Gate and on Horse Mountain.

Iron Gate fossil ore mine.—This mine is located on the northeast side of the Jackson river at Iron Gate. It was operated several years in the early 80s. Ore has been mined in the face of the gap on the slopes and crest of the fold and on the strike of the formation away from the river for some 900 feet. The bed is said to be somewhat under 2 feet in thickness. A view of this mine is shown in plate LXVII, figure 1. The composition of the ore taken from Bulletin No. 285 of the U. S. Geological Survey as furnished by the Longdale Iron Company is as follows:

	Per cent.
Metallic iron	46.50
Insoluble	19.90
Phosphorus	0.49

Horse Mountain mine.—This mine is located on the southeast slope of Horse Mountain, well up on the mountain, and just north of the Low Moor

Oriskany mine. This was opened in 1905 and is now producing 1,200 or more tons per month. The bed has a thickness of about 2 feet. The composition of the ore, as furnished by the operators, the Low Moor Iron Company, is as follows:

	Per cent.
Metallic iron	44.82
Silica	15.51

Botetourt County.

This county has abundant outcrops of the Oriskany horizon, chiefly in its northwestern half. These have furnished ore for charcoal furnaces for a century and have since produced the greatest mine in the State. The Etna and Retreat furnaces were located on the east side of Purgatory Mountain and used ores from this mountain. Since these furnaces went out of blast the ores have been mined in small amount for shipment. The Salisbury furnace, located on Catawba creek near its junction with the James river, used Purgatory Mountain ores. Catawba furnace was located on Catawba creek, 11 miles west of Fincastle. Jane and Rebecca furnaces were located near Dagger's Springs and used ores from Sand Bank Mountain.

Sand Bank mines.—These mines were recently worked by the Princess Iron Company. An incline and broad-gauge railway connected the mines with the Chesapeake and Ohio Railway at Gala.

The southeast slope of Rich Patch Mountain has been mined at intervals along the border of the county. The ore occupies the position of the upper member of the Helderberg limestone and has local thicknesses of 40 feet. The ore has been mined several hundred feet on the dip and it is known to extend in places 700 feet.

Callie mine.—The Callie furnace and mines are located on the south slope of this mountain near the Alleghany county line. Formerly a narrow-gauge railway connected with Clifton Forge. This mine was re-opened by the Princess Furnace Company in 1907. An analysis of the ore, as given in the Tenth Census report, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	46.17
Phosphorus	0.07

Wilton mine.—This mine joins the Callie on the southwest. It is now operated by the Princess Furnace Company and supplies ore to the Princess furnace. A narrow-gauge railway connects the mines with the furnace at Glen Wilton.

Fig. 1.—Adams Peak, looking southwest. The white line marks the position of outcrop of iron ore in the bench of shale on the northwest side of the mountain.

Fig. 2.—The Grubb iron mines washer. The mines are located on the mountain behind the stream from the washer.

IRON ORE OUTCROPS AND WASHER, BLUE RIDGE REGION, VIRGINIA.

Circle mine.—This mine joins the Wilton on the southwest. This was opened in 1906 by the Longdale Iron Company.

Roaring Run mine.—The Roaring Run furnace and mines were located 7 miles southwest of Roaring Run, northeast of the Oriskany mine.

Grace mine.—The Grace charcoal furnace and mines are located 7 miles southwest of Roaring Run, northeast of the Oriskany mine.

Oriskany mine.—This mine is located 4 miles west from Oriskany station and 11 miles directly south from Covington, partly in Botetourt county and partly in Craig. This is the greatest iron mine in the State. It has produced 1,000,000 tons of ore and is now producing at the rate of 400 tons per day. A narrow-gauge railway connects with the Chesapeake and Ohio Railway at Oriskany. This mine furnishes most of the ore for the company's 3 furnaces which are located at Iron Gate, at Buena Vista, and at Shenandoah. An illustration of this mine is shown in plate LXVII, figure 2. The composition of the ore as furnished by the operators, the Alleghany Ore and Iron Company, is as follows:

	Per cent.
Metallic iron	45.88
Insoluble	16.29
Phosphorus	0.12
Manganese	2.18

In the foothills of the Ritch Patch Mountain below the Oriskany mine some mining has been done.

Ried mine.—An operation is now carried on here by the Alleghany Ore and Iron Company under the name of the Ried mine. The composition of the ore, as furnished by the operators, is as follows:

	Per cent.
Metallic iron	40.37
Insoluble	21.81
Phosphorus	0.43
Manganese	0.69

Big Hill mine.—This mine is located 3 miles south of Glen Wilton and operated by the Longdale Iron Company. Big Hill is a small anticlinal which brings Oriskany measures to the surface through the Devonian shale.

Of the Blue Ridge ores, this county has important deposits both of limonite and of red hematite. The two Cloverdale furnaces and the Arcadia furnace probably used this limonite. Ore has since been mined along both the northwest and the southeast base of the Blue Ridge.

Grubb or Lynchburg mine.—This mine is located 2 miles northwest of Blue Ridge Springs and 11 miles northeast of Roanoke on the southeast slope of the Blue Ridge. The ore body, located in shale near the contact with the Valley limestone, is about 40 feet thick and dips with the bedding toward the mountain. This is one of the largest of the Blue Ridge limonite mines and has been operated for 25 years. It is mined by open cut and underground to a vertical depth of 180 feet. A branch of the Norfolk and Western Railway extends from Blue Ridge Springs to the mines. Plate LXV, figure 2, is an illustration of the Grubb washer and mines. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	41.20
Silica	14.08
Phosphorus	1.23
Manganese	1.13

Crozier mine.—This mine is located a mile east of the Grubb mine and similarly situated except that it is at the foot of the mountain in relatively flat country instead of being on the slope of the mountain.

Houston mine.—This mine is located 2 miles northwest from the Grubb, on the opposite side of the Blue Ridge. In the 80s the mine was operated in a series of openings and produced considerable ore. A railway connected with the Norfolk and Western Railway at Houston. A number of other similar mines have been operated in this vicinity on both sides of the Blue Ridge.

Blue Ridge hematite, known as specular ore, occurs in the southeastern part of the county near the crest of the Blue Ridge. In the vicinity of the Grubb mine this type of ore has been mined at intervals for a distance of 4 miles along the southeast slope of the mountain. Of this distance about 2 miles are in Bedford county. The ore is from 3 to 6 feet thick in much folded beds which have in general a steep dip. The largest operation is the Edith mine.

Edith mine.—This mine is located ½ mile northeastward from the Grubb mine, well up on the side of the Blue Ridge, 500 feet above the bottom of the Grubb mine. An incline and a narrow-gauge railway connects with the Grubb mine. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	37.09
Silica	36.91
Phosphorus	0.37
Manganese	0.27

Fig. 1.—Wood iron mine. Faulting or folding has duplicated the outcrop.

Fig. 2.—Arcadia iron mine.

IRON (HEMATITE) MINES, BLUE RIDGE REGION, VIRGINIA.

Grubb Specular mine.—This mine is located immediately southwest of the Edith mine and is similarly situated. Operated by the Virginia Iron, Coal and Coke Company.

Lemon mine.—This mine is located a mile southwest of the Edith. Operated by R. P. St. Clair. Ore is hauled in wagons to the Grubb tipple.

Near Buchanan the hematite ore has been mined for several miles along the northwest side of the Blue Ridge. The bed here is from 4 to 6 feet thick and dips at high angles northwest. It has been faulted or folded so as to present several outcrops.

Arcadia mine.—The chief mine is the Arcadia, operated by the Pulaski Iron Company. This mine is located 4 miles south of Buchanan, well up on the Blue Ridge, 1,000 feet above the Valley. Ore is taken down the side of the mountain on aerial tramway and over a mile of narrow-gauge railway to a branch of the Norfolk and Western Railway. An illustration of one of the openings is given on plate LXVI, figure 2.

A sample of the ore taken and analyzed by the writer gave as follows:

	Per cent.
Silica	41.14
Metallic iron	33.34

Wood mine.—This mine is located immediately west of the Arcadia. It is now operated by G. G. Harvey, and ore is delivered in wagons to the Arcadia narrow-gauge railway. An illustration of this mine, showing the workings on two outcrops of the ore, is given on plate LXVI, figure 1. These workings are reported to intersect at the upper end. An analysis of this ore, as given in the Tenth Census report, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	42.89
Phosphorus	0.41

Craig County.

This county has several parallel ranges of great mountains of which Sinking Creek Mountain, Bald Mountain, Potts Mountain, and presumably Johns Mountain carry Oriskany measures. In early days there was a charcoal furnace and a forge on Craig's creek, 1.5 miles above New Castle, which used these ores. Except in the eastern end of the county there is no railway, and elsewhere it is not known what the horizon carries in the way of ore.

Oriskany mine.—The larger portion of the big cut of the main Oriskany mine lies in Craig county. The mine is described under Botetourt county.

Fenwick mine.—This mine is located on the southeast slope of Bald Mountain, which is a spur of Rich Patch Mountain, near the Botetourt county line, and joins the Oriskany mine on the northeast. Opened in 1900, this mine produces 4,000 to 7,500 tons of ore per month, producing 55,973 tons in 1904. It has been operated for several miles along the mountain by steam shovel and underground work. An analysis of the ore, as furnished by the operators, the Low Moor Iron Company, is as follows:

	Per cent.
Metallic iron	44.60
Silica	22.30

Roanoke County.

The northern part of this county is covered with mountains of Carboniferous sediments. Of the Blue Ridge limonite the county has one large mine, the Rorer, and a number of smaller ones.

Rorer mine.—This mine is located 3 miles south of Roanoke, on the west side of a small mountain. It was opened for shipment about 1880 and has had a constant production ever since. The mining is now largely done by steam shovel. The composition of the ores, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	38.68
Silica	20.91
Phosphorus	1.14
Manganese	1.20

Southwest of Rorer, on the strike of the formation, ore has been mined for a mile or more. Although there is no topographic feature along this line, all of the ores are apparently similarly situated stratigraphically.

Griffin mine.—Of these mines the Griffin, a small mine, was operated in 1903 by the West End Furnace Company.

Gale mine.—This mine is located a mile southwest of Rorer. This is one of the largest of these mines. It is not now operated.

Castle Rock mine.—This mine is located 6 miles southwest of Roanoke and 2 miles northwest of Cave Spring in a rather flat area near Sugar Loaf hill. This was operated about 1895. A railway formerly connected with the Roanoke Southern Railway.

Fig. 1.—Iron Gate gap of the Jackson river through Rich Patch Mountain. Fossil iron ore was mined from the far side of the gap above the lower sandstone. The white ridges are Clinton and Medina sandstone. Oriskany ore was mined on the far slope of the mountain.

Fig. 2.—Oriskany iron mine. Mining is by steam shovel.

IRON GATE GAP AND ORISKANY IRON MINE, ALLEGHANY COUNTY, VIRGINIA.

Starkey mine.—This mine is located 4 miles southwest of Roanoke and ¾ of a mile from Starkey. It was operated in a small way by the Pulaski Iron Company about 1902. The ore was hauled in wagons to Starkey.

Griffin specular mine.—This mine is located 6 miles southwest of Roanoke on the north slope of Buck Mountain. Ore has been mined but not shipped. This is the Blue Ridge bedded red hematite and has a thickness of 2 feet. This location is of interest, as it is the most southwesterly known working of this type of ore. A sample taken from the ore, which was piled at the mouth of the mine and analyzed by the writer, gave as follows:

	Per cent.
Metallic iron	40.97
Silica	31.16

Montgomery County.

This county carries ore at its north border in the Oriskany horizon near the crest of Gap Mountain which was mined for the Sinking Creek furnace. It also carries a little ore near the contact with the Valley limestone and the underlying shales near the south border of the county. This is reported to have been mined south of Christiansburg.

Giles County.

This county has had iron ore mined at 3 different points, namely, near Newport in the southeast corner of the county, near Ripplemead on the New river, and near Interior on Stony creek. Near Newport the Sinking creek furnace built in 1873 operated on local ores. Ores were mined above the limestone on the south side of Spruce Run Mountain and at other places about Newport.

Johnson mine.—This mine is located ⅓ mile above Big Stony Junction and on the east side of the New river. The ore is magnetite and occurs in the Valley limestone. It appears to have been mined chiefly below the surface of the New river. It was mined in a small way sometime in the 80s and ore shipped to Pennsylvania. The ore is of Bessemer grade. The composition, as given by McCreath, is as follows:

	Per cent.
Metallic iron	63.55
Silica	5.21
Phosphorus	0.05
Sulphur	0.002

Porterfield mine.—This mine is located 3 miles southwest from the Johnson mine on the strike of the strata. Ores have been mined in several places in a small way from the clay above the Valley limestone. It was worked for a few months in 1906 and ore hauled in wagons to Ripplemead. The composition of the ore, as reported by McCreath, under the name of *Pack Tunnel* mine, is as follows:

	Per cent.
Metallic iron................	48.82
Siliceous matter.............	19.76
Phosphorus	0.05
Sulphur	0.16

Interior mines.—The south side of Peters and East River mountains carry Oriskany measures with some ore. This valley is the southwestward continuation of the Potts creek valley. It has recently been prospected for iron ore and surveyed for a railway. Ore has been mined at the Interior mine, located ½ mile northwest of Interior on the south slope of Peters Mountain. The ore was taken down the mountain on an incline to a washer located on the Big Stony Railway. Some ore was hauled to Interior in wagons from the north slope of the opposite Fork Mountain.

Pulaski County.

This is a Valley county. The Oriskany horizon occurs on the northwest border of the county near the crest of Walker Mountain and in the western part in Draper Mountain. This latter occurrence carries a number of producing mines. The southern part of the county has limestone limonite ores of a part of the New River-Cripple Creek area. This county did not produce much for charcoal furnaces and its production was in comparatively recent times. It has two charcoal furnaces in the southern part, and has had a bloomery forge. The Radford furnace, located 8 miles southeast of Pulaski City, was built in 1868, while Boom furnace, in the southern corner of the county, operated from 1882 to 1906. This is the last one of the Virginia cold blast, water-power charcoal furnaces. Pulaski City, standing at the gateway of the New River-Cripple Creek area, has two active modern coke furnaces and is the main center of iron smelting in the district. Some of the best mines of the district are in this county and are now operated.

Clark's bank.—This mine is located a mile north of Allisonia. The ore is limonite. This mine has been operated several times for iron ore and, in 1902 and 1903, for zinc, producing 8,000 tons of that ore from the same opening that was mined for iron. A narrow-gauge railway connected with the Norfolk and Western Railway at Dalton, 1 mile north. The mine is not now operated and the track has been removed. The composition of the ore, as furnished by the New River Mineral Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	52.50
Silica	5.59
Phosphorus	0.15
Manganese	0.46

Radford Furnace mine.—This mine is located on Mack's creek, 2 miles southwest of the New river railway bridge. The ore is "mountain" ore. The mine was operated years ago in a small way for Radford furnace.

Tasker mine.—This mine is located about 1 mile east of New river railway bridge and 2 miles northeast of Allisonia. This mine produced 9,000 tons of "mountain" ore in 1898-90, and in 1907 is operated by the West End Furnace Company, producing 100 tons per day. The composition of the ore, as furnished by the operators, is as follows:

	Per cent.
Metallic iron	47.80
Silica	13.40
Phosphorus	0.14
Manganese	0.44

Farris mine.—This mine is located about 3 miles southeast of Boom furnace on the northwest slope of Mack's Mountain, on the contact of limestone and sandstone. The ore is mostly "mountain" ore in thin seams in the clay. This was one of the best producing mines in the district. It was opened in 1904 and is said to have produced 30,000 tons of ore in that year. A narrow-gauge railway connects with the Norfolk and Western Railway at Allisonia. The composition of the ores, as furnished by the operators, the Pulaski Iron Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	39.59
Manganese	0.48
Phosphorus	0.39

Rich Hill mine.—This mine occupies the point of the ridge which lies between New river and Little Reed Island creek. The ore is limonite. It has produced more ore than any other mine in the district. Opened for modern mining about 1886, it has produced 600,000 tons of iron ore since that time. The washers are located at the foot of the ridge on the north side and deliver to railway cars. A view of this mine is shown on plate LXIX, figure 2. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	43.81
Silica	14.65
Phosphorus	0.18
Manganese	0.66

Reed Island mines.—These are a series of mines located on the same ridge with the Rich Hill mine, which together with this mine extend for $1\frac{1}{2}$ miles, occupying the larger portion of the limestone ridge, which rises 200 feet above New river and Little Reed Island creek. The ore is limonite and occurs distributed through a considerable thickness of clay. These mines have supplied Boom furnace and have also furnished considerable quantities of ore for shipment. The washers are located on the south side of the ridge on Little Reed Island creek and deliver to railway cars. A view of this mine is shown on plate LXVIII, figure 2. The composition of the ores, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	42.42
Silica	18.92
Phosphorus	0.17
Manganese	0.37

Under Rock mine.—This mine is located a mile southwest of Boom furnace on the west bluff of Little Reed Island creek. The ore is limonite. The mine has not been operated for several years.

Draper Mountain lies in Pulaski and Wythe counties, just beyond the northeast corner of the New River-Cripple Creek area. The mountain is an anticline which has been faulted on the northern and southern sides and whose crest, and most of the northern limb, have been removed by erosion. The strata involved in the folding are great thicknesses of Ordovician, Silurian, Devonian, and Carboniferous sediments. The Ordovician shales appear in the eroded crest of the anticline, the Draper valley. The Silurian rocks, chiefly sandstones, form the elongated crescentic crest of the mountain. The Oriskany horizon appears in normal position on the north side and on the ends of the mountain. South of Pulaski it is brought to the surface through the Devonian shales by a

Fig. 1.—Locust Hill iron mine.

Fig. 2.—Reed Island iron mine.

MINING BY BILLING, NEW RIVER-CRIPPLE CREEK IRON AREA, VIRGINIA.

fault. The Devonian and Carboniferous shales appear chiefly on the north slope of the mountain. Oriskany ores appear in the vicinity of the Oriskany horizon and other limonite ores occur at the contact of the shales and limestones. In Pulaski county this mountain carries a number of mines, chiefly Oriskany.

Clayton mine.—This mine is located 1 mile south of Pulaski on the north slope of Draper Mountain. The ore occupies the position of the Helderberg limestone which a fault has here brought to the surface. The mine was opened for shipment in 1905. A narrow-gauge railway delivers crude ore to the washer at the foot of the mountain and washed ore to Pulaski. The composition of the ore, as furnished by the operators, the Pulaski Iron Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron................	41.12
Manganese	0.51

Peak Knob mines.—The Peak Knob mines are a series of openings about Peak Knob, the east end of Draper Mountain. The horizon of the Clayton mine is traceable eastward 2 miles and about the base of Peak Knob and around to the south side of the mountain. Lump ore has been mined on three sides of the Knob. Ore is now mined on the north side by Hagar and Mahady and hauled in wagons to Pulaski, and mined on the east end of the mountain by Hatcher and Shaffer and hauled ½ mile to a railway siding. The composition of the ore as mined in 1898, as furnished by the New River Mineral Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron................	53.46
Silica	4.58
Phosphorus	1.22
Manganese	0.40

Wythe County.

Wythe county is a Valley county. It has the greatest development of limestone limonite ores of any county in the State and includes within its boundaries the greater portion of the New River-Cripple Creek area. It has the Oriskany horizon on the northwest border near the crest of Walker Mountain and in small amount in Cove Mountain and has this horizon-producing ore in Draper Mountain in the northeastern part of the county. This county has produced iron from the soft limestone limonite ores for over a century and has had a total of more than a dozen charcoal furnaces. The pioneer furnaces of the county, built at the beginning of the last century, were the Cedar Run, Speedwell, and Poplar Camp. Of these the Cedar Run (Parry Mount) furnace with three successive stacks was operated by the Grahams from 1800 till the coming of coke furnaces. A number of charcoal furnaces were built in this county in the early 80s. Two coke furnaces are now operated, one at Max Meadows and the other at Ivanhoe.

Barren Springs mine.—This mine is located 3 miles west of Boom furnace on the south bank of New river. It occupies the upper portion of a knoll, which rises some 200 feet above New river, and consists of a series of operations over a large acreage in a rather shallow limestone clay. A narrow-gauge railway connects the operations with the washer which is located beside the Norfolk and Western Railway. This ore was mined for the Barren Springs furnace in 1854. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	44.27
Silica	12.50
Phosphorus	0.14
Manganese	0.47

Bertha mine.—This mine is located 1 mile south of the Barren Springs mine. However, the workings of the two mines connect and together they occupy an area 2 miles long. Prior to 1898 this was operated by the Bertha Mineral Company for zinc and the mine was the greatest producer of soft zinc ores in the State. Since that time it has been worked in the same pits by the Pulaski Iron Company for iron ore. The ore is limonite. It is washed at Bertha station, 1 mile west. The composition, as furnished by the operators, is as follows:

Natural State.

	Per cent.
Metallic iron	44.98
Manganese	0.53

From Carter's station, which is located 2 miles up New river from Barren Springs, there extends southwestward a strip of ore territory which is 6 miles long by ½ mile wide. This was first worked for the Cedar Run furnace in 1800 and quite continuously ever since, and in the last decade, extensively. It has been worked on most of the hills in the area. The Carter bank at the northeast end is not now worked nor is the Walton mine at the southwest end. A narrow-gauge railway extends lengthwise through the area and to Foster Falls and at the northeast end delivers to a wire tramway which crosses New river. The Red Hill or Cedar Run and the Sanders mines are now operated by the Virginia Iron, Coal and Coke Company. The ore is all limonite in clay above limestone.

Carter bank.—This mine is the most easterly of these operations. It consists of a long, narrow, deep cut in clay between limestone. It is not now operated. An analysis of this ore, as given in the Tenth Census report, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	55.90
Phosphorus	0.12

Cedar Run mine.—This mine consists of a series of operations scattered over several miles of territory west of the Carter bank. It is now operated chiefly by steam shovel.

Sanders mine.—This mine is located west of the Cedar Run mine and consists mainly of one large operation which is carried on by the steam shovel and the hydraulic methods.

Walton mine.—This mine is located a mile or two west of the Sanders mine and consists of a number of pits. It was formerly mined for the Walton furnace, which was located near the mine. The composition of the ores of these mines, as furnished by the operators, is as follows:

Natural State.

	Sanders Per cent.	Cedar Run Per cent.	Walton Per cent.
Metallic iron	46.03	41.17	41.90
Silica	10.90	19.31	13.80
Phosphorus	0.15	0.22	0.13
Manganese	1.09	0.97	1.03

Morris mine.—This mine is located just south of the Bertha mine on the north slope of Roaring Falls Mountain. It produces "mountain" ore, which is the most massive of any in the district. It is a small mine and but recently opened. Lump ore only is mined and hauled in wagons to Barren Springs. The composition of this ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	40.38
Silica	20.11
Phosphorus	0.55
Manganese	0.47

Hurst mine.—This mine is located about a mile south of Little Reed Island creek near the Pulaski county line on the contact of the limestone and the sandstone. The ore is semi-limonite. Mining is by the sluice trough method with water pumped from the creek. The ore is sluiced down the hill to the washer near the railway. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	40.67
Silica	18.09
Phosphorus	0.53
Manganese	1.24

Patterson mine.—This mine is located immediately south of the Hurst mine, but has been operated below the contact of sandstone and limestone in various openings for ¾ of a mile southward. The washers deliver to the railway. The ore is limonite. The mine was abandoned in 1906. The composition of the ore, as furnished by the operators, the Pulaski Iron Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	49.86
Manganese	0.30

Crawford mine.—This mine is located 2 miles southwest of the Patterson mine and 3 miles east of Foster Falls station, near the contact of the limestone and sandstone, but over the limestone. The ore is semi-limonite. The mine has been operating steadily for years. The washers are on the railway. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

	Per cent.
Metallic iron	35.61
Silica	28.50
Phosphorus	0.069
Manganese	0.30

Tipton mine.—This mine is located about 3 miles southeast of Foster Falls station. It is a contact mine but chiefly above the shale and sandstone and produces "mountain" ore. This was one of the first mines

Fig. 1.—Hematite mine.

Fig. 2.—Rich Hill iron mine. Top of a limestone "horse" is exposed near the operator.

HYDRAULIC MINING IN NEW RIVER-CRIPPLE CREEK IRON AREA, VIRGINIA.

opened for modern mining and is second in point of production in the district, having produced nearly 500,000 tons of ore. The washer near the mine delivers to the railway. The composition of the ore, as furnished by the operators, the Pulaski Iron Company, is as follows:

Dried at 212° F.

	Per cent.
Metallic iron	43.60
Phosphorus	0.74
Manganese	1.56

Foster Falls mines.—On the south slope of Roaring Falls Mountain near the contact of the limestone and the sandstone, for a distance of 3 miles east of Foster Falls there is a series of mines which are grouped under the above head. Some of the mines are above the limestone while others are above the shale. The ores are therefore limonite and "mountain" ore. The "mountain" ores are characterized by high manganese content. The mines were first worked for Poplar Camp furnace a century ago and extensively in recent times. A narrow-gauge railway extends from Crawford mine through Foster Falls mine to Foster Falls. The composition of these ores, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	35.96
Silica	17.10
Phosphorus	0.25
Manganese	4.52

On the west side of the river at Foster Falls, contact mines have been worked for a mile or more by the Virginia Iron, Coal and Coke Company. The ore is semi-limonite. The mines are connected with Foster Falls by narrow-gauge railway and include the *Hematite* and *Posey.*

Hematite mine.—This mine lies just west of Foster Falls. It is an old mine now operated in a small way by hydraulicing. A view of this mine is shown on plate LXIX, figure 1. The composition of the ore, as furnished by the operators, is as follows:

Natural State.

	Per cent.
Metallic iron	42.90
Silica	19.17
Phosphorus	0.09
Manganese	0.67

Posey mine.—This mine lies west of Hematite. It was operated about 5 years by hydraulicing and sluicing, and abandoned in 1905. A new operation was opened west of Posey. The composition of the Posey ore, as furnished by the operators, is as follows:

Natural State.

	Per cent.
Metallic iron	45.04
Silica	19.36
Phosphorus	0.11
Manganese	0.36

Poplar Camp mine.—This mine is located 1.5 miles southeast of Jackson's Ferry. This is a fault deposit lying between the limestone and the sandstone. The mine had been operated for lump ore only up to 1906, when it was opened by the Pulaski Iron Company on a larger scale and ore hauled in wagons to the railway at Jackson's Ferry. A sample taken and analyzed by the writer gave:

	Per cent.
Metallic iron	40.77
Insoluble	13.92
Phosphorus	1.19
Manganese	6.80

Southwestward from Poplar Camp mine along the north foot of Poplar Camp Mountain in a distance of 3.5 miles there is a series of small mines nearly identical in situation with the Popular Camp mine. This line seems to be a fault line where the sandstone has been thrust on top of the limestone and the ores are lying in the mouth of the fault and are characterized by high phosphorus and high manganese.

Indian Camp mines.—These mines are a series of pits along a mile of this line. They were first operated about 1894 and at one time had narrow-gauge railway connection with the Norfolk and Western Railway at Austinville. Average analyses from 4 banks, furnished by the New River Mineral Company, show as follows:

	Per cent.
Metallic iron	47.91
Silica	9.69
Phosphorus	1.98
Manganese	1.23

William Jackson mine.—Southwest of the Indian Camp mine William Jackson, about 1898, mined some 6,000 tons of ore, which gave the New River Mineral Company the following results on analysis:

	Per cent.
Metallic iron	49.89
Silica	11.40
Phosphorus	1.22
Manganese	0.85

Gregory mine.—Southwest from the William Jackson mine, since 1893, the New River Mineral Company has mined some 20,000 tons, which gave the following results:

Natural State.

	Per cent.
Metallic iron	35.63
Silica	20.21
Phosphorus	0.72
Manganese	0.60

In the vicinity of Ivanhoe there has been considerable mining chiefly for the Ivanhoe furnace, which was built as a charcoal furnace in 1882. The ores are all limonite of relatively high grade and occur usually well concentrated in clay through a shallow depth.

Ivanhoe mine.—Southwest from Ivanhoe for 1.5 miles the crest and slopes of a ridge have been mined extensively. The most of this is now owned and operated by the Ivanhoe Furnace Company. The following composition of the ores has been furnished by the New River Mineral Company (column I), and by the Ivanhoe Furnace Company (column II).

Natural State.

	I.	II.
	Per cent.	Per cent.
Metallic iron	43.92	42.00—44.00
Silica	16.83	14.00—18.00
Phosphorus	0.14	0.15
Manganese	0.73	0.40— 1.00

Painter mine.—The north slope of this ridge and a mine north of Painter creek were operated by the Lobdell Carwheel Company.

Simmerman mines.—These mines are located a mile east of Ivanhoe. They were operated intermittently between 1890 and 1896. They consist of 5 small pits.

Sisk and Gray mines.—These mines are located 1 mile southeast of Ivanhoe on top of the precipitous bank of New river. Between 1891 and 1895 the New River Mineral Company took some 25,000 tons of ore from these mines. The following composition has been furnished by the operator:

Natural State.

	Per cent.
Metallic iron	44.36
Silica	14.79
Phosphorus	0.11
Manganese	0.39

There has been a number of other small operations in the vicinity of Ivanhoe.

Wythe Lead and Zinc mines.—These mines, located 2 miles east of Ivanhoe, have produced a little iron ore in connection with the lead and zinc mining and now produce some ore which is the tailings from the magnetic concentrator.

Eight miles west of Ivanhoe in the vicinity of the present town of Cripple Creek there has been considerable charcoal furnace activity. Within a distance of 4 miles of each other there have been 5 charcoal furnaces. Present operations are at the head of Francis Mill creek 2 miles south of Cripple creek. The mines are in the vicinity of the contact of the limestone and the sandstone. In a kettle-shaped depression between Hussey and Iron mountains, which carries limestone in the bottom, are located the *Little Wythe* and the *Norma* mines.

Little Wythe mine.—This mine occupies the bottom of the depression. A narrow-gauge railway connects with the Norfolk and Western Railway near Cripple Creek. The composition of this ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	42.75
Silica	13.77
Phosphorus	0.25
Manganese	0.32

Norma mine.—This mine is located immediately south of the Little Wythe. It was opened in 1905. The composition of the ore, as furnished by the operators, the Pulaski Iron Company, is as follows:

Natural State.

	Per cent.
Metallic iron	42.65
Phosphorus	0.12

Porter mine.—This mine is a contact mine on the north side of Hussey Mountain.

There were two charcoal furnaces formerly operated near Speedwell, which used the 'limonite' ores. The extension of the Norfolk and Western Railway to that point in 1906 has opened the region to shipment. The Virginia Iron, Coal and Coke Company now operates 3 mines in this vicinity.

Ganaway mine.—This mine is located ½ mile southeast of Speedwell. It is equipped with an 8-log washer and is producing 100 tons of ore per day.

Percival mine.—This mine is located 1½ miles southwest from Speedwell. It is equipped with an 8-log washer and is producing 100 tons of ore per day.

Andis mine.—This mine is located 2 miles southwest of Speedwell. It is equipped with a 5-log washer and is producing 75 tons of ore per day.

Lick Mountain is a Valley ridge of Cambrian sandstone and shale, situated a few miles north of the New River-Cripple Creek area. This has been prospected for both iron and manganese and some lump ore has been mined and hauled by wagon to Wytheville. It is reported that such mining was done during 1905.

On the north side of the Draper Mountain from Clark's Summit to Hamilton Knob there is a line of outcrop of limestone, presumably the Valley limestone, which has the Carboniferous shales on the north side and in most places on both sides.

Clark's Summit mine.—This mine is located ½ mile south of Summit station and at the east end of the above mentioned limestone. The mine was extensively operated by the Virginia Steel Company about 1893. The ores were then washed at the mine. It was operated in 1905 by J. M. Spriggs for lump ore.

Henson mine.—This mine is located on the north slope of Hamilton Knob at the west end of the limestone above mentioned. It was operated some years ago and its ores washed in a local washer, but is now abandoned.

Locust Hill mine.—This mine is located on the south side of Hamilton's Knob, about 3 miles southeast from Max Meadows. A narrow-gauge railway connects with the furnace at Max Meadows. The ore-bodies are from 6 to 20 feet thick and dip down the mountain with the Devonian shale. The mine was opened about 1899 and has been operated quite continuously since then. A view of this mine is shown on plate LXVIII, figure 1. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	37.54
Silica	18.79
Phosphorus	0.34
Manganese	1.55

Smyth County.

This county has a long record in the production of small quantities of iron ore. Barton's and Nichols's forges in the Rye Valley and Chatham Hill forge on North Fork of the Holston were built at the beginning of the last century. During the Civil War an attempt was made to operate a furnace, and, since the war a charcoal furnace has been in successful operation. Recently there has been some small shipments of ore. This county extends across the Great Valley. In the southern part of this valley there are anticlinal mountains of Cambrian sandstone which carry "mountain" ores. In that part of the limestone valley which lies south of these mountains "limonite" ore occurs. This is found especially on the head waters of Cripple creek and in Rye Valley. The Oriskany horizon appears in Walker Mountain in the northern part of the county.

On the head waters of Cripple creek ore was mined between 1876 and 1904 for the White Rock charcoal furnace. The most important of these mines are the *Crigger, Porter,* and *Home* banks.

Crigger bank.—This mine is located ½ mile above the junction of the upper branches of Cripple creek. It produced, between 1881 and 1885, some 25,000 tons of "limonite" ore.

Porter bank.—This mine is located in the Valley on the divide between the New and Holston rivers waters about 2 miles east of Sugar Grove. It has produced some 35,000 tons of "limonite" ore, which was washed near the mine and hauled 6 miles to the furnace. It is owned by the Lobdell Carwheel Company. This ore is high in manganese and carries some lead.

Home bank.—This mine is located near the furnace 5 miles southwest from Rural Retreat. It was mined between 1876 and 1904 and produced "mountain" ore carrying about 38 per cent. metallic iron. In the Cambrian mountains west of the furnace other "mountain" ores have been mined in a small way, at a number of places.

In Rye Valley ores were mined in an early day for forges and in later time a small amount was hauled in wagons to Marion. The completion of the Marion and Rye Valley Railway to Sugar Grove in 1903 opened this region to shipment. Considerable prospecting has shown ore in various places. All of these valley ores are "limonite" which is high in manganese.

In the mountains, which lie to the north of the valley, and between it and the main valley, there has been some mining. These mountains are made up of Cambrian shales and sandstones, which have been thrown into a number of closely compressed folds. Some of the synclinal valleys between the ridges carry traces of the Valley limestone. The ores have carrying ore. Limonite ore has been mined from the clay of the Valley limestone near Tiptop in two recent operations.

Bell Hill mine.—This mine is located 1½ miles east of Tiptop and ½ mile northwest of Springville. Ore was mined here from 1900 to 1903, washed in a local washer and hauled one mile over a narrow-gauge railway to the Norfolk and Western Railway.

May mine.—This mine is located a mile or more west of the above mine and was operated about the same time. Lump ore only was mined, which was hauled to Tiptop.

Russell County.

Iron ore was mined in a small way for early forges, one near Honaker and the other near Dickensonville. In 1906 test shipments were made from the *Hall mine,* which is located 6 miles southwest from Castlewood. The ore is limonite and occurs in clay above the Valley limestone. The composition, as furnished by the Union Iron and Steel Company, is as follows:

Natural State.

	Per cent.
Metallic iron	44.13
Silica	20.91
Phosphorus	0.17

Scott County.

This county is a Valley county. The Valley limestone is the surface rock of the greater portion of the county. The Oriskany measures appear in Clinch Mountain and probably produced iron ore in the early part of the last century for the White Forge, which was located 5 miles northeast of Moccasin Gap.

Buchanan and Dickenson Counties.

These are the two Virginia counties in which the lower measures are covered by the flat-lying Coal Measures rocks. They may have some Coal Measures iron carbonate, but the writer has no knowledge that it occurs in commercial quantity.

Wise County.

The greater part of this county has for its surface rock the Coal Measures. The southern corner of the county has Silurian measures at the surface and includes a small but important part of the fossil ore area. The anticlinal Wallen ridge carries beds No. 3 and No. 4 of fossil ore, which are mined in the vicinity of Big Stone Gap. There is no record of ore mining in this region till the recent coming to Big Stone Gap of the Louisville and Nashville and the Virginia and Southwestern Railways. The completion of the Union coke furnace in 1902 has made Big Stone Gap the center of the iron industry in this region.

Oreton mines.—These mines are located 3 miles south of Big Stone Gap and ½ mile south of Oreton. Kelly and Irvine are operating No. 4 on the south slope of Wallen ridge. The composition of the ore, as furnished by the Union Iron and Steel Company, is as follows:

Natural State.

	Per cent.
Metallic iron	44.90
Silica	15.81
Phosphorus	0.29
Lime	0.22

Keystone mine.—This mine consists of a series of operations north of Oreton on the south slope of Wallen ridge. The Keystone Coal and Iron Company is operating chiefly No. 3, but also No. 4.

Irondale mines.—These mines are located 2 miles south of Big Stone Gap. They are the oldest and most extensively operated mines in the district. Kelley and Irvine have operated No. 3 and No. 4 over the crest and south slope of Wallen ridge for half a mile. The composition of the ore, as furnished by the Union Iron and Steel Company, is as follows:

Natural State.

	Per cent.
Metallic iron	40.14
Silica	27.98
Phosphorus	0.32
Lime	0.61

Yeary or Bunn mine.—This mine is located immediately south of Big Stone Gap on the crest and north slope of Wallen ridge. W. E. Yeary operates No. 3. The composition of the ore, as furnished by the Union Iron and Steel Company, is as follows:

Natural State.

	Per cent.
Metallic iron	42.34
Silica	18.36
Phosphorus	0.29
Lime	0.11

The Oriskany horizon outcrops at the base of Wallen ridge and scattered ore is found in the Helderberg limestone clay. A sample shipment of the ore was made from Oreton.

Lee County.

This county has fossil ores in Poor Valley ridge and in Wallen ridge. Between 1825 and the Civil War two forges were operated in this county. These were the Milam forge, situated on Martin's creek, near Rose Hill, and the Bowling Green, or Bales forge, situated 4 miles southeast of Rose Hill. Pennington forge at Pennington Gap was operated after the war. The only furnace of the county was the Laurel, which operated after the war. Since the building of the Louisville and Nashville Railway there has been much mining for shipment along the Poor Valley ridge. Most of these mines are located close to the Louisville and Nashville Railway and their tipples deliver to the railway cars.

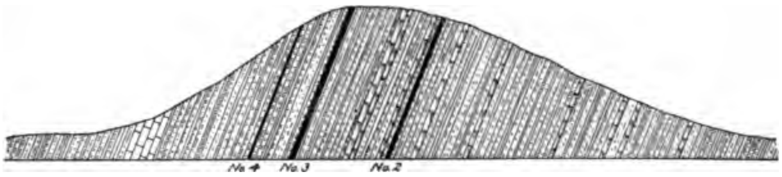

Fig. 67.—Geologic structure section across Poor Valley ridge showing the relative positions of the three beds of fossil iron ore.

Pennington mine.—This mine is located south of Pennington Gap and was operated in a small way for Pennington forge. The composition of the ore, as sampled from the stock pile at the forge and analyzed by McCreath in 1887, is as follows:

	Per cent.
Metallic iron	50.50
Silica	18.75
Phosphorus	0.158

Lavine mine.—This mine is located midway between Pennington and Ben Hur 1 mile from the railway on a spur of Poor Valley ridge. A narrow-gauge railway connects with the Louisville and Nashville Railway. It is operated by Kelly and Irvine. This mine is not located on the Poor Valley monocline, which carries most of the mines of the region, but in closely folded strata situated east of the monocline. The composition of the ore, as furnished by the Union Iron and Steel Company, is as follows:

Natural State.

	Per cent.
Metallic iron	43.20
Silica	22.31
Phosphorus	0.34
Lime	0.56

Ben Hur mine.—This mine is located on the north side of Poor Valley ridge, west of Ben Hur station, where the railway cuts across the Poor Valley ridge. It has been mined 1,500 feet on the strike and 150 feet on the dip. The composition of this ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	34.01
Silica	34.50
Phosphorus	0.27
Manganese	0.16

Truro mine.—This mine is located southwest of Ben Hur mine, ⅓ of a mile northeast from Noes Siding on the north side of Poor Valley ridge. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	36.00
Silica	33.37
Phosphorus	0.23
Manganese	0.16

Noes Siding mine.—This mine is located southwest from Truro and ¾ of a mile northeast from Ocoonita on the north side of Poor Valley ridge. It is operated by Kelly and Irvine; has been mined 225 feet on the dip. The composition of this ore, as furnished by the Union Iron and Steel Company, is as follows:

Natural State.

	Per cent.
Metallic iron	42.30
Silica	27.60
Phosphorus	0.19
Lime	0.10

Between Noes Siding and Hagan no mining has been done.

Grabill mine.—This mine is located 600 feet northeast of Hagan station and is operated by B. C. Grabill in a small way. The tunnels are at water-level 75 feet below the railway. The ore is hauled in wagons to Hagan.

Boones Path mines.—These mines are located 2 miles southwest from Hagan on the north slope of Poor Valley ridge. These mines are operated from 7 tipples along ½ mile of outcrop. It is the largest operation in the vicinity and is operated by the Boones Path Iron Company. The composition of this ore, as furnished by the Union Iron and Steel Company, is as follows:

	Per cent.
Metallic iron	40.91
Silica	16.70
Phosphorus	0.45
Lime	5.18
Magnesia	0.93

Southwest from these mines the railway lies on the south side of the ridge and little mining has been done along the Poor Valley between there and Cumberland Gap.

Ewing mine.—This mine has its tipple 1 mile east of Ewing. The mine is located 2½ miles southeast from the tipple and its ore is brought

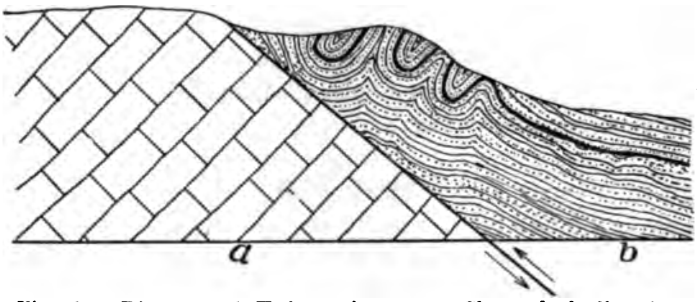

Fig. 68.—Diagram of Ewing mine. (*a*) Shenandoah limestone. (*b*) Clinton measures carrying fossil iron ore, represented by black line, faulted up on the limestone and closely folded.

to the tipple over a narrow-gauge railway. The mine is located in the end of a faulted segment of Clinton strata which have been thrust over on the Valley limestone. (Figure 68.) The beds are closely folded, contorted and fractured. The ore is thin but of better grade than most of the ore of the region, carrying lime instead of silica. The composition of 26 carloads of this ore, as furnished by the operators, the Union Iron and Steel Company, is as follows:

Natural State.

	Per cent.
Metallic iron	34.09
Silica	6.58
Phosphorus	0.58
Lime	7.72
Magnesia	3.95

PIEDMONT COUNTIES.

The counties treated below under this head lie east of the western range of the Blue Ridge. Their rocks are chiefly crystalline schists, the most of which are probably metamorphosed sedimentary rocks. These for the most part have been more or less closely folded with the axes of the folds striking northeast and southwest. As the result of this the outcrop of a given formation usually strikes in the same direction. The schistosity usually dips at high angles to the southeast. The ore-bodies usually follow either the bedding or the schistosity and in either case usually dip at high angles. The ores are mostly magnetite, specular hematite, and limonite. The limonite is usually the gossan of a sulphide. In the northeast this sulphide is usually pyrite, with the pyrite sometimes gold-bearing, so that gold mines and iron mines are associated. In the southwest much of the sulphide is pyrrhotite. As the pyrrhotite usually carries some chalcopyrite the iron mines of the southwestern Piedmont counties are usually associated with copper mines. A corner of Bedford county carries some of the Blue Ridge hematite. In general the counties forming the two most northeasterly tiers of the Piedmont carry iron ore while the other Piedmont counties do not.

Loudoun County.

Iron ore was mined in this county for the Potomac furnace, which was built in 1839. The ore was limonite and was mined near the furnace, a short distance below Point of Rocks.

Stafford County.

On the property of Augustine Washington, the father of George Washington, iron ore was mined about 1727 for the Accokeek furnace. This furnace was abandoned in 1753. However, this was not for want of ore, as the mine was considered capable of supplying another furnace in Revolutionary War time. There is no known record of any iron ore mining in this county subsequent to 1753.

Spottsylvania County.

This county carries a strong development of pyrite through the northwestern side. The gossan cap of this was early worked for charcoal furnaces. The first furnaces were those of Governor Spotswood. The Germania, located in the northern corner of the county near the Rappahannock river, was built about 1714. This was the first furnace in the

South and the first furnace in America to produce pig iron. The other Spotswood furnace, built about 1827, was located in the southwestern part of the county about a half mile from the North Anne river. The Catherine furnace was located about 3 miles west of Chancellorsville. For many years ore was mined at a number of places scattered through the territory between this furnace and the Rappahannock river.

Louisa County.

Near Mineral City pyrite is now mined. A description of these mines is given under Pyrite on pages 198-202. The gossan from these pyrite deposits was mined for the Victoria and the Rough and Ready charcoal furnaces in the middle of the 19th century. Magnetite was mined for the latter furnace from two mines near the furnace.

Albemarle County.

This county has pyrite gossan. Old's furnace, located 12 miles from Charlottesville, was an old furnace in Revolutionary War time. Presumably it used a gossan ore.

Stony Point mine.—Near Stony Point, some 6 miles northeast of Charlottesville, at the northwest base of Southwest Mountain, gossan has been extensively worked in modern times. It is reported that between 1878 and 1885, 2,500 carloads of iron ore were shipped from here to Pittsburg furnaces. As stated under Copper, pages 502-503, there is a continuous outcrop of ore for ¾ of a mile with widths of from 5 to 6 feet, and it has been mined to a depth of 130 feet. The gossan is underlain by some chalcopyrite and the mine has produced some copper. At North Garden magnetite and limonite have been mined. An analysis of the North Garden ore, as made for the Tenth Census report, gave:

	Per cent.
Metallic iron	46.69
Phosphorus	0.055

Nelson County.

Greenway mine.—Specular hematite was mined in 1880 in the southern corner of the county at the Greenway mine, located 2½ miles west of Greenway. It is said to have been mined to a depth of 200 feet for a length of 500 feet with widths up to 12 feet. An analysis made for the Tenth Census gave as follows:

	Per cent.
Metallic iron	53.02
Phosphorus	0.049

At Roseland there are extensive deposits of phosphatic titaniferous iron rock. This has been extensively prospected but not mined as an iron proposition. A further account of this is given under Ilmenite and Phosphates, on pages 232 and 300-301.

Buckingham County.

Limonite ore was mined in this county before 1840 for the Bear Garden furnace near New Canton on the James river. The ore was the gossan of a pyrite lead. Professor Rogers reports, "About a mile east of Whispering Creek, nearly in line with Willis Mountain, a heavy bed of magnetic oxide crosses the road leading from Maysville to Ca Ira, and may be traced for some distance in a northeast-southwest direction. It is from 6 to 8 feet in width."

Mecklenburg County.

The magnetic and specular ores, which occur in Granville county, North Carolina, are reported to extend northeastward into Mecklenburg county, Virginia.

Amherst County.

Elk creek charcoal furnace was operated in the eastern corner of this county in the first half of the 19th century on local magnetic and limonite ores. About 1880 these ores, particularly the magnetite and specular hematite, were zealously exploited. Near Elk creek furnace a 3-foot thickness of specular ore was prospected, which, according to the Tenth Census report, carried:

	Per cent.
Metallic iron	38.42
Phosphorus	0.118

Within a mile of this limonite ore was mined which, according to the Tenth Census report, carried:

	Per cent.
Metallic iron	44.54
Phosphorus	0.85

Riverville mines.—These mines, located within 2 miles of Riverville west and north, consisted of a number of operations in specular and magnetic ore, which lay in beds in widths up to 16 feet, dipping at high angles, and were associated with quartzite and mica shist. Mining was carried to a depth of about 100 feet. No. 10½, sampled across a breast of 16 feet, gave the Tenth Census analyst:

	Per cent.
Metallic iron	40.51
Phosphorus	0.095

No. 11 of Adams, Scott & Co., with a thickness of 4 feet, gave the Tenth Census analyst:

	Per cent.
Metallic iron	39.75
Phosphorus	0.126

No. 11 of the Dover Company, with a thickness of 3 feet, gave the Tenth Census analyst:

	Per cent.
Metallic iron	48.47
Insoluble	28.53
Phosphorus	0.10
Sulphur	0.35

Maud vein.—Near Stapleton the Maud vein, a mine similar to the Riverville mines, worked for a distance of 900 feet and to a depth of 80 feet with a width of 3 feet, gave the Tenth Census analyst:

	Per cent.
Metallic iron	49.89
Phosphorus	0.139

Appomattox County.

Appomattox had a number of ancient charcoal furnaces which were located in the northwestern part of the county near the James river. Of these the Stonewall was one of the more recently operated. These furnaces used chiefly the limonite ores of the region. It is not known that these ores have been operated in recent times. They were prospected at the time of the boom in the James river region in the early 80s.

Campbell County.

The Ross furnace, located 2 miles south of the present James river bridge, is one of the oldest furnaces in the region. In 1781 Jefferson reports that it was making 1,600 tons of pig iron annually. Under the name of Oxford furnace it was operated in Civil War time. Its chief bank is located a few hundred yards northeast of the furnace site. The mine was a deep open cut located on top of one of the higher elevations of the region. The ore is limonite. At present fine manganese ore is being mined in quantity on the strike of the old iron ore-body and only a couple hundred yards distant. It is reported that ore was shipped from Lawyers in the 80s.

Bedford County.

While Bedford county is a Piedmont county, a small corner of the county extends into the Blue Ridge and it carries an important development of the Blue Ridge hematite ore. From the Botetourt county line northeastward for a distance of some 2 or more miles this ore has been worked on the southeast slope of the Blue Ridge. Most of the operations have been small excavations on the outcrop of the bed. Present mining consists of extensive underground operations in which the bed has been entered at the more favorable points where ravines cut it.

Ironville mine.—This mine, located ½ mile north from Ironville, was first opened in 1879. It has been operated at various times since. Present workings extend several hundred feet on the strike and through 200 feet on the nearly vertical dip of the bed. The ore is hauled in wagons to Ironville. The composition of the ore, as furnished by the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	34.66
Silica	39.06
Phosphorus	0.39
Manganese	0.15

Dewey mine.—This mine was opened more recently than the Ironville but has been more extensively worked. It is located immediately northeast of the Ironville mine and the underground workings of the two mines are said to connect. The main workings now operated are drifts on the nearly vertical bed for a distance, said to be 1,500 feet, through 6 or 7 levels nearly up to the original outcrop workings. The ore bed is said to vary in thickness from 3 to 12 feet. Recently at two places at this mine operations have been started in sinking on the bed below water level. The ore-body has been somewhat folded and in places is said to be shifted a few feet by faulting. A narrow-gauge railway some 3 miles long connects the mine with the tipple near Montvale. The composition of the ore, as furnished by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	36.90
Silica	34.85
Phosphorus	0.28
Manganese	0.23

Pittsylvania County.

Pittsville mine.—An important deposit of magnetic iron ore occurs near Pittsville in the northwestern part of the county. This ore was first mined about 1880 by the Pig River Mining Company, which is

Fig. 1.—Shaft house of the Barr magnetite mine, near Pittsville, Pittsylvania county.

Fig. 2.—Barr limonite mine, near Pittsville, Pittsylvania county.

IRON MINES, PITTSYLVANIA COUNTY, VIRGINIA.

reported to have mined 90,000 tons. The ore is fine-grained to massive magnetite. The lead is quite variable in both strike and dip. It has been mined for a half mile of its length. These workings are reported to have an average width of about 3 feet and were mined to a depth of 150 feet. A sample taken across the face of the lead and analyzed for the Tenth Census gave as follows:

Natural State.

	Per cent.
Metallic iron	59.83
Phosphorus	0.09

Barr Magnetite mine.—J. H. C. Barr has mined the extension of the lead of the Pittsville mine since 1896. The lead here lies between walls

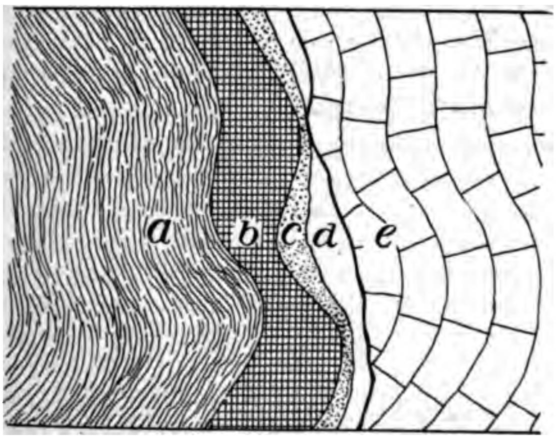

Fig. 69.—Section in the Barr magnetite mine, showing relation of the ore to the adjacent formations. (*a*) Mica schist. (*b*) Magnetite. (*c*) Umber-bearing clay. (*d*) Space. (*e*) Crystalline limestone.

of quartz schist and crystalline limestone. (Figure 69.) The lead here has considerably greater widths than is reported for the Pittsville mine and has been worked to a somewhat greater depth. A view of the shaft house at this mine is shown on plate LXX, figure 1. The composition of the ore, as given by the operator, is as follows:

	Per cent.
Metallic iron	64.25
Silica	4.52
Phosphorus	0.008

Barr Limonite mine.—Two miles from the Barr magnetite mine the same operator is mining limonite ore. It is washed in a local washer and delivered over a narrow-gauge railway to Pittsville. Massive outcrops of limonite occur along the crest and slopes of a ridge for half a mile. Where mined the ore is massive or as closely spaced stringers in clay. A view of this mine is shown on plate LXX, figure 2. The composition of the ore, as furnished by the operator, is as follows:

	Per cent.
Metallic iron	47.00
Silica	12.25
Phosphorus	0.85
Manganese	2.70

Franklin County.

Gossan was mined in this county near the Floyd county line a few miles northeast of the Toncray mine for an early local furnace. Magnetic ores of importance occur in this county. H. B. C. Nitze traced the magnetic lead from Rocky Mount, Franklin county, southwestward 24 miles to Stewart's Knob in Patrick county.

Rocky Mount mine.—The ore at Rocky Mount was mined at an early date for the Saunders' furnace. In 1880 these ores were mined by the Pig River Mining Company and shipped to Pennsylvania. The ore is a fine-grained pure magnetite with walls of dense hornblende schist dipping 60° southwest. A sample taken at a depth of 20 feet across the 9-foot working face of the mine for the Tenth Census gave as follows:

Natural State.

	Per cent.
Metallic iron	53.59
Silica	14.67
Phosphorus	0.018
Manganese	0.12
Titanic oxide	none
Sulphur	0.36

Patrick County.

A part of the magnetic lead which extends southwest through Franklin county is found in Patrick. Ore was mined at the Hairston mine for the Union furnace.

Hairston mine.—This mine is located at Stewart's Knob in the northwestern part of the county. In 1906 a narrow-gauge railway was constructed from Philpot to the mines a distance of 12 miles for the purpose of furnishing an outlet for these ores. The ore is magnetite, similar to that at Rocky Mount, and occurs in a number of leads which are from 3 to 6 feet wide and associated with hornblende schist. It is operated by the Virginia Ore and Lumber Company. An average of 10 analyses, made by Mr. W. W. Davis from samples taken by him for a private report, shows as follows:

Natural State.

	Per cent.
Metallic iron	59.93
Silica	7.72
Phosphorus	0.08
Manganese	0.17
Sulphur	0.19

Henry County.

Nitze says that the magnetic ores which occur near Danbury, Stokes county, North Carolina, extend into Henry county, Virginia.

Floyd County.

Toncray mine.—Gossan was mined in the southwestern part of this county on the West Fork of Little river at the Toncray mine for the Shelor's and West Fork furnaces. In the northeastern part of the county pyrrhotite and pyrite occur which are reported to carry nickel in minable percentages. (See pages 580-582 for a further account of this sulphide.) The county is without a railway and there have been no modern iron ore operations.

Carroll County.

This county contains the greatest development of the "gossan lead." Gossan ore was mined for two or more forges on Chestnut creek. At two points in this county the "lead" has been crossed by a railway and gossan has been extensively mined at both places.

Chestnut Yard mines.—At Chestnut Yard the gossan has been mined out for several miles along the lead. At the "Great Outburst," which is a part of the Chestnut Yard operations, the lead from which the gossan has been removed is 175 feet wide. At this point pyrrhotite ore, "mundic," is now being mined for the acid plant at Pulaski by the Pulaski Mining Company. Plate XXX is an illustration of this mine.

An analysis of "mundic" from the "Great Outburst," furnished by the New River Mineral Company, is as follows:

	Per cent.
Metallic iron	57.26
Insoluble	3.68
Sulphur	38.61
Copper	0.82
Manganese	0.19

After this sample was burned as completely as possible over a blast lamp it gave as follows:

	Per cent.
Metallic iron	60.40
Sulphur	1.64

Betty Baker mine.—At Betty Baker mine the gossan was mined between 1889 and 1902 for a mile along the lead where it had a width of from 10 to 30 feet. The composition of the ore, as given by the operators, the Virginia Iron, Coal and Coke Company, is as follows:

Natural State.

	Per cent.
Metallic iron	36.15
Silica	16.36
Phosphorus	0.12
Manganese	1.40

Magnetic ores are reported in this county, but the writer has no knowledge that they have been worked.

Grayson County.

Gossan ore was mined in this county for the Pine Hope furnace, located 3 miles southeast from Independence. Scattered outcrops of the northern "gossan lead" are said to occur in this county westward from Chestnut Yard. Magnetic ore is known in this county. It is reported that such ore was mined near Independence for the Pine Hope forge. Near Fries magnetic ore has been prospected and it is reported that some was used in the Chestnut forge. Magnetite ore is reported near the Mouth of Wilson on the State line. A sample from the Pugh prospect a half mile south of the State line gave on analysis the following results, reported by Nitze:

	Per cent.
Metallic iron	45.44
Silica	22.74
Phosphorus	0.022
Sulphur	0.049

Near the point where Little Helton creek crosses the State line titaniferous magnetite has been prospected with a good showing. A sample from the 25-foot Young outcrop a quarter of a mile south of the State line gave an analysis, reported by Nitze, as follows:

	Per cent.
Metallic iron	50.77
Silica	5.12
Phosphorus	0.005
Sulphur	0.04
Titanic oxide................	4.95

A titaniferous magnetite in a hornblende schist is reported in the southeast corner of the county. This ore was worked about 1886 just south of the State line for the Collins forge. An analysis of this ore, as given by Nitze, is as follows:

	Per cent.
Metallic iron	54.72
Silica	6.20
Phosphorus	0.047
Sulphur	0.038
Titanic oxide	4.86

COASTAL PLAIN COUNTIES.

These counties in Virginia have not been producers of commercial iron ore. In 1609 the colonists mined some ore which was taken to England and there made 16 tons of metal. The iron works at Falling Creek, in the present Chesterfield county, which were built between 1619 and 1622, were to run on local ores. These works were destroyed by the Indians in 1622. Since that time it is not known that there has been any iron mining in these counties. In both North Carolina and Maryland iron ore has been mined from strata similar to those which constitute the Virginia Coastal Plain. In Maryland the ore is carbonate which occurs in lumps scattered through clay in layers, and has been extensively mined.

List of Iron Mines in Virginia.

In the list appended below are included those mines that are now producing or have produced in the last two years, or have been recently prospected and will probably shortly become producers.

Name of mine.	County.	Kind of ore.	Operator.
Big Ike	Warren	Blue Ridge limonite	F. G. Grove
Happy Creek	Warren	Blue Ridge limonite	H. J. Seibel, Jr.
Liberty	Shenandoah	Oriskany	Shenandoah Iron and Coal Co.
Rileyville	Page	Blue Ridge limonite	
Black Rock	Augusta	Blue Ridge limonite	The Vesuvius Mining Co.
Bare Bank	Augusta	Blue Ridge limonite	
Crozier	Augusta	Blue Ridge limonite	
Buena Vista	Rockbridge	Blue Ridge limonite	Buena Vista Iron Co.
Dixie	Rockbridge	Blue Ridge limonite	Alleghany Ore and Iron Co.
Rumsey	Alleghany	Oriskany	Low Moor Iron Co.
Dolly Ann	Alleghany	Oriskany	Low Moor Iron Co.
Longdale	Alleghany	Oriskany	Longdale Iron Co.
Fancy Hill	Alleghany	Oriskany	Longdale Iron Co.
Stack	Alleghany	Oriskany	Low Moor Iron Co.
Horse Mt.	Alleghany	Fossil	Low Moor Iron Co.
Rich Patch	Alleghany	Oriskany	The Goshen Iron Co.
Bess	Alleghany	Oriskany	Low Moor Iron Co.
Double Ridge	Alleghany	Oriskany	Low Moor Iron Co.
Sand Bank	Botetourt	Oriskany	Princess Iron Co.
Callie	Botetourt	Oriskany	Princess Furnace Co.
Wilton	Botetourt	Oriskany	Princess Furnace Co.

Name of mine.	County.	Kind of ore.	Operator.
Circle	Botetourt	Oriskany	Longdale Iron Co.
Oriskany	Botetourt	Oriskany	Alleghany Ore and Iron Co.
Grubb	Botetourt	Blue Ridge limonite	Virginia Iron, Coal & Coke Co.
Grubb Specular	Botetourt	Blue Ridge hematite	Virginia Iron, Coal & Coke Co.
Edith	Botetourt	Blue Ridge hematite	Virginia Iron, Coal & Coke Co.
Arcadia	Botetourt	Blue Ridge hematite	Pulaski Iron Co.
Wood	Botetourt	Blue Ridge hematite	G. G. Harvey
Fenwick	Botetourt	Oriskany	Low Moor Iron Co.
Rorer	Roanoke	Blue Ridge limonite	Virginia Iron, Coal & Coke Co.
Porterfield	Giles	Limestone magnetite	
Tasker	Pulaski	"Mountain ore"	West End Furnace Co.
Farris	Pulaski	"Mountain ore"	Pulaski Iron Co.
Rich Hill	Pulaski	Limestone limonite	Virginia Iron, Coal & Coke Co.
Reed Island	Pulaski	Limestone limonite	Virginia Iron, Coal & Coke Co.
Clayton	Pulaski	Oriskany	Pulaski Iron Co.
Peak Knob	Pulaski	Oriskany	Hatcher and Shaffer Hagar and Mahady
Barren Springs	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Bertha	Wythe	Limestone limonite	Pulaski Iron Co.
Cedar Run	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Sanders	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Morris	Wythe	"Mountain ore"	Virginia Iron, Coal & Coke Co.
Hurst	Wythe	"Mountain ore"	Virginia Iron, Coal & Coke Co.
Patterson	Wythe	Limestone limonite	Pulaski Iron Co.
Crawford	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Tipton	Wythe	"Mountain ore"	Pulaski Iron Co.
Foster Falls	Wythe	"Mountain ore"	Virginia Iron, Coal & Coke Co.
Hematite	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Posey	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Poplar Camp	Wythe	"Mountain ore"	Pulaski Iron Co.
Ivanhoe	Wythe	Limestone limonite	Ivanhoe Furnace Co.
Little Wythe	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Norma	Wythe	"Mountain ore"	Pulaski Iron Co.
Ganaway	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Percival	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Andis	Wythe	Limestone limonite	Virginia Iron, Coal & Coke Co.
Clark Summit	Wythe	"Mountain ore"	J. M. Spriggs
Locust Hill	Wythe	Oriskany	Virginia Iron, Coal & Coke Co.
Slemp Creek	Smyth	"Mountain ore"	
Holston	Washington	Magnetite	Ivanhoe Furnace Co.
Taylor's Valley	Washington	"Mountain ore"	Taylor's Valley Iron Co.
Hall	Russell	Limestone limonite	M. A. Hall
Oreton	Wise	Fossil	Kelley and Irvine
Keystone	Wise	Fossil	Keystone Coal and Iron Co.
Irondale	Wise	Fossil	Kelley and Irvine
Yeary	Wise	Fossil	W. E. Yeary
Lavine	Lee	Fossil	Kelley & Irvine
Ben Hur	Lee	Fossil	Virginia Iron, Coal & Coke Co.
Truro	Lee	Fossil	Virginia Iron, Coal & Coke Co.
Noes	Lee	Fossil	Kelley and Irvine
Grabill	Lee	Fossil	B. C. Grabill
Boones Path	Lee	Fossil	Boones Path Iron Co.
Ewing	Lee	Fossil	Union Iron and Steel Co.
Chestnut Yard	Carroll	Pyrrhotite	Pulaski Mining Co.
Hairston	Patrick	Magnetite	Virginia Ore and Lumber Co.
Barr	Pittsylvania	Magnetite	J. H. C. Barr
Barr	Pittsylvania	Limonite	J. H. C. Barr
Ironville	Bedford	Blue Ridge hematite	Virginia Iron, Coal & Coke Co.
Dewey	Bedford	Blue Ridge hematite	Virginia Iron, Coal & Coke Co.

List of Furnaces in Virginia.

Name.	Place.	County.	Annual capy. in tons.	Operator.
		Coke Furnaces.		
Alleghany	Iron Gate	Alleghany	30,000	Alleghany Ore and Iron Co.
Bristol	Bristol	Washington	50,000	Virginia Iron, Coal & Coke Co.
Buena Vista	Buena Vista	Rockbridge	54,000	Alleghany Ore and Iron Co.
Crozier No. 1	Roanoke	Roanoke	100,000	Virginia Iron, Coal & Coke Co.
Crozier No. 2	Roanoke	Roanoke		Virginia Iron, Coal & Coke Co.
Dora	Pulaski	Pulaski	50,000	Virginia Iron, Coal & Coke Co.
Gem	Shenandoah	Page	36,000	Alleghany Ore and Iron Co.
Graham	Graham	Tazewell	40,000	Virginia Iron, Coal & Coke Co.
Ivanhoe	Ivanhoe	Wythe	25,000	Ivanhoe Furnace Co.
Longdale No. 1	Longdale	Alleghany	40,000	The Longdale Iron Co.
Longdale No. 2	Longdale	Alleghany		Low Moor Iron Co.
Low Moor A.	Low Moor	Alleghany	100,000	Low Moor Iron Co.
Low Moor B.	Low Moor	Alleghany		Low Moor Iron Co.
Covington	Covington	Alleghany		
Max Meadows	Max Meadows	Wythe	60,000	Virginia Iron, Coal & Coke Co.
Princess	Glen Wilton	Botetourt	15,000	Princess Furnace Co.
Pulaski	Pulaski	Pulaski	55,000	Pulaski Iron Co.
Radford	Radford Furnace	Pulaski	4,000	Richard Wood
Radford-Crane	Radford	Montgomery	50,000	Virginia Iron, Coal & Coke Co.
Union No. 1	Big Stone Gap	Wise	50,000	Union Iron and Steel Co.
Victoria	Goshen	Rockbridge	50,000	The Goshen Iron Co.
West End	Roanoke	Roanoke	48,000	West End Furnace Co.
		Charcoal Furnaces.		
Foster Falls	Foster Falls	Wythe	3,000	Virginia Iron, Coal & Coke Co.
Liberty	Liberty Furnace	Shenandoah	25,000	Shenandoah Iron and Coal Co.
Reed Is. Boom	Reed Island	Pulaski	3,000	Virginia Iron, Coal & Coke Co.
White Rock	Rural Retreat	Smyth	2,500	Lobdell Carwheel Co.
		Electric Furnaces.		
Holcomb Rock	Holcomb Rock	Bedford	2 furnaces	Willson Aluminum Co.

Total number of blast furnaces 26, of which 22 are coke and 4 are charcoal.
These furnaces produced in 1906, 483,525 long tons of pig iron.

Methods of Mining.

Iron ore occurs in Virginia in a variety of different ways. These different modes of occurrence demand different methods in mining. The chief methods in open cut mines are steam shovel mining, milling, sluicing, hydraulicing, and pick-and-shovel mining.

The steam shovel is extensively used in mining limonite ore in Virginia. It is most used in the New River-Cripple Creek district, but also used on the Blue Ridge and Oriskany ores. In the first mentioned district where it is necessary to move large quantities of lean clay the steam shovel is particularly adapted. This method is not used to advantage where the clay is thin, where there are many limestone horses in the ore, or where the ore-bodies are scattered. In the Oriskany district much ore lies covered by not more than 20 feet of soft rock. This overburden is removed by steam shovel and then the ore itself lifted by the same means. Here the more solid ore requires blasting before the shovel can move it. The shovels are mounted on broad- or narrow-gauge railway trucks and deliver to cars operated on a parallel track. Plate LXIV, figure 1, and plate LXVII, figure 2, illustrate the use of the steam shovel in mining.

Milling is shown in plate LXVIII, figures 1 and 2, and in figures 70, 71, and 72 below. The process consists essentially of caving the material of the bank directly to cars. The material of the bank is loosened by hand with the pick and allowed to roll down the steep slope to the cars. The cars are placed in position to receive the material by heading them into tunnels. Commonly the tunnels are short, merely long enough to receive one or two cars, and the ore is milled down the outer slope. The tunnel may be longer and then a shaft is driven from above to meet the end of the tunnel and the ore milled down the shaft. This latter method is not much used, as it involves extra work in handling cars. Milling is a cheap method of mining and is extensively used in the New River-Cripple Creek region. It is serviceable where the minable material is of sufficient thickness and where the overburden is not too great. It can be used in confined situations where a steam shovel cannot.

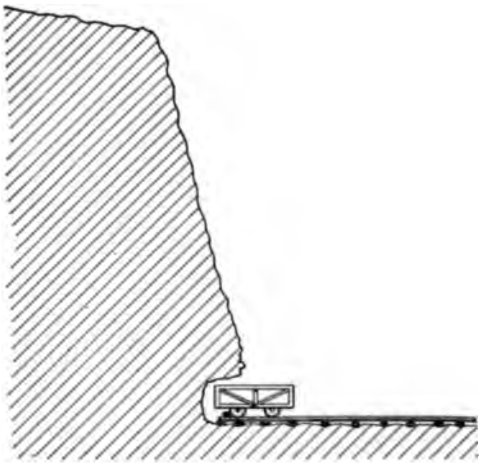

Fig. 70.—Diagram illustrating milling of iron ore from the face of a slope.

Sluicing is a method of mining in which the material of the bank is loosened usually by hand with a pick and allowed to roll down a slope the same as in milling. The water is pumped through 6-inch or larger iron pipes to the summit of the mine. It is allowed to pour through dirt ditches to the point at which it receives its load and from there conducted in iron troughs to the washer. This method of mining is used in the New River-Cripple Creek region. It is usable in mining ore-bearing clays where there is a slope of one to eight between the mine and the washer and where water is available. It can be used in more confined situations than either the steam shovel or milling and has the advantage over these methods that the material arrives at the washer in excellent condition for washing.

Hydraulicing is the method of mining in which a stream of water from a nozzle is directed against the bank with sufficient force to tear down the bank. The broken down material is carried by the spent water through sluice troughs to the washer. The water is pumped to the mine the same as in sluicing, while at the mine a second pump forces the water through

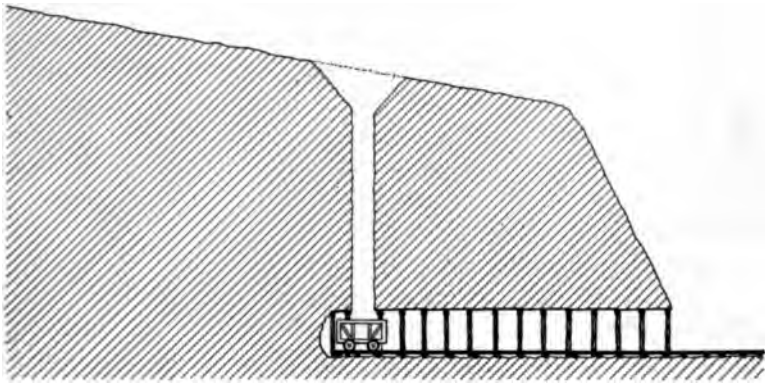

Fig. 71.—Diagram illustrating milling of iron ore (first stage).

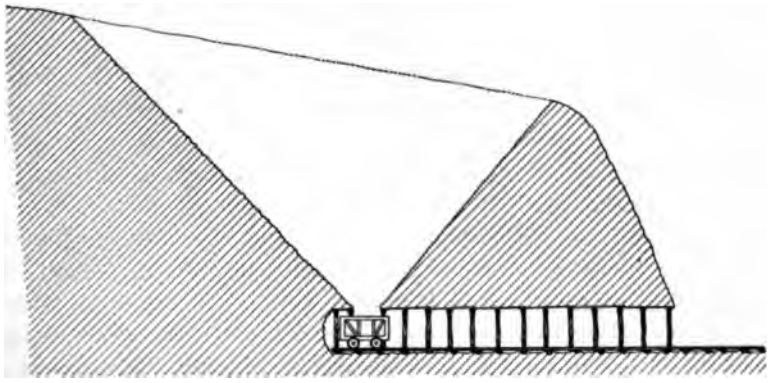

Fig. 72.—Diagram illustrating milling of iron ore. Represents a later stage than Fig. 71.

the nozzle. This method is used in several mines in the New River-Cripple Creek region. It is usable under conditions similar to those required by sluicing but is not as usable in such confined situations. Plate LXIX, figures 1 and 2, illustrate this method of mining.

Pick-and-shovel mining of ore-bearing clay is expensive and is used only as a last resort. It finds its chief application in rich, shallow deposits where other methods are not available. It is also used in confined situations on the richer portions of deposits which have been mined mainly by the cheaper methods. Pick-and-shovel mining in rich lump ore and in solid ore is not so expensive and is much used. For lump ore it is used in prospects where the quantity of wash ore is doubtful, in mines which have been abandoned as not producing sufficient wash ore to maintain a washer, and in deposits which contain both lump and wash ore but contain too little of the latter to maintain a washer. In these cases the lump ore is separated from the clay and fine ore by screening with a wire screen of about one inch mesh. Surface occurrences of solid ore are much mined by pick-and-shovel. This applies to massive limonites, gossan, and to the outcrop of fossil and Blue Ridge hematite. All of these are so solid that drilling and blasting are required.

Underground mining has to deal almost entirely with massive ore. Ore-bearing clays such as are mined by open cut methods in the New River-Cripple Creek region will not bear the expense of underground mining. Many of the deep-seated limonites have associated clay, but the limonite usually constitutes more than one-half of the material mined. The methods used in mining these ores vary with the character of the ore, with the shape, size, and attitude of the deposit, and with the character of the enclosing rock.

The Valley limonites are rarely mined underground. The limonites of the Blue Ridge are mined underground to some extent. As these deposits are of irregular shape and extent, systematic methods are not readily applied to the mining of them. They are mined in shaft and tunnel in the method best adapted to the individual deposit.

The Oriskany ore, in general, has a fairly constant thickness and attitude in any given mine and can be mined systematically. Most of the ore-bodies so far mined dip at high angles. In mining such deposits several parallel horizontal tunnels are usually run one above the other along the strike of the deposit in the ore. The lower tunnel is used as a main car level and serves for most of the lateral transportation of the ore. The upper tunnel is located near the upper limit of the ore. Most of the ore is mined near the top of the ore-body in robbing rooms which are 10 to 12 feet high. As the ore is removed timbers are set so as to support the debris above. When a room of sufficient size has been created, timbers are laid horizontally on the floor of the room and covered with smaller cross timbers. When the vertical supports are broken by blasting, the debris from above sinks to the floor and the horizontal timbers, previously placed, are in position to serve as caps for the supports in the room which is to be excavated underneath. The ore as mined is thrown down shoots to a car level. The car levels usually extend horizontally to the surface but in greater depths ore may be lifted in a vertical shaft. Figure 73 illustrates this method. Most of the limonites are so solid as to require constant drilling and blasting. Several mines are equipped with air drills. In many of the mines the natural circulation of the air in the mine is

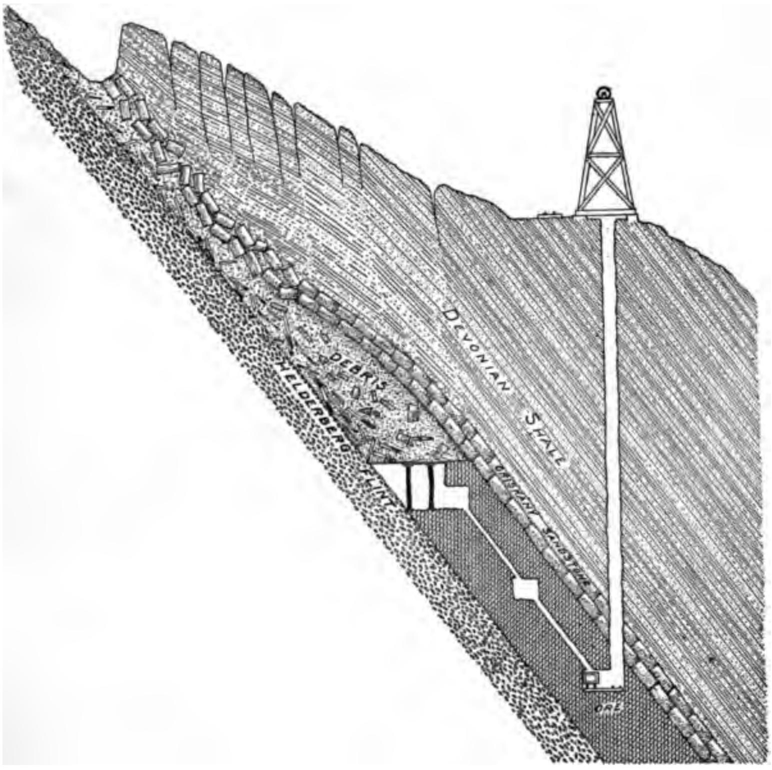

Fig. 73.—Section showing relations of Oriskany ore to the adjacent formations, and the method of working deep-lying ore.

sufficient for ventilation but in the more extensive and complex mines a forced circulation is produced by means of fans.

The outcrop of the hematite of the Blue Ridge has such abrupt and continuous changes of elevation that it is mined to a considerable depth as a surface working. At greater depths methods similar to those used in the Oriskany ores are used. The problem here is however much simpler. The ore-body is usually nearly vertical with good walls of compact shale or strong sandstone. Comparatively little timbering is necessary and it is not necessary to support the debris from above. In the fossil hematite the ore-beds may be flat-lying or dipping at angles up to nearly vertical. These beds are mined in thicknesses varying from 16 inches up to 4 feet. The thinness of the beds makes mining a more difficult problem than the mining of the Blue Ridge hematite. The similarity of these beds to coal beds makes the methods of coal mining applicable to the mining of this ore. The room-and-pillar method is generally used. The methods vary considerably with the dip of the strata. With a dip of a few degrees and a relatively light overweight, parallel entries are driven in the ore about 45 feet apart and wide enough for the small entry cars. From these entries 16-foot wide rooms are turned off at right angles to

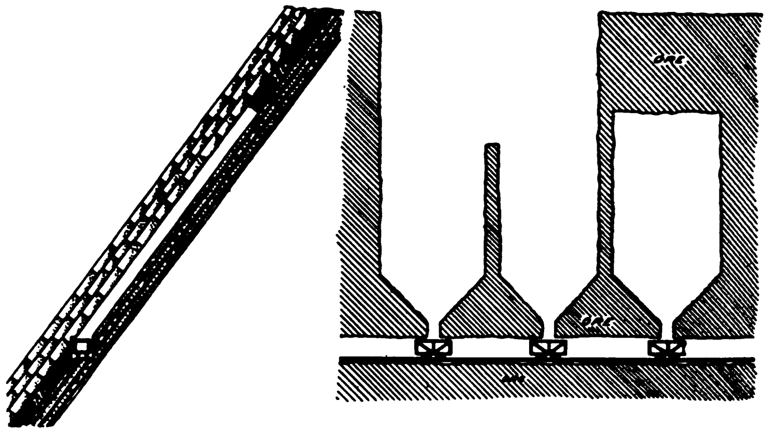

Fig. 74.—Diagram illustrating method of mining in steeply dipping beds of fossil iron ore.

the entries leaving 40-foot square pillars. When the entries have been extended as far as desired the pillars are robbed beginning at the inner end. Where the size of the pillars is properly adjusted to the overweight, the back edge of the pillar will be crushed by the overweight and render blasting unnecessary. Figure 74 illustrates this method. Where the ore bed is dipping at a high angle, a car level is run in the ore nearly on the horizontal. From this stopes are turned off about 34 feet apart, a few feet wide below but widening above to 30 feet and leaving between adjacent stopes 4-foot pillars. Ore is won chiefly by blasting from the upper end of the stopes. This delivers ore to the car below without further handling. When the stope has reached upwards not more than 100 feet the 4-foot pillars are robbed back. Figure 75 illustrates this method. In these steeply dipping beds the ore is easier mined than in the flat-lying beds and can be mined in smaller thicknesses. In the flat-lying beds the cheap ore is won from the pillars, while in the steeply dipping beds the cheap ore is won from the stopes. Most fossil hematite contains some portion of the bed which is so soft that it can be bored with some hand-power auger drill.

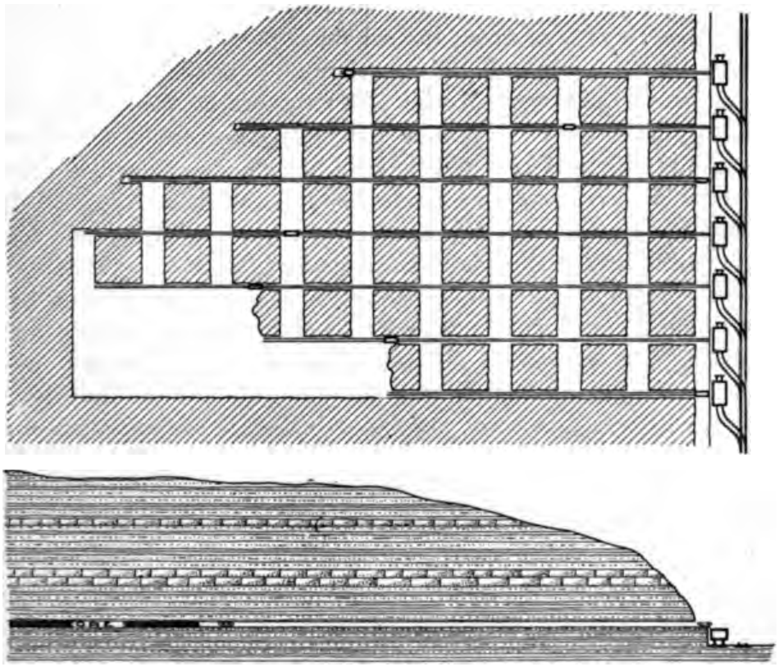

Fig. 75.—Diagram illustrating method of mining in flat-lying beds of fossil iron ore.

Ore Dressing.

Most iron ores mined in America are sent to the furnace as mined. As most of the Virginia iron ores are limonite, and as most of this occurs associated with clay it requires treatment before it can go to the furnace. In the limestone limonites the limonite constitutes from 3 to 25 per cent. of the total material of the bank. It is, then, obviously necessary to handle from 4 to 30 tons of material to get one ton of ore. In the Oriskany ore the limonite usually constitutes over half of the material mined. In the Blue Ridge limonites the limonite usually constitutes a smaller per cent. of the material mined than in the Oriskany ores. Some limonite ores have associated with them also in addition to the clay, silica in the form of flint, chert, quartz sand, or quartz crystals.

To remove the clay, log washers are used. A log washer consists essentially of an axis mounted in a gently sloping trough and having arms spirally arranged about the axis. The logs are usually mounted in pairs and revolve in opposite directions. The material to be washed is delivered to the logs from above well down toward the lower end while a stream of water enters at the upper end. The revolving logs agitate the material and deliver the ore to the upper end while the water carries the clay in suspension out at the lower end. Where the material washed contains sand, gravel, or flint this material is delivered with the ore. Sand is removed from the ore by a revolving screen, mounted so as to receive the heads from the washer. Where there is much coarse flint or mud balls, the sand screens are made to discharge to picking belts, tables, or inclined troughs where this objectionable material is removed by hand. Where there is considerable fine flint or gravel which is removed neither by the sand screen nor by hand picking, jigs are used. The separation by the jig depends on the different specific gravities of the ore and the objectionable material. In the process of jigging the sized material is delivered to screens where it is acted on from below by pulsing water which carries off the lighter material at a higher elevation than that at which the heavier ore is discharged. Jigging is a relatively slow and expensive process compared with washing. It is not used at most of the washers in Virginia.

In charcoal furnace days the limonite was usually roasted before it was sent to the furnace. The roasting was commonly done in open heaps which were formed of alternate layers of waste charcoal and ore. Rarely special kilns were used in which to roast the ore. In modern practice the ores are not roasted either for coke or charcoal furnaces.

Uses.

Iron ore is used chiefly for the manufacture of the metal iron. This use consumes all but a small quantity of the iron ore mined. Used for this purpose, the blast furnace produces pig iron from the ore. Of the pig iron thus produced in the United States in 1904, 84 per cent. was converted into steel. Iron ore is also used for paint, for fix or fettling in puddling furnaces and as flux in smelting the precious metals.

Production.

Iron Ore.										Pig Iron.	
Amount.							Value.				
			Kinds.					Per ton at the mines.			
Among the states as a producer of iron.	Percentage of the total iron ore mined in the United States which was mined in Virginia.	Total.	Red hematite.	Among the states as a producer of brown hematite.	Brown hematite.	Magnetite.	Total.	In Virginia.	In the United States.	Amount.	Average price per long ton of No. 1 foundry pig iron at Philadelphia.
Rank				*Rank*							
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6,931	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	18,810	$32.75
6	.....	67,319	.....	.....	.....	.....	$158,307	$2.35	$2.25	22,163	20.88
11	.....	23,217	.....	.....	.....	.....	.....	.....	.....	9,096	22.75
12	1.5	*47,168	.....	.....	.....	.....	108,258	2.18	5.75	*17,233	33.25
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*21,445	48.88
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*26,475	42.75
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*29,451	30.25
.....	.....	.....	.....	.....	.....		.....	.....	.....	*29,985	25 50
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*13,046	22.25
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*12,434	18.88
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*16,928	17.63
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*18,873	21.50
7	2.3	162,791	37,000	4	115,246	10,545	384,331	2.36	2.90	*29,934	28.50
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*83,71	25.12
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*87.731	25.75
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*152,907	22.38
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*157,483	19.88
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*163,782	18.00
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*156,250	18.71
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*175,715	20.92
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*197,396	18.88
7	3.4	498,154	8,746	2	483,208	6,200	935,290	1.93	2.30	*251,356	17.75
7	3.4	543,583	16,212	1	522,908	4,463	.....	.....	.....	*327.912	18.40
6	4.5	558,916	3,274	1	653,342	2,300	.....	.....	.....	*330,727	17.52
7	4.5	741,027	26,120	1	711,753	3,154	1,428,801	1.91	2.04	342,847	15.75
5	5.3	†616,965	41,665	1	568,800	6,500	1,050,977	1.70	1.66	302,856	14.52
.....	5.1	†600,562	35,843	1	562,493	2,226	873,305	1.45	1.14	298,086	12.66
5	4.5	712,241	36,815	1	674,926	500	987,077	1.39	1.14	346,589	13.10
4	5.4	859,466	31,271	1	828,195	.....	1,220,619	1.42	1.42	386,277	12.95
5	4.1	711,128	13,570	1	697,558	.....	974,031	1.37	1.08	307,610	12.10
6	2.9	557,713	2,963	1	554,750	.....	1,226,290	2.20	1.14	283,274	11.66
5	4.0	†986,476	17,173	1	968,143	1,160	1,766,410	1.79	1.42	365,491	19.36
4	3.3	†921,821	3,664	1	918,157	.....	1,489,318	1.62	2.42	490,617	19.98
5	3.2	†925,394	13,156	1	910,214	2,024	1,466,423	1.58	1.71	448,662	15.87
4	2.8	†987,958	31,677	2	953,128	3,153	1,667,456	1.69	1.84	537,216	22.19
5	2.3	†801,161	31,609	2	764,948	4,604	1,432,624	1.79	1.89	544,034	19.92
5	2.0	†550,253	17,952	2	528,853	3,448	951,478	1.73	1.56	310,526	15.57
.....	1.8	†752,045	35,357	2	711, 70	3,518	1,276,003	1.70	1.77	510,210	.....
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	483,525	.....

hort tons, all others are long tons.
ncludes a small amount produced by West Virginia.

The preceding table of production and value of iron ore and pig iron in Virginia is compiled from the publications of the U. S. Geological Survey, from the U. S. Census Report and from the Reports of the American Iron and Steel Association. From this table it can be seen that the ratio of the pig iron production to the iron ore production has not been a constant one. This is due to the fact that there has been both exportation and importation of iron ore. Prior to 1880 there was little transportation of iron ores to or from the State or even within the State. For the most part each furnace smelted its own local ore. About 1880 there was considerable shipment of ore to West Virginia and Ohio furnaces, chiefly from the region about Clifton Forge. At this time also there was some shipment to Pennsylvania of Piedmont magnetite and of Blue Ridge linomite. In recent years there has been considerable importation of Lake Superior ores. There has been at various times some small importation of ores from adjoining states. At present there is gossan coming into the State from Tennessee and fossil ore being shipped out from Lee county. The large increase in production of iron ore about 1880 was nearly coincident with the first extensive building of coke furnaces. The second rapid increase about 1890 was at the time of the second period of coke furnace building.

Since 1900 the iron ore production of the State has added to the wealth of the State $1,500,000 annually, while the annual value of the pig iron produced has been approximately $10,000,000. This State has had a constant and increasing production of iron ore for 180 years. The total value of the ore that has been produced in this time is estimated by the writer to be $36,000,000.

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II. COPPER.

General Statement.

The existence of copper ores in Virginia has been known since the early settlements in the State, and while many attempts have been made to mine the ores, resulting in the opening of many mines in each of the copper districts, not until recent years have they been, with one or two exceptions, produced in paying quantities.

In his "*A History of American Manufactures from 1608 to 1860*," Doctor J. Leander Bishop says on page 599 of Volume I: "Thirty hundred weight of copper ore with forty tons of Iron are mentioned by Anderson as having been received, ... from Virginia in 1730. In Mecklenburg county, on the Roanoke, not very distant, a mine of copper which promised considerable gold was operated about seventy years ago on the lands of Solomon Draper."

Distribution of the Ores.

The ores of copper have wide distribution over the State, although there are at present but few producing mines.

Geographical distribution.—The distribution of the principal copper deposits in Virginia is given on the accompanying map, figure 76. The known geographic areas of these ores in the State are:

I. The Piedmont Region.
   (a) The Virgilina District, which includes Halifax county, Virginia, and Person and Granville counties, North Carolina.
   (b) The deposits near Keysville in Charlotte county; those near New Canton, Arvonia, and Dillwyn, in Buckingham county; and those on or near Southwest Mountain in Albemarle county.

II. The Blue Ridge Region.
   Includes those deposits from near Front Royal southward, and embracing parts of Warren, Fauquier, Rappahannock, Madison, Page, and Greene counties.

III. The Southwest Virginia Region.
   Includes the "Gossan Lead" of the Floyd-Carroll-Grayson counties plateau.

IV. The Triassic Areas.
   Includes the deposits near Leesburg and Drakeville, in Loudoun and Culpeper counties.

Geological distribution.—The copper ores are confined, geologically, to the crystalline rocks, either the schists or the massive igneous rocks, of the Piedmont and Blue Ridge regions, and to the red shale—sandstone series of the Triassic areas. The ores in the Virgilina district and a part of those to the northeast, near Keysville, in Charlotte county, occur in quartz fissure veins, which intersect masses of altered volcanic rock (meta-andesite) of pre-Cambrian age. Those of the Blue Ridge region of northern Virginia are disseminated through and segregated in, basaltic flows of pre-Cambrian age, designated by Keith as Catoctin schist.

The "Gossan Lead" of the Floyd-Carroll-Grayson plateau, in southwest Virginia, is apparently a mineralized faulted zone in crystalline schists of doubtful age, probably pre-Cambrian in part. The rocks are in part altered sediments and in part igneous masses of basic and acid types, principally the former.

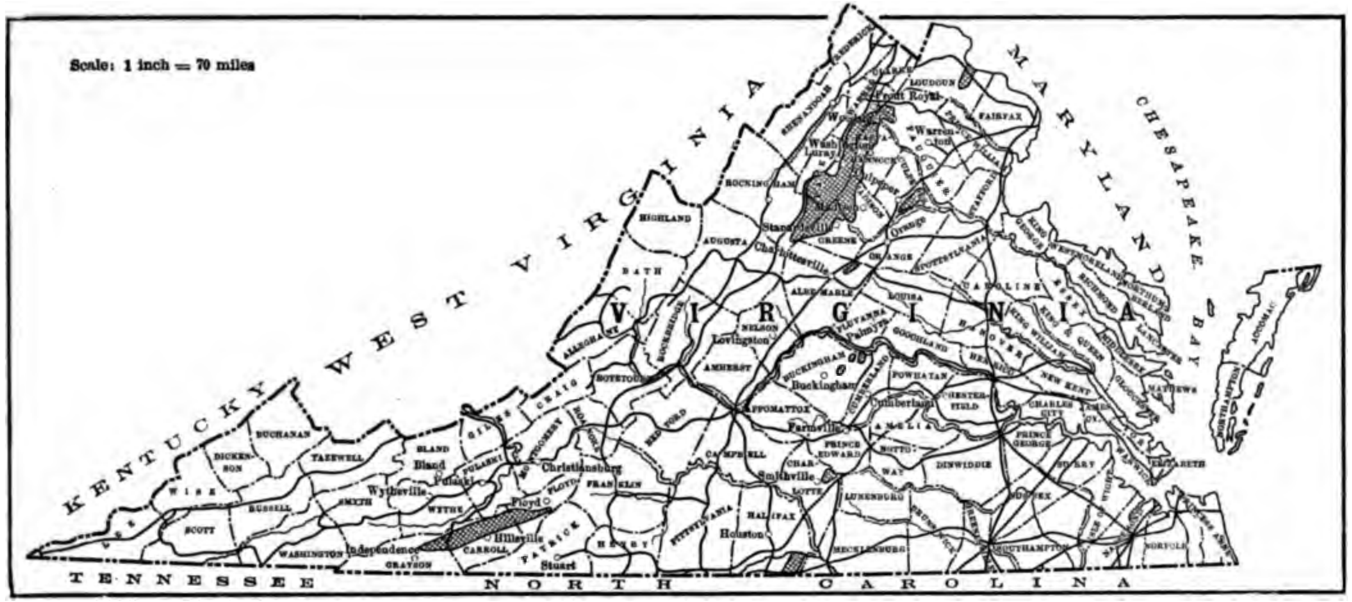

Fig. 76.—Map of Virginia showing distribution of the principal copper areas. Cross-lined areas represent copper. (After Watson, E. & M. J.)

The geologic conditions are so unlike in the different copper areas of the State, that the kinds of ore, their association and genesis, must be considered separately by areas, as enumerated above.

THE VIRGILINA DISTRICT.

Introductory statement.—The Virgilina copper district, which derives its name from the town of Virgilina, located on the Virginia-Carolina boundary, is situated 47 miles east of Danville, on the Atlantic and Danville division of the Southern Railway. The Norfolk and Western and Richmond and Danville roads lie not far to the north and west.

The mines thus far developed all lie upon a low ridge, a flat-topped elevation of from 100 to 250 feet above the neighboring stream-valleys, which is from 2 to 3 miles in width. Prospecting and mining are confined to an approximate north-south distance of 18 miles along the ridge, and to an average cross distance of from 2 to 3 miles. Although of no conspicuous height, the ridge forms a somewhat prominent feature in the landscape, and is traced northward in Virginia for a continuous distance of 10 miles. A similar area is found as far north as Keysville in Charlotte county. In North Carolina its southward extension is estimated by Hanna to be about 30 miles, reaching nearly to Durham.

General geology and petrography.—The country-rock is schist. Natural outcrops are relatively rare and seldom more than 2 or 3 feet high, forming sharp and narrow reefs which are persistent for short distances only. The microscope reveals the igneous origin of the rocks, though their true igneous nature is usually not readily recognized in the field. Ordinarily they are schistose, soft, green and purple colored rocks, the schistosity having a strike of N. 10° to 20° E., and an eastward dip of from 70° to 80°. Diabase dikes of later geologic age cut the schists in several places.

The minerals composing the altered volcanic rock are: Plagioclase, light green amphibole, chlorite, epidote, zoisite, calcite, iron oxide (partly magnetite), quartz and apatite. Of these, only the feldspar, a part of the iron oxide (magnetite), and apatite are original. Both chlorite and epidote, intimately associated with more or less hornblende, are abundantly developed in most of the thin sections, sometimes one, sometimes the other, predominating; but the two are at all times intimately associated.

Kinds and occurrence of the ores.—The workable ores comprise chalcocite or glance (copper sulphide) and bornite (copper-iron sulphide) in quartz, and to a slight degree impregnations of the country-rock adjacent to the veins. At shallow depths cuprite (copper oxide) and malachite (green copper carbonate) occur as alterations of the original sulphides. A little native copper occurs in places. Chalcopyrite and pyrite are almost entire-

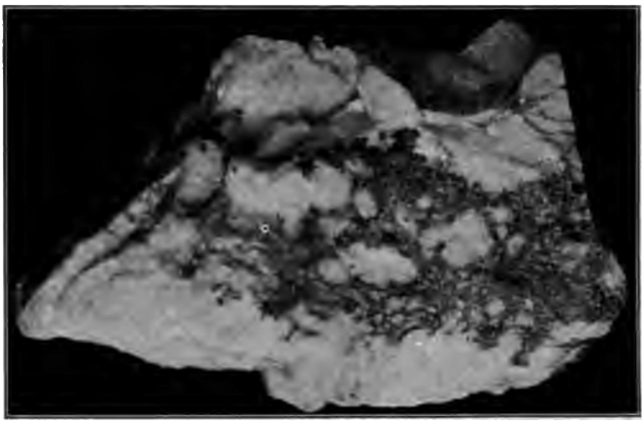

Fig. 1.—Specimen of copper ore (chalcocite and bornite in quartz) from the Virgilina copper district—Virginia and North Carolina.

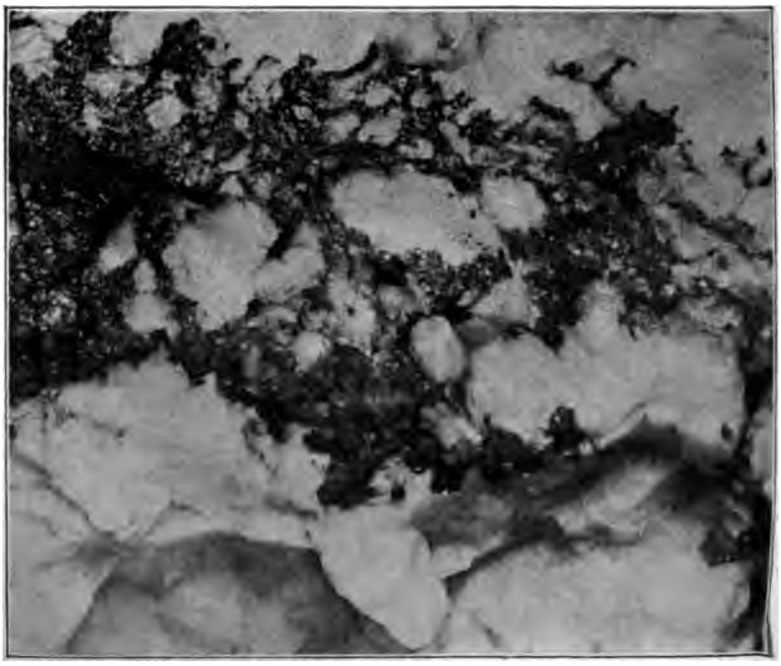

Fig. 2.—Specimen of copper ore. Same as Fig. 1.

COPPER ORE, VIRGILINA DISTRICT, VIRGINIA.

ly absent, although the latter is more abundant in the High Hill mine on the Virginia side than in any of the North Carolina mines belonging to this area. The ores are free from arsenic and antimony, but they carry at times very appreciable values in gold and silver, particularly the latter.

The ore occurs in quartz veins. In some places it is disseminated as finely divided particles through the more massive portions of the rock, with the workable ore entirely confined to the quartz veins. The gangue is composed chiefly of quartz with considerable calcite and epidote admixed locally. Plate LXXI shows the occurrence of the ore, bornite and glance, in the quartz gangue.

The veins.—The district has many veins, which in general are more or less parallel, having a course of N. 5° to 10° E., and having overlapping ends. These cross the schistosity of the enclosing rock in part, and in part are parallel to it.

Mining developments show that copper occurs in almost all of the veins in greater or less quantity. The veins are lenticular bodies of quartz, and forming in some cases very uniform continuous outcroppings at the surface. They show, in general, a lenticular structure, and like the gold veins of the southern Appalachians, they appear to be a succession of lenses connected by stringers of quartz. Figure 77 shows the bulbous or lenticular form of the quartz veins. The largest veins show outcrops nearly continuous for a half mile to a mile and more, and the underground workings show a continuous body of quartz. Even the largest veins have a bulbous or lenticular form, and the veins pinch and widen both horizontally and vertically. This is strongly marked in the smaller veins, and the lenses are frequently connected by a mere film or plate of quartz, which in certain horizontal cross-section may be wanting so that the vein appears to have given out.

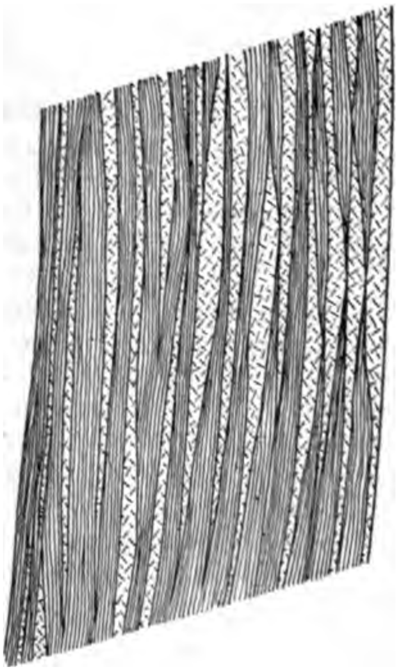

Fig. 77.—Diagram illustrating the structure of veins formed by the tearing apart of schist included between fault-fissures or adjacent to fissures. (After Weed and Watson.)

A marked banded structure is sometimes observed in the veins, commonly seen near the walls, though it some-

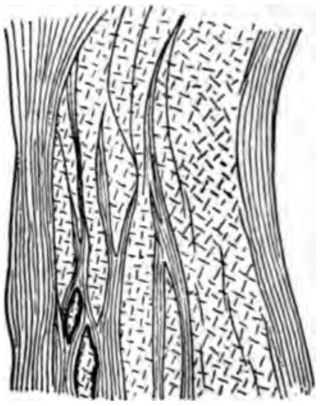

Fig. 78.—High Hill vein at shaft No. 4. North face of 60-foot level. Vein 8 to 9 feet wide. Soft, fissile schist on the right. (After Weed and Watson.)

times prevails for the entire width of the vein. This banding is due to included plates of the altered schist, which are often so thin as to be mere films or dark streakings in the white gangue. Figure 78, a section of the High Hill vein at shaft No. 4, Halifax county, shows the banded structure. The schist-films are often marked by ore. In places the banded structure is marked where the gangue consists largely of calcite. In some cases it appears as though a slight movement had torn apart the wall in a ragged way and quartz had filled in between the sheets of rock.

The veins show a general uniform strike of N. 5° to 10° E., though there are a few exceptions in which cross veins show a direction of as much as N. 20° E.

Description of the Mines.

Historical.—The district has been more or less prospected for the last 50 or more years, as shown by the pits and shafts extending 8 miles north, and as far south, of the State line.

In the North Carolina portion of the belt, the Gillis mine was operated as early as 1856, and a fine body of glance ore exposed. Considerable activity was manifested in the district in 1886-87 when the Blue Wing mine was opened and 500 or more tons of the ore extracted. The Yancey mine, now one of the mines of the Person Consolidated Company, was prospected at this time, but on account of unfavorable reports made by experts, it remained idle until 1897. The district was again the scene of active operations in 1897, and some 225 carloads of the ore were taken out and shipped. Active prospecting and development work were again in progress from 1898 to 1904. Just at this time, 1906, only one property is producing in the district, namely, the mines of the Person Consolidated Company, located on the southern end of the belt in North Carolina.

INDIVIDUAL MINES.

Figure 79 is a sketch map of the Virgilina copper district showing the location of the principal mines.

The High Hill mine.—Although idle at present, 1906, the High Hill mine is one of the largest and most important mines in the Virgilina copper district. The property comprises 620 acres of land, located 9 miles north of Virgilina. It extends from the banks of the Hyco river southward to the cross-roads leading from South Boston. It is owned by the Virginia Copper Company and it represents the most important development in the Virginia part of the field.

The property is crossed by several well-defined and persistent veins which have been developed as follows: In 1904, the main or principal vein was prospected for a distance of 9,702 feet, and the second parallel vein a distance of 6,204 feet. The westernmost of the two, or the High Hill vein, is clearly traceable for 3 miles, extending from the Hyco river to a point one mile south of the company's holdings. A careful examination for the entire distance reveals very generally a quartz outcrop, rising from a few inches to 3 feet above the surface, and from 2 or 3 to 12 or 15 feet in width. In a few places it is broken down and can only be recognized by a scattered quartz drift. It is very persistent in direction and has been opened by an adit (tunnel) and by 12 shafts, every one of which shows ore.

The only place where the adjacent schists have been exposed is at the No. 7 shaft, where a pit 20 feet deep and about 20 feet west of the shaft shows schists impregnated with copper and bornite. Throughout most of the property the outcrop is from 125 to 166 feet above the river. The 7 most northerly shafts are well timbered and expose the vein at depths of from 55 to 140 feet. Both veins are found to be highly mineralized for their entire distance. In March, 1904, the No. 4 shaft was 339 feet deep and the No. 3 shaft 367 feet deep, both vertical. (Plate LXXIV, figure 2.) The average amount of shaft sinking was 1,149 feet, with 2,306 feet of levels opened up but not stoped.

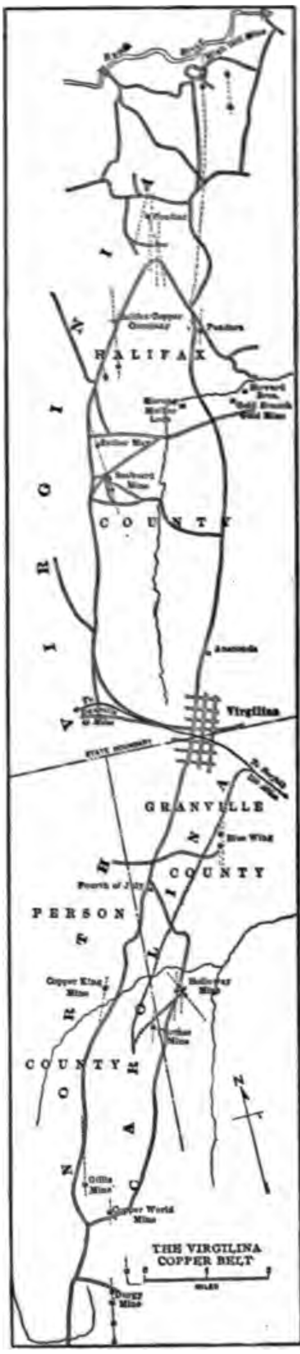

Fig. 79.—Map of the Virgilina copper belt showing location of principal mines. (After E. K. Judd.)

The High Hill vein is almost continuously copper-bearing though of unequal value. The average width is 4 feet, and the ore-shoot developed by shafts Nos. 3 and 4 is about 1,000 feet long; that of No. 2 shaft is about 200 feet long.

The shafts nearest the Hyco river are 107 feet deep and are connected by a level 180 feet, and is continued 130 feet further south from the shaft. No. 8 shaft is 72 feet deep and has a 9-foot drift at the bottom. A total of 167,000 pounds of ore have been shipped which averaged about 15 per cent. copper; the richest carload showed on sampling 27.83 per cent.; the poorest 7.6 per cent. The gold and silver values are variable but samples from the stock piles of first class ore yielded 8.46 oz. of silver and 0.22 oz. of gold, per ton.

The equipment at the High Hill mine is extensive, including steam-hoists, boilers, air-compressor and drills; and a commodious mill containing crushers, pump, packing belt, trommels, jigs, hydraulic classifiers, and Wilfley tables. The company has produced up to March, 1904, 212,455 pounds of refined copper and 2,485 pounds of refined silver. The concentrates carry $4.00 per ton in gold.

The Anaconda mine.—The Anaconda mine is located close by the main road about 1.5 miles north of Virgilina. The vein is opened by a shaft 140 feet deep with drifts run north and south on the 100-foot level, 85 and 115 feet long respectively. About 7 carloads of ore have been shipped from this mine which varied from 3 per cent. of copper in the first carload to 12 per cent. in the last 5 carloads shipped. It is expected that the vein, which promises well, will be further developed as it has not received an extensive trial. The ore thus far extracted has been taken from one shoot.

The Dorothy mine.—This mine is located on the west side of the ridge 3.5 miles northwest of Virgilina and is developed by 2 shafts which are 60 and 100 feet deep, respectively, with levels run at the 25- and 100-foot levels. One carload of ore has been shipped and several are on the dump.

The Halifax Mining Company's mine.—The Wall mine located about halfway between the High Hill mine and the town of Virgilina is owned by the Halifax Mining Company. The vein is about 4 feet wide and is developed by a shaft 150 feet deep with drifts extending north and south from it.

The Chappel mine.—This mine joins the High Hill property on the northeast. It is developed by two shafts 55 and 87 feet deep with about 150 feet of drifts.

Other openings.—Numerous smaller prospect openings have been dug on the outcrop of the veins north of Virgilina in Halifax county, Virginia. In nearly every one of these reasonably good indications are shown, but in

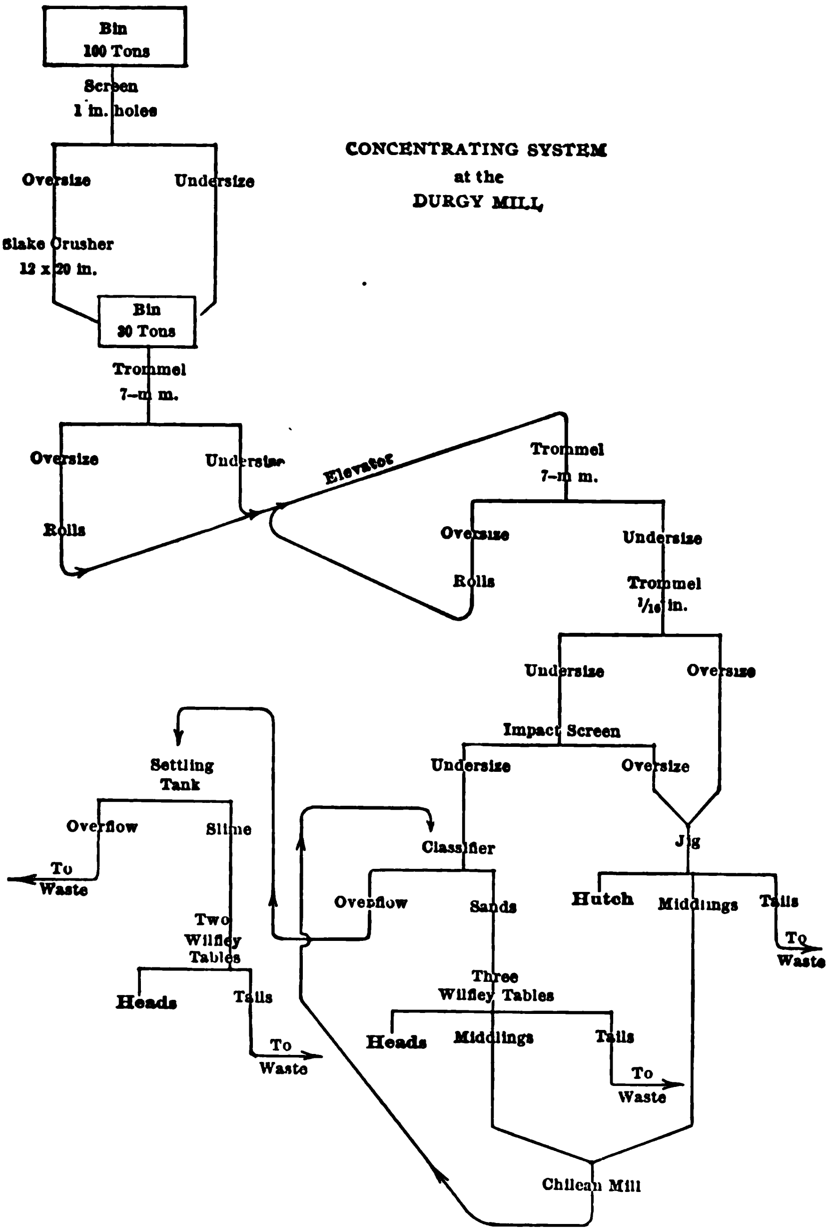

Fig. 80.—Concentrating system at the Durgy mill, Virgilina copper belt. Person county, North Carolina. (After E. K. Judd.)

most of them developments have not extended far enough to warrant definite statements.

Figure 80 gives the scheme for concentrating the ore at the Durgy mill in the North Carolina portion of the Virgilina district.

THE KEYSVILLE AREA IN CHARLOTTE COUNTY.

Several prospects for copper ore have been worked in the vicinity of Keysville in the northeast corner of Charlotte county. The nearest one 2.5 miles southwest of Keysville comprises a shaft and several open pits sunk in a belt of sericite-quartz schist. The foliation of the schist shows a northeast southwest strike, and a dip of about 80° southeast. The ore is green carbonate, malachite, associated with quartz lenses and stringers, which conform to the foliation of the inclosing schist. The openings had been abandoned when visited in July, 1906, and very little ore was in evidence.

The second prospect, located about 6 miles southwest of Keysville and known as the *McNeny mine*, was working in July, 1906. The first opening, a shaft about 60 feet deep, was made 12 years ago, and is about a quarter of a mile east of the Weaver shaft which was working during July of the present year. Some work was done in 1905 and again resumed in March, 1906. The shaft is sunk on an incline of 30° to the southeast, following closely the dip of foliation of the rock, and in July had reached a depth of 100 feet.

The copper-bearing rock is identical, lithologically, with that of the Virgilina district, lying a short distance to the southwest, and is accordingly an altered volcanic rock, andesite. It is thinly schistose and otherwise much altered by epidotization. So far as developments have gone the quartz masses carrying the ore conform to the foliation of the inclosing altered volcanic rock. The quartz bodies are apparently not so large as those in the Virgilina district, but the character of the ore, its occurrence and associations, are similar to those of the Virgilina district. Gray glance (chalcocite) and bornite, with some green carbonate, malachite, make up the ore. Glance seems more abundant than bornite. Neither pyrite nor chalcopyrite was observed. Lean ore occurring as impregnations in the altered volcanic rock is sometimes observed next to the quartz masses.

THE BUCKINGHAM COUNTY DEPOSITS.

Copper ores have been prospected at three localities in the northeastern part of Buckingham county, namely, near New Canton, Arvonia, and Dillwyn. Neither of these localities has as yet proved productive, although the prospects are reasonably encouraging, especially at Anaconda, 5.5 miles northwest of Dillwyn, and at the Lightfoot mine, 2 miles northwest of Arvonia.

New Canton mines.—Beginning at a point three-quarters of a mile south of New Canton, and extending for a distance of nearly a mile along a southwesterly course, a number of openings, principally shafts, have been sunk. The most extensive workings are on the Johnson place, formerly known as the *Staples mine,* where the main shaft has reached a depth of 265 feet, with a total length of 1,000 feet or more of drifts, run at different levels from the shaft.

The country-rock is mica schist, partly chlorite, and usually more or less garnetiferous. The foliation has a general strike of north 20° east, and a dip that is very nearly vertical. At the *McKenna shaft* the ore is largely pyrite, containing some intermingled chalcopyrite, which occurs principally as thin lenses interspersed within the schist as impregnations, while thread-like stringers of ore occasionally cut across the foliation of the rock. The mineralized zone varies from a fraction of an inch up to 2 feet.

At the *Johnson shaft,* 450 feet southwest from the McKenna shaft, pyrrhotite is associated with pyrite and chalcopyrite; and in places, glassy crystalline grains and larger pieces of quartz, often more or less rounded, are incorporated in the ore. Garnet is also occasionally found associated with the ore. Further, at the Johnson shaft, the ore is associated with a hard and fine-grained, dark greenish-gray, massive rock, resembling an altered igneous type. The ore is reported to be both gold- and silver-bearing.

The United States Mineral Company's mine.—This company has recently done some development work with promising results at Anaconda, formerly known as Eldridge's Mill, situated 5.5 miles northwest of Dillwyn, and 4 miles west of Johnson, stations on the Buckingham branch of the Chesapeake and Ohio Railway. Pay rock has been taken from a 60-foot shaft sunk at this locality.

The copper-bearing rock is a fine-grained, dark green, eruptive rock, which has been greatly altered by pressure, and the development of chlorite and epidote, being not unlike that of the Virgilina district. Crystals of red garnet are not uncommon in the rock. The ore is cupriferous pyrite with some chalcopyrite occurring principally in quartz masses, which usually conform with, but at times cut across the foliation of the inclosing eruptive rock. Some secondary green carbonate, malachite, derived from the sulphides, occurs.

The Lightfoot mine.—The Lightfoot mine is located about 2 miles northwest of Arvonia, directly on the east side of Slate creek and at an elevation of about 20 feet above the stream level. The ore-bearing rock is a dark green thinly foliated chloritic schist, which bears striking evidence of its derivation from an original eruptive rock. It is quite similar to that described above from the United States Mineral Company's mine 5.5 miles northwest of Dillwyn. The rock is considerably epidotized in places, is crushed and fractured, and carries quartz stringers and eyes. Some small masses of calcite were observed. Strike of the schistosity is northeast-southwest with a steep northwest dip.

The mine is developed by an 85-foot shaft from which several short drifts have been run. Preparations are now in progress for sinking the shaft several hundred feet deeper, extending the drifts, and opening new ones on lower levels.

Much ore is in evidence both on the dump and in the shaft. It comprises cupriferous pyrite chiefly, with some chalcopyrite. Good values in gold are indicated by a large number of assays made of the ore.

THE ALBEMARLE COUNTY DEPOSITS.

The Stony Point copper vein.—Northeast of Charlottesville on the western foot-slopes of Southwest Mountain, in Albemarle county, is a vein cutting through micaceous schists which was worked for about a year as an iron deposit. The upper part of the vein, the gossan, is composed of limonite which was shipped to the Pittsburg furnaces.

The mines are located in the foot-hill country at the west base of Southwest Mountain, on a small branch of the North Fork of Rivanna river. They are located about 2 miles to the east of Stony Point and a quarter of a mile from the main Charlottesville pike. The mines are 2.5 miles from the railroad and 12 miles from Charlottesville. This property was bought by Major Mason in 1878 who worked it in 1885. Numerous openings have been made including shaft, drifts and open cuts, or pits. The shaft which is inclined is reported to have reached a depth of 130 feet. The principal mining has been the gossan for iron ore, of which 2,500 carloads are reported to have been shipped, some of which is reported to have averaged very high in iron. Mining was discontinued here about 15 years ago.

The country-rock is a bleached and altered, thinly foliated, sericitic schist. The hanging-wall rocks appear to be more altered than those of the foot-wall. The vein is from 5 to 6 feet wide, which width is nearly uniform throughout its extent. In the northern part of the property the

vein strikes north 35° east (magnetic) and dips 55° south. To the south end of the property the vein strikes south 80° east. It consists of a solid mass of gossan which appears when broken more or less cellular, with siliceous portions and occasionally with quartz streaks. The dump is composed of siliceous iron ore with occasional blocks of white quartz containing bands and thin layers of chalcopyrite. No pyrite was observed either in the quartz or in the altered schists about the vein.

The iron of the gossan has probably resulted from the alteration of chalcopyrite, which alteration extends to a depth of more than 100 feet. It seems not improbable that a thickness of secondary copper glance will be encountered between the gossan and the unaltered primary ore. Samples of the chalcopyrite were assayed with reported yields of $5.00 per ton in gold and 15 per cent. in copper.

AMHERST COUNTY DEPOSITS.

Amherst county contains green-stained rocks at the *Folley*, and numerous old openings attest the endeavor of earlier explorers to find workable deposits. Professor Rogers again remarks, "that no distinct vein or bed of copper ore is indicated, but rather an impregnation of the talcose rock of the neighbourhood. more or less strongly with the compounds of the metal. In some of these places the manufacture of copper has been attempted, but without the success that would justify a prosecution of the enterprise."

THE BLUE RIDGE COPPER DEPOSITS.

Location and history.—As indicated on map, plate LXXII, the Blue Ridge copper region is located in the northern part of the State, and includes those deposits from near Front Royal southward and embracing parts of Warren, Fauquier, Rappahannock, Madison, Page, and Greene counties. Copper ores have been known to exist in the Blue Ridge mountains since the earliest settlements. The native copper of the region probably furnished the Indians with the metal from which their ornaments and axes were made.

A few attempts were made to extract the metal in colonial times but not until 1854-56 were large sums of money expended in this region in attempts to work the ores. Operations were suspended at the beginning of the Civil War and the properties remained practically idle until within the past 10 or 12 years, when attempts were again made to work the ore at many places over the region. During the past 2 years, 6 companies and a few private individuals have been engaged in development work.

Geology.

In the copper region, the Blue Ridge is made up of a central core of igneous rocks, mostly a dense and black basaltic type flanked by syenite and other igneous types, frequently altered to schistose forms. Resting against these rocks at the base of the mountains and forming the Valley region to the west is the folded sedimentary series, which Keith designates as Cambro-Silurian in age. So far as known the sedimentary rocks are not copper-bearing but the ores of the region are confined to the igneous rocks of the basalt type.

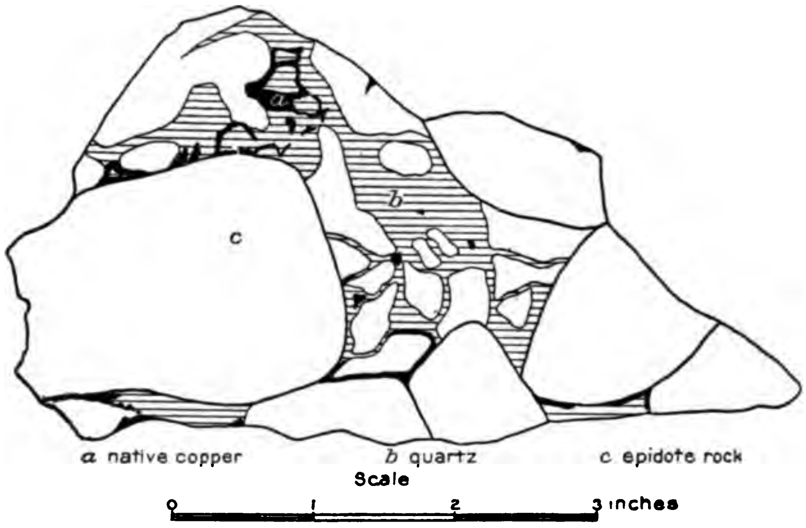

Fig. 81.—Brecciated epidotized basalt with ore and quartz. Stony Man Peak. (After Weed and Watson).

The basaltic rock is dense, heavy and dark-colored, and parts of it are altered and sometimes schistose. According to Keith the schistose character of the rock is emphasized in the Harper's Ferry region and the rock is designated by him Catoctin schist. Further south in the copper region the schistose character of the rock is much less well-defined, though in places it is sheeted vertically from close jointing along shear zones.

Keith recognizes two varieties of the basalt near Harper's Ferry, a lower diabase sheet and an upper basalt sheet, both altered and the upper one largely epidotized. An amygdaloidal phase of the upper epidotized sheet is shown in places. A coarse-grained, usually massive, and dark grayish green syenite has been traced at irregular intervals along the west side of the mountains from Dickey's Hill south of Front Royal in Warren county, southward to High Top in Greene county.

The upper sheet of basaltic rock is generally much altered by secular decay and in part forms a greenish chlorite and epidote schist. According to Keith the igneous rocks including the basalt or Catoctin schist are Algonkian (pre-Cambrian).

Character and Mode of Occurrence of the Ores.

The ores consist chiefly of cuprite and native copper with small amounts of the sulphides, bornite and chalcopyrite. The native copper often occurs as nucleal masses surrounded by cuprite. Bornite is in excess of chalcopyrite. The ore occurs along crevices and joint-planes, in small, irregular shaped lenses of quartz, and as disseminated grains through the more epidotized portions of the basalt. It occurs mostly where the rocks are fractured and epidotized as shown in figure 81. When ore-bearing the rocks are yellowish-green in color, due largely to the formation of epidote and in part of chlorite. Figure 82 shows a partial basalt shell filled with epidote, and the epidote rimmed by bornite next to the basalt. Figures 83 and 84 show the occurrence of native copper in quartz and in asbestiform serpentine.

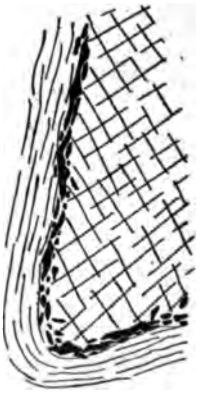

Fig. 82.—Part of basalt shell filled with epidote and rimmed by bornite "Empire Vein," Warren county. (After Weed and Watson.)

The ores do not extend more than 50 feet below the surface at many of the localities and at some it is less. From their occurrence in shear zones in the rock; from the confinement of the ore mainly to the secondary epidote and quartz veinlets; and from the character of the ore itself, it is believed that the ores have been formed by a concentration of material leached out of locally copper-rich portions of the igneous rocks. The shear zones have afforded a place for the gathering of these solutions and the deposition of material. The ores seldom occur in actually continuous masses, but can sometimes be traced for miles by the copper-bearing debris.

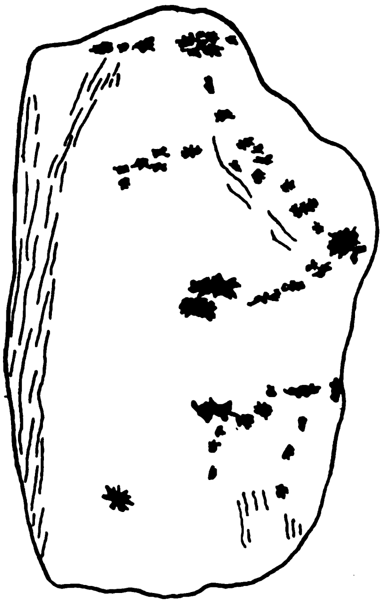

Fig. 83.—Quartz with a little calcite and native copper. Black areas copper. Lined area schistose basalt. Fletcher, Greene county. (After Weed and Watson.)

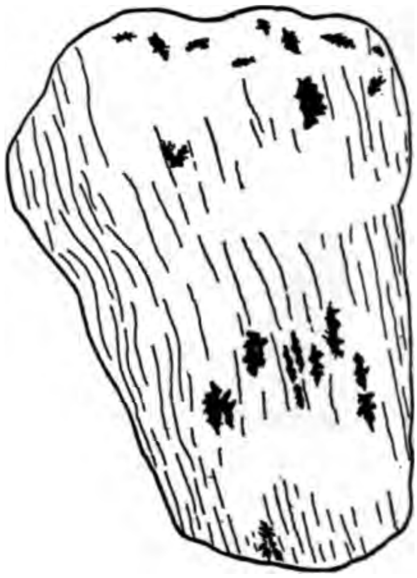

Fig. 84.—Asbestiform serpentine with native copper. Black areas copper. 7 miles southeast of Luray, Page county. (After Weed and Watson.)

DESCRIPTION OF THE MINES.

Warren County.

The copper ores found in the region east and south of Front Royal have attracted attention for many years. In recent years several mining companies have done more or less exploration work and their shafts and tunnels have afforded a favorable opportunity for the study of geologic conditions. The district embraces the main Blue Ridge summit extending from Linden southward.

East of Front Royal and south of Linden, on a tract of land reported to have been originally granted to Lord Fairfax and subsequently transferred to Chief Justice Marshall, good indications of copper appear in the outcrops and as loose masses over the surface. In the early part of the last century a number of shallow pits were sunk at several places, but no shipments were made until 1861, when 35 tons were collected from the surface and from a 50-foot shaft and shipped abroad. This shipment of ore is reported to have averaged over 10 per cent. in copper.

The Sealock property.—This property has been very extensively developed by shafts, drifts, and small openings. It is located about 3 miles in a direct line from Linden. The principal shaft on this property, known as the Phillips' shaft, was sunk to a depth of 80 feet, and a considerable quantity of good ore is reported to have been extracted. A recent tunnel 200 feet long has been driven into the hillside on another part of the property with the object of cutting the so-called copper "vein" on which the Solomon shaft was driven. The ore thus far taken out consists chiefly of native copper and cuprite with malachite, the green carbonate, and a small amount of azurite, the blue carbonate. Some chalcopyrite also occurs. An examination of the dumps at many of the openings on this property by the writer in 1905 showed many beautiful specimens of copper ore.

Dickey's Hill mines.—Dickey's Hill forms a high outlier of the Blue Ridge proper, lying to the west of the main divide. The copper ore is not uniformly distributed over this ridge but occurs in a few localities where more or less work has been done to determine the size and character of the ore-bodies. The *Mill's property (Cove Farm)* represents a recent working located about 8 miles from Front Royal.

In 1905 a copper-bearing outcrop of epidote rock exposed in a ledge 50 feet long and 20 feet wide and located about 200 feet below the summit of the mountain had been opened. The opening was a cut about 7 feet wide and 35 feet long extending back into the hillside. The copper ores comprised native copper, malachite, and azurite, chrysocolla, and lower down a litte bornite. At the time of my visit in 1905 the property had not been sufficiently developed to warrant a definite statement.

Rudacill property.—In August, 1905, this property was being worked by the Virginia and Pittsburg Copper Company. The company has made openings at two points on the south end of Dickey's Hill near the summit, where some shallow openings have been put down and a couple of cabins erected. At that time the workings were located in the cove southeast of the end of the ridge at a point halfway up the slope, comprising a cut about 75 feet long, and about 100 yards distant therefrom, and a shaft sunk to a depth of about 50 feet. The ore comprised native copper, considerable carbonate, malachite, and copper oxide.

The Bentonville-Overall District.

This district is located 12 to 15 miles south of Front Royal and some of the earliest prospecting for copper in the Blue Ridge region was to the south of Bentonville, a station on the Norfolk and Western Railway. Within the past 12 or 15 years considerable work has been done on a number of properties in this vicinity.

In 1905, operations had been suspended except some prospecting work on the *Empire "vein"*, located on the summit of the ridge known as Mathews Arm, near the Page-Warren county line. Several pits have been dug on the Empire "vein" showing chiefly malachite with some bornite and cuprite.

In 1903-04, a shaft and several openings were put down on the *Martin* property, located about 2 miles northwest of the Empire "vein" and about 2 miles southeast of Bentonville, about halfway down the ridge slope. The shaft is reported to have reached a depth of 90 feet. An inspection of the material on the dump showed the ore to consist essentially of malachite and azurite with some bornite.

A second shaft is located lower down on the ridge toward the southwest on the land of F. C. Hartley. This is of long standing and was worked more than 30 years ago. Several other smaller openings, some of which are recent others of long standing, are made in the vicinity.

Rappahannock County.

The Ambler property.—Several openings have been made on this property comprising an open cut and tunnel, a shaft and several smaller openings. The shaft is sunk on the north end of the property some distance below the ridge crest and is reported to be 40 feet deep. An examination of the dumps from the shaft showed bornite and native copper with malachite. Similar conditions were noted at the open cut and tunnel. A couple of miles from the Sealock property is a fine exposure of copper ore in a rocky ledge known as Cottam rock on the Ambler place.

The Manassas Gap Copper mine.—The openings of this company are located on the slope near a small stream, which forms a part of the headwaters of the Rappahannock river, distant from the latter about 600 feet and 6.5 miles south from Front Royal. Openings have been made on the property at five different places, 4 of which are on the east slope of a steeply sloping ridge, the other on top of the ridge, Raven Den Mountain. These comprise shafts, tunnels, and some open work. The greatest depth reached in the shafts is reported to be 60 feet and the most extensive tunnel approximates 200 feet in length. The same kind and character of ore was observed by the writer on the dumps at these openings as from

Fig. 1.—View showing shaft house, ore dump, and basalt cliffs, at the Blue Ridge Copper Company's mine, Madison county. (Unpublished report by Weed and Watson.)

Fig. 2. View of the shaft house at the Virginia Consolidated Copper Company's mine, near Ida, Page county. (Unpublished report by Weed and Watson.)

COPPER MINES IN THE NORTHERN BLUE RIDGE REGION, VIRGINIA.

the mines described above. In 1905, the company's equipment comprised a saw-mill, blacksmith shop, and a varied assortment of mining tools.

Page County.

The copper properties southeast of Stanley, in Page county, lie on the flank of the Blue Ridge to the east and west of the summit of the ridge, which forms the dividing line between Page and Madison counties. The district has long been known as showing some of the most promising outcrops of copper ores in the Blue Ridge region, and the development near Ida post-office, on the headwaters of Hawk's Bill creek and in Dark Hollow are more extensive than any other part of the Blue Ridge.

The Virginia Consolidated Copper Company's mine.—One of the most extensive developments in the Blue Ridge district of Virginia is that of the Virginia Consolidated Copper Company, with head offices at McKeesport, Pennsylvania. The property, comprising 160 acres, is located on one of the foothills at the west base of the Blue Ridge, about one mile west of Ida, and about 5 miles southeast of Luray. The company has made extensive developments but operations were temporarily suspended in January, 1905. A manager's house, a laboratory, shaft-house and other outbuildings have been erected, and the shaft-house equipped with 2 12-H. P. Fairbank-Morse gasoline engines; the one for hoisting, the other for ventilation and working two compressed air drills.

In the summer of 1905 an incline shaft had been sunk 308 feet deep, with drifts run on the 80-, 120-, and 280-foot levels. The drift at the 80-foot level extends for 70 feet to the east. The 120-foot level has been driven from 180 feet west in solid rock. The 280-foot level shows 250 feet of work. (The shaft house at this mine is shown in plate LXXIII, figure 2.)

The ore comprises the oxidized forms, malachite and azurite, and some red oxide and native copper. No sulphide ores were seen by the writer.

Madison County.

The Blue Ridge Copper Company's mine.—The property of the Blue Ridge Mining Company of Chicago comprises about 180 acres of land in Dark Hollow, at the head of Robinson river and about one mile to the southeast of Milam's Gap (also known as Fisher's Gap), very near the crest of the Blue Ridge. This is the best developed property in Madison county. The exposures of copper ore found in this vicinity are reported to have been worked before the Civil War, but they have been abandoned for many years.

The operations of the present company were begun some 5 years ago. The workings comprise what is known as the old shaft or shaft No. I, located at an elevation of about 250 feet above the confluence of the two main head-water branches of the Robinson river. This shaft and the small opening a short distance to the southwest were made some years ago. Two drifts were run from the shaft, one in a north 12° west direction for 20 feet, and the other in the opposite direction for 9 feet. A few tons of ore are reported to have been shipped from this shaft. (Plate LXXIII, figure 1.)

The new shaft, No. 2, is an incline 42 feet in length and located about 100 feet below the mouth of the old shaft. From the bottom of this incline a drift has been run for 40 feet in a northeasterly direction for the purpose of intersecting the zone of copper-bearing rock on which the old shaft was started. In 1904, a third shaft was begun, located northwest of and higher up the hill than the old shaft, No. 1.

The ores found in these openings comprise native copper, blue and green carbonates, a little cuprite and some chalcopyrite. The workings of this company are located quite close to the contact of basalt and syenite, shaft No. 2 being not more than a stone's throw away. The ore is confined to the basalt and as yet has not been observed in the syenite.

Stony Man openings.—To the northeast of Milam's Gap and near Stony Man peak some prospecting for copper ores was done many years ago. A shaft filled with water at the time of my visit is reported to have reached a depth of 60 feet, with the usual quantity and mineralogical forms of ore shown as described above.

Greene County.

The Blue Ridge region of Greene county contains several copper prospects, only two of which have been opened by mining operations. These are the *Sims mine,* 5 miles north of Stanardsville, and the mines of the *Hightop Copper Mining Company,* 7 miles east of Elkton.

The Sims mine.—The Sims mine is located 5 miles north of Stanardsville, the county-seat of Greene county, and on the eastern slope of the Blue Ridge. A number of shallow openings have been made in places and a shaft 30 feet deep has been sunk. A short cross-cut driven 25 feet north is made at a depth of 30 feet. The ore is native copper, cuprite and chalcopyrite in small amounts.

The Hightop Copper Mining Company's mine.—The mine of the Hightop Copper Company, the most extensively developed one in Greene county, is located 7 miles east of Elkton on the summit and southern side of the

Fig. 1.—General view of the Blue Ridge from the Virginia Consolidated Copper Company's mine, near Ida, Page county. (Unpublished report by Weed and Watson.)

Fig. 2.—View of shaft No. 3. High Hill copper mine of the Virginia Copper Company, Halifax county. (Unpublished report by Weed and Watson.)

BLUE RIDGE AND SHAFT OF COPPER MINE, VIRGINIA.

southeast spur of Hightop Mountain, at an elevation of 3,000 feet above sea-level. In the fall of 1905, the workings consisted of extensive stripping of the ledges exposed on the mountain side, of a cross-cut tunnel about 150 feet in length below a shaft reported to be 80 feet deep, sunk from the bottom of an open cut driven on the hillside.

The ore observed at the openings of this company consisted of native copper, cuprite, some malachite, and in places a little bornite and chalcopyrite.

A tunnel, entering the hillside at a distance of 400 feet below the summit of the ridge, has been driven for a distance of 111 feet, along a S. 50° E. course. The open cut and shaft mentioned above are 200 feet above the tunnel and the same distance below the top of the ridge. The mining camp of this company is probably the most extensive one in the district.

THE SOUTHWEST VIRGINIA REGION.

The "Gossan Lead" of Floyd, Carroll, and Grayson Counties.

General statement.—Probably the most noted copper region of Virginia is in the southwestern portion of the State, in a belt of crystalline rocks passing through Floyd, Carroll, and Grayson counties. The region is a part of the eroded Blue Ridge upland, marked by well rounded summits and deeply trenched streams, and is referred to as the Floyd-Carroll-Grayson plateau. (Map, figure 29, page 192.)

The region was actively prospected in the early fifties and the rich secondary copper ores found beneath the gossan were boxed and shipped to Baltimore. During 1854-5 there were 8 producing mines on the "Gossan Lead." The aggregate amount of ore shipped for the 6 months, from January 1855 to July 1855, was 1,545,363 pounds. The ore averaged about 25 per cent. copper, and at that time the metal was worth 26 cents per pound.

General geology.—The "Gossan Lead" lies in the crystalline schists and its strike conforms very closely to that of the enclosing rocks. A careful examination shows the vein to be traceable for a distance of 18 miles. From one end to the other there are old pits whose dump heaps show the typical gossan ore (figure 85), and as several of the old mine-workings could be continuously followed underground for miles running at a depth of from 20 to 60 feet below the surface, there seems little doubt that it is one of the greatest veins in the Appalachians.

The immediate wall rock of the "lead" is sericite schist. On the southeast or hanging-wall side of the vein the rocks are ordinary mica-schists cut by altered diorite masses. The rocks on the foot-wall side appear to be somewhat different and are similar to the Ocoee rocks of the southern Appalachians. A belt of much altered hornblende syenite extends upward and across the foot-wall series and is found near the "Gossan Lead" in the vicinity of Betty Baker. These facts and the structure of the vein itself prove faulting and, as the dip of the vein is from 45° to 60° the faulting is apparently of the overthrust type, which type predominates in this part of the Appalachian region.

General character of the vein.—The vein consists essentially of pyrrhotite with disseminated particles and stringers of chalcopyrite. It

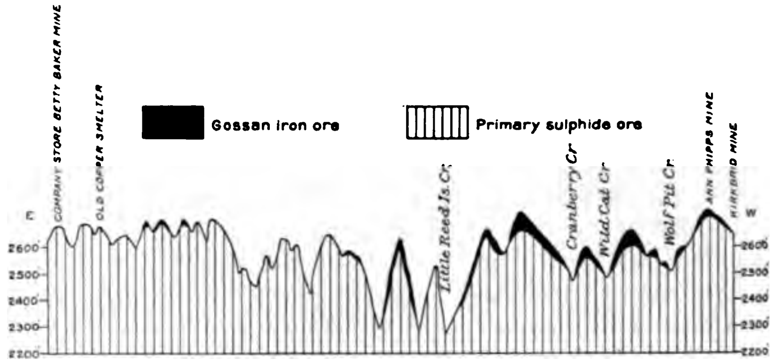

Fig. 85.—Profile of "Gossan Lead" from Betty Baker mine to Kirkbride mine, showing gossan (limonite) reserves. Carroll county. (After Weed and Watson, unpublished report.)

is not in every place a solid mass of pyrrhotite from wall to wall, but rather a series of layers, partly of pure pyrrhotite admixed with more or less micaceous material, an altered form of the country-rock. The primary ore is exposed at the openings of the Pulaski Mining Company at Chestnut Yard (Great Outburst) at the southwest end of the "lead." (Plate XXX.) Projecting masses or intercalations of the schists occur in the vein and, in places, where the fresh material is observable, a considerable proportion of the vein consists of coarse biotite schist, impregnated with chalcopyrite and interleaved masses of pyrrhotite. Figure 86 shows the interleaving of pyrrohotite with talc at the Pulaski Mining Company's openings on Chestnut creek at the "Great Outburst." At the same openings considerable hornblende is associated with the pyrrhotite in places, as shown in figure 87. Quartz lenses occur on the hanging-wall of the vein.

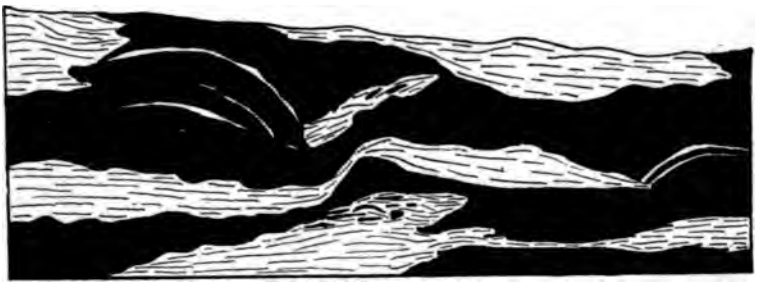

Fig. 86.—Pyrrhotite interleaved with talc. Black is pyrrhotite. Lined areas are talc. Chestnut Yard, Carroll county. Two-thirds natural size. (After Weed and Watson.)

Fig. 87.—Pyrrhotite with columnar hornblende and chalcopyrite. White is pyrrhotite. Black is chalcopyrite. Parallel lines are hornblende. Chestnut Yard, Carroll county. (After Weed and Watson.)

The vein varies in width from 22 feet to perhaps 100 feet. A diamond drill hole was put down to a depth of 524 feet on the vein at the Betty Baker mine, proving the deposit to a depth of 734 feet below the outcrop. Other borings proved the width of the vein at Betty Baker to be 35 feet. The strike of the vein varies in accordance with that of the country-rock; at Betty Baker it is N. 35° E., and it shows various deviations from this when traced southward, reaching as much as N. 60° E. in places. It has not only suffered from strike faulting, but shows sharp folding or change of strike southwest of the Cranberry mine; and at the Betty Baker mine a horizontal displacement of 62 feet was measured close to the point where the wagon road crosses the ledge. The dip varies somewhat but averages about 45°. Marked discordance in the dip of the vein and that of the enclosing schists is observed in places.

In places, the vein-filling comprises rock fragments of varying character cemented by the sulphides, principally pyrrhotite. These fragments are often well rounded, sometimes subangular and include rock types not seen on the surface either at the vein or nearby.

Description of Mines.

The mines which were most extensively worked on this "lead" are: the *Betty Baker, Cranberry, Kirkbride, Vaughn, Copperas Hill,* and *Chestnut Ridge* at the "Great Outburst." The location of these mines and the general trend of the "Gossan Lead" are shown on the accompanying map, figure 88. In addition to these, numerous other smaller mines were opened in different places on the "lead," the principal ones of which were the *Ann Phipps, Wolf Pit,* and *Wild Cat* mines.

Carroll County.

Vaughn mine.—As indicated on the map, figure 88, the Vaughn mine is southwest of the Kirkbride, and has not been worked for many years. The shafts are numerous and they occur at such frequent intervals that there can be but little doubt of the continuity of the vein. As determined by the old shafts, the direction of the vein was about 65° east with a dip of 45°. The workings of the Vaughn mine and those on the adjacent properties made a continuous drift of 4 miles long. The ore from this mine was pounded up and put in boxes, and hauled to Max Meadows, where it was shipped to Baltimore. Mr. H. E. Vaughn reports that the ore was 75 feet wide in some places.

Cranberry mine.—The location of this mine is given on the accompanying map, figure 88. The mine was closed down in 1859 after working for a period of about 7 years. A copper smelter was once operated at this locality and there was at that time a considerable settlement. The old workings for black copper consisted of long tunnels, with drifts along the vein, and frequent air-shafts along the surface, some of which were used for hoisting. The strike of the vein is north 55° east. A shaft 104 feet deep, located in the creek bed, was worked for yellow copper ore. This mine was reopened again about 12 years ago by Edgar C. Moxham, Mining Engineer of New York City. In 1902 some diamond drill holes were put down by the Virginia Iron, Coal and Coke Company.

Wild Cat mine.—Crossing Cranberry creek to the southwest from the Cranberry mine is the Wild Cat mine, which was developed by a series of shafts. These are still open down to the water level and show the strike of the vein to be north 65° east, and a dip of 45°.

The Betty Baker mine.—This mine is located about 3 miles southeast of Sylvatus and a short distance west of Big Reed Island creek. It has been

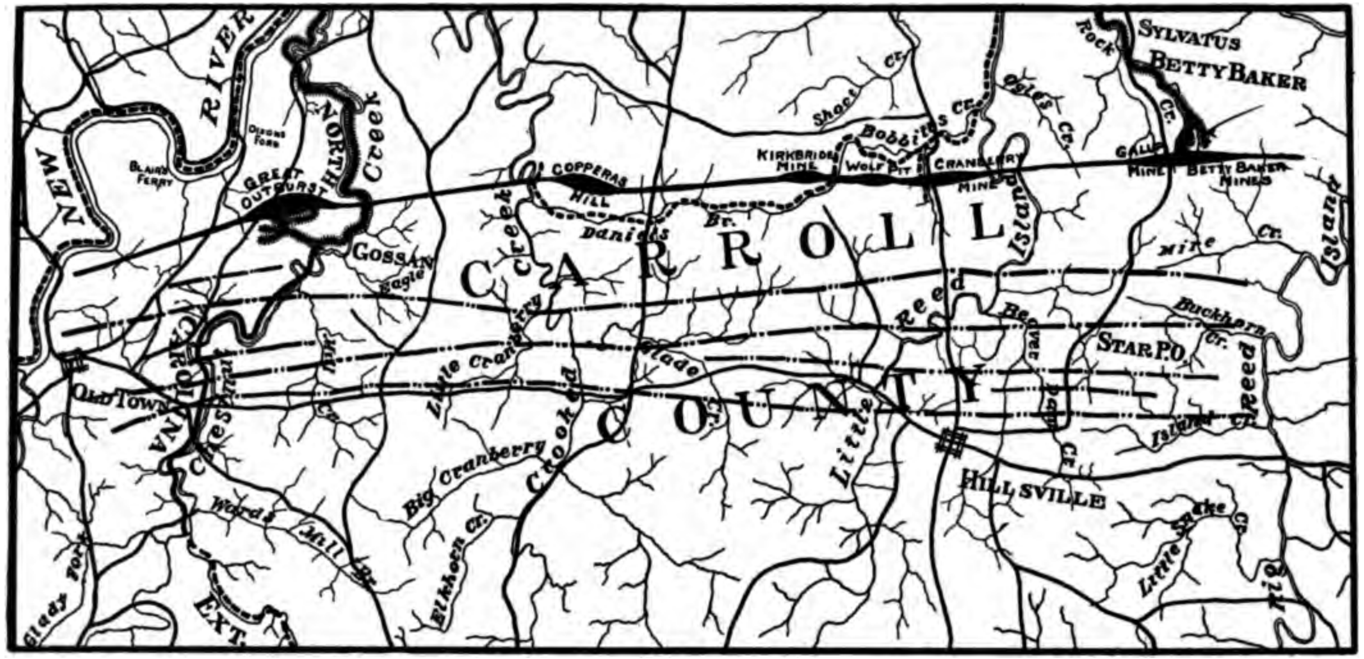

Fig. 88.—Map of the Carroll county pyrrhotite area, showing position of the "Great Gossan Lead" in heavy black band and the principal copper mines located on it. Broken lines indicate other probable leads. (After Weed and Watson, unpublished report.)

extensively operated, as indicated by the numerous cuts, shafts, and drifts, extending over a considerable northeast-southwest distance. Many of the older workings are in poor condition and little could be seen from an examination of the walls. At the time of my visit in 1905 the shafts were filled with water and could not be entered. The narrowest place encountered on the vein was reported at No. 7 shaft, about one mile west of the office of the Betty Baker mine. At this point the vein was squeezed to 5 feet. At the east end of the Betty Baker property the surface shows a width of about 300 feet of limonite.

Before closing down the Betty Baker mine in 1900, 1,800 tons of the "mundic" (pyrrhotite) were shipped to the Southern Chemical Company at Winston-Salem, North Carolina, where it was used in acid-making. The ore contained 33 per cent. of sulphur, and after roasting it carried 58 per cent. of iron. Shipments to the Winston-Salem works were stopped when the plant was absorbed in the consolidation of the Southern Fertilizer Manufactures. Plate LXXV shows views of shaft and open cut at this mine.

The Gardner and Goad mines.—These are separate mines, located close together in the northeastern part of Carroll county, about 10 miles from Betty Baker and not far from the Floyd county line. The openings are made in a dike of altered (schistose) hornblende rock, which cuts across the normal schists of the region. Occasional specks or nuggets of native copper have been found along the weathered outcrop and the dike has for this reason been referred to as a native copper vein. The strike of the country-rock (schists) near the mines varies from north 50° to 65° east, and dips about 60° south. The mines have been opened by shafts and tunnels of moderate depth and length. The ore is chalcopyrite in more or less rounded nodules ranging in size up to that of a hickory-nut. Post-mineral movement has squeezed these out into pyrite mirrors and streaks.

The "Great Outburst."—The openings on this property are located near the Carroll-Grayson county line, near Chestnut Yard, on the Cripple Creek extension of the Norfolk and Western Railway, between Chestnut creek and New river. The gossan of the vein has been extensively mined from numerous shallow workings for iron. The pyrrhotite vein is very wide here. It is not a continuous mass of pyrrhotite from wall to wall, but the ore is interleaved with micaceous and talcose schist. Plate XXX is a view of the vein as opened in 1905. The pyrrhotite contains stringers and small masses of chalcopyrite through it, usually not in large enough quantity to make it a workable copper proposition alone. The Pulaski Mining Company has been and is mining the pyrrhotite for acid-making, with occasional shipments of the secondary black copper concentrated below the gossan.

Fig. 1.—Shaft at Betty Baker mine, west of road, Carroll county. (Unpublished report by Weed and Watson.)

Fig. 2.—Open cut at Betty Baker mine, Carroll county. (Unpublished report by Weed and Watson.)

PYRRHOTITE MINES CONTAINING COPPER. "GREAT GOSSAN LEAD," CARROLL COUNTY, VIRGINIA.

Grayson County.

As indicated on the map, figure 88, the "Gossan Lead" extends from Carroll into Grayson county, and, in the vicinity of Old Town, other probable ones are shown, but, so far as I am aware, the mining of copper along these belts has been largely, if not entirely, limited to Carroll county.

In the extreme western and southwestern portions of Grayson county, strong indications of copper exist in places. Less than a mile south of Troutdale, on the Greer place, the quartz-feldspar porphyry on Fox creek contains large granular masses and small grains of chalcopyrite. In the southwestern corner of the county, near the North Carolina line, some prospecting for copper has recently been done on the Douglas Land Company's property. Good specimens of the sulphides, bornite and chalcopyrite, and the green carbonate, malachite, were obtained. The openings are made in a green schist not far removed from the porphyry contact.

Floyd County.

The Toncray mine.—The Toncray mine is located about 8 miles south southeast of Floyd court-house. It was last operated by the New York and Virginia Copper Company. For several years past this company was actively engaged in prospecting the property and large sums of money were expended in buildings and machinery, and the employment of a large force of men. The property has been developed by several tunnels and shafts. Work had just been suspended at the time of my visit in 1905. The vein is, like that described above in Carroll county, pyrrhotite. It was opened in search of the black oxide of copper, a large amount of which was reported found. Intermingled with the unaltered pyrrhotite is considerable chalcopyrite, which seems to be present here in amount larger than at other mines in Carroll county. It is reliably reported that in the upper tunnel a band of the yellow copper sulphide, chalcopyrite, was found which measured 6 to 8 inches wide. The rock inclosing the vein is the usual gray-colored mica schist.

Franklin County.

The Howell mine.—This mine, so-called, is near the Rocky Mount-Floyd court-house road, and is located about 1.5 miles from Huff's store, in the extreme western edge of Franklin county. Very little work has been done. The ore is pyrrhotite, carrying a small amount of intermingled chalcopyrite. The "vein" is found in the altered micaceous schists. Other deposits similar to this one are reported a short distance to the northeast and southwest of the Howell mine.

THE COPPER ORES OF THE RED BEDS OF THE TRIASSIC.

Several of the Virginia counties covered by the red sandstones and shales of the Triassic formation contain deposits of copper ores of too low grade to permit of profitable working. Numerous attempts have been made to mine these ores at many different points, but as yet without success. During the early part of the last century attempts were made to mine the ore over parts of Loudoun, Culpeper, and Orange counties.

Loudoun County.

Five miles east of Leesburg and near Sugar Run in Loudoun county, the Triassic series contains greenish or bluish calcareous sandstones and shales intercalated in the lead rocks. The light-colored beds contain films or thin coatings of malachite on joint surfaces, and sometimes carry specks of the phosphate of copper and of copper glance. The area of mineralization is, according to Keith, extensive, and considerable work has been done; but the ore is too generally diffused to be profitably worked.

Culpeper County.

Near Stevensburg, 10 miles east of Culpeper, copper-bearing shales were worked. The conditions here are more or less closely similar to those described in Loudoun county. Rich specimens of copper ore are reported to have been frequently obtained during the early history of this region.

Professor Rogers' observations on this region seem to be applicable at the present time. He says: "Unhappily these indications have kept alive the hope of discovering in these shales veins of a workable copper ore and has led to repeated enterprises in mining, from which no really profitable result appears ever to have been derived. Most of the openings, either ancient or modern, have disclosed nothing more than a calcareous shale slightly *filmed* with the green carbonate, and making in some cases a superficial show of richness where analysis discovers only an insignificant amount of the enticing mineral."

Orange County.

Orange county contains areas of copper-stained rocks in the Triassic sandstones. *Taylor's copper mine* is mentioned by Professor Rogers, who says, "though opened with high expectation of profit, has long been abandoned."

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III. ZINC AND LEAD.

Historical.

The first authentic records of lead mining in Virginia date back more than 150 years, and the old lead mines at Austinville on New river, in Wythe county, were the first to be worked. Colonel Chiswell, a native of Wales and one of the earlier adventurers in southwestern Virginia, was one of the first operators of the Austinville mines. Chiswell's operations at Austinville commenced in the year 1750 and closed shortly after the beginning of the Revolutionary War in the year 1776, covering a period of about 25 years. From that time to the present mining has been carried on almost continuously in the Virginia area.

For many years after the Virginia mines were operated, mining was confined exclusively to the lead ores. The zinc ores seem not to have been recognized at the Austinville mines until sometime during the Civil War, when several tons were shipped to the smelting works at Petersburg.

Zinc ores were first discovered at Bertha near Austinville, in Wythe county, during the year 1886. Mining of zinc ores in Virginia properly dates from the opening of the mine at Bertha in 1879, at which time a small shipment of ore was made to Providence, Rhode Island. The metal obtained from these ores proved to be of such rare purity that attention was directed at once to them and a smelting plant was built at Pulaski, which was later remodeled and enlarged and is owned and operated at present by the Bertha Mineral Company. The "Bertha" spelter is of exceptional purity and has a world-wide reputation.

Much if not most of the ores yielding the lead made into bullets, for use by the Confederate soldiers in the Civil War, was produced by the Virginia mines, principally those of Wythe county, with some from the mines near Faber, in Albemarle county. Ore was first discovered on the property near Faber in Albemarle county in the year 1869.

Distribution.

Excepting the single deposit in the extreme southwestern part of Albemarle county, the known commercial deposits of lead and zinc in Virginia are limited to the Valley province, west of the Blue Ridge. All mining and prospecting for lead and zinc ores in this province have been confined to the western half, extending from and including Roanoke county on the east to and including Scott county on the southwest. Ores, both of lead and zinc, are known to occur either sparingly or in quantity in the following southwestern counties of the State: Roanoke, Montgomery, Pulaski, Wythe, Smyth, Bland, Tazewell, Russell, and Scott. Of this number only one county, Wythe, has shown as yet producing mines. More or less prospecting has been attempted in a majority of the counties named above and very small amounts of the ore have been mined in a number of them.

Geologically the occurrence of lead and zinc ores in southwest Virginia is limited to the magnesian limestone of Cambro-Ordovician age, known as the Shenandoah or Valley limestone. The known commercial

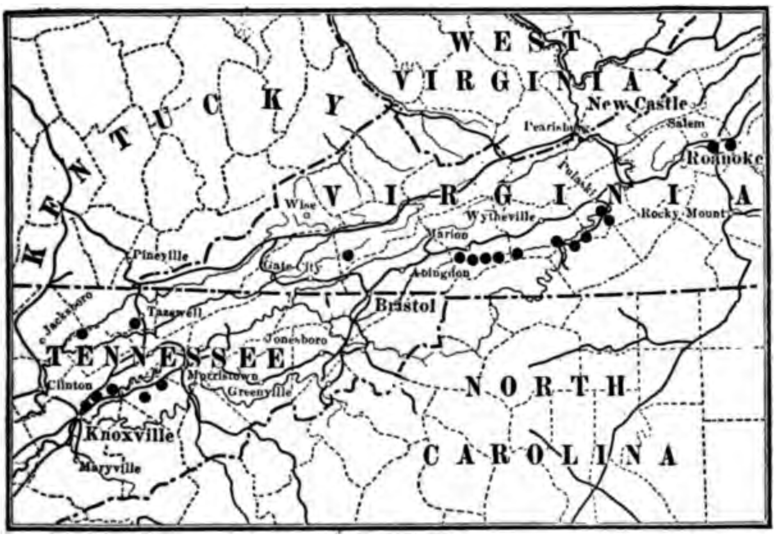

Fig. 89.—Map of southwest Virginia and east Tennessee, showing distribution of lead- and zinc-ores. Lead- and zinc-deposits indicated by heavy dots. Scale, 1 inch = 120 miles. (After Watson, Trans. A. I. M. E.)

deposits of these ores occur near the eastern side of the Valley though several promising prospects are opened near the western side. Map, figure 89, shows the location of the principal openings worked for lead and zinc in southwest Virginia and east Tennessee.

General Geology.

Only those features of the general geology, which are essential to the understanding of the ore-deposition, will be considered here. The rocks included within the limits of the zinc and lead region of Virginia-Tennessee range from Lower Cambrian to Carboniferous in age. They are, without exception, of sedimentary origin; and include shales, sandstones, conglomerates, and limestones, presenting considerable variety in composition and in appearance. They have been more or less metamorphosed, and in consequence are considerably changed, as a rule, both lithologically and structurally.

The ore-bearing formation in Virginia is the Shenandoah limestone, of Cambro-Ordovician age. The formation is a magnesian limestone, dark to light gray or nearly white in color, usually fine-grained and massive, and containing much chert distributed through parts of it in the form of nodules and layers. Wide variation in composition is noted from slight siliceous marble to calcareous sandstone.

Folds and faults characterize the entire area of the Great Valley of the Virginia-Tennessee district. The folds have a general trend paralleling approximately the axis of the Valley, which is northeast-southwest in direction. The dips on the western side of the anticlines are frequently vertical, and in places overturned, and many of the folds have been compressed until broken. The usual dip on the southeast side of a fold is from 30° to 45° to the southeast. The faults are associated with the anticlinal folds, the breaks occurring usually on or near the northwestern side of the anticlines. The faults are of the overthrust type, with the fault-planes usually dipping from 30° to 50° southeast, with an estimated displacement, by Keith, in some of the faults of the Tennessee area, of nearly 3 miles. The faulted zone is usually characterized by much brecciation, and it is along these zones that localization and concentration of the lead- and zinc-ores have taken place.

The Appalachian Valley has been a land-area since early Mesozoic time, during which time the field-evidence indicates several periods of uplift, followed by intervals of quiescence. The periods of quiescence, which followed each uplift, were sufficiently long to enable the streams to establish a system of base-levels over the entire region, and the region was also stationary for a time sufficient to admit of the interstream areas being lowered to an approximately uniform level. The harder and more resistant rocks, such as sandstone and quartzite, were never entirely reduced, but they mark partly unreduced residuals, which stand in relief above the general level of the erosion-plane.

Accordingly, evidence favoring several periods of base-leveling and planation is recorded over the area. The oldest and most extensive peneplane was probably formed in Cretaceous time. Subsequent uplifts were followed by shorter periods of quiescence, which record other peneplanes cut during the Eocene and Neocene periods.

The Ores and Associated Minerals.

The ores include (1) the original sulphide forms sphalerite, sulphide of zinc, gelenite, the sulphide of lead, pyrite, the sulphide of iron, and in several places chalcopyrite, the double sulphide of iron and copper; and (2) the secondary or oxidized forms which have been derived from the original sulphides and occur in the residual decay of the limestone. These include calamine, hydrous silicate of zinc, smithsonite, carbonate of zinc, and cerussite, carbonate of lead.

The associated non-metallic minerals, named in the order of their importance, are dolomite, calcite, barite, fluorite, and quartz. Of these dolomite and calcite constitute the principal ones and they occur in vastly the largest amount. Barite, fluorite, and quartz are not always present but are confined to several of the mines in southwest Virginia.

The Lead Ores.

Galenite.—The principal occurrence of galenite is in association with the zinc ores in the zinc mines. At the principal Virginia zinc mines galenite occurs in fairly large amounts in intimate association with sphalerite. Its usual occurrence is granular and massive-granular less frequently in the form of crystals. Selected specimens from the Austinville mines in Wythe county gave the following results on analysis:

		Per cent.
	Lead	73.89
	Iron	0.22
	Zinc	9.31
	Sulphur	16.20
	Silica	0.54
	Total	100.16
equivalents in		
	PbS	85.29
	ZnS	13.87
	FeS_2	0.46

Cerussite.—This mineral has been found in more than a trace only at the Austinville mines in Wythe county, where it is not altogether an uncommon ore among the altered forms. It occurs distributed through the residual clays of the limestones as stringers and small irregular masses. The earthy form greatly predominates, the clayey admixture being readily identified by its weight. Crystals grouped in clusters and aggregates of white and light grayish color distributed through the clay are not uncommon. It also occurs as white powder-like coating on the crystals and masses of granular galena.

The Zinc Ores.

Sphalerite.—This mineral, forming the most important ore over much of the Virginia area, was the original zinc mineral from which the secondary zinc ores concentrated above ground water-level have been derived. It is found usually below the ground water-level, and in some of the mines not yet worked to this depth it has been found but sparingly. It varies in color from yellow, through brown to nearly black, the black color being due to impurities, particularly iron. In some of the larger mines sphalerite is associated with much galenite in places, some pyrite and very occasionally with scant chalcopyrite.

The sphalerite occurs in the form of disseminated grains, masses and stringers in the magnesian limestone and similar form, but mostly as stringers in quartz-fluorite lenses intercalated in a talcose schist in Albemarle county. At Cedar Springs, Wythe county, and Rye Valley, Smyth county, the blende is of exceptional purity, as indicated in the analyses below. It is of yellow color, massive in form, with perfect cleavage, but not preserving outward crystal form. Analyses made of the blende in the laboratories of the Virginia Polytechnic Institute on selected pieces collected by the writer from the mines in Albemarle, Wythe, and Smyth counties gave:

	Wythe county Austinville Per cent.	Wythe county Cedar Springs Per cent.	Smyth county Rye Valley Per cent.	Albemarle county Per cent.
Zinc	65.01	66.76	66.94	62.11
Sulphur	31.93	33.44	33.26	34.45
Iron	1.94	0.50	0.30	3.44
Lime	0.08	trace	trace	0.05
Magnesia	none	trace	trace	none
Silica	0.33	0.10	0.08	0.26
Total	99.29	100.80	100.58	100.31
Zinc sulphide	99.94	99.56	99.86	92.70

Smithsonite.—In some of the mines smithsonite forms a fairly important ore of zinc. It occurs in the residual clays derived from the magnesian limestone concentrated, usually, in the bottom portions of the clays and resting immediately on the irregular weathered surface of the limestone, as shown in figures 90 and 92. It is intimately associated with calamine.

Smithsonite occurs both in the granular and earthy forms, principally the latter, as crystalline incrustations, and as a porous or spongy material with the cavities frequently filled with the powdery and earthy form of the ore. In color it varies from light gray through yellow to brown according to the impurities present.

The calculated amounts of smithsonite and calamine, from analyses made by F. P. Dewey, on specimens of the ore of the Falling Cliff zinc mine at Bertha, Wythe county, gave the following results:

	Per cent.	Per cent.
Smithsonite	75.52	79.99
Calamine	22.22	12.05

Calamine.—This mineral formed originally the principal secondary ore of zinc mined in the district. It is much more abundant than smithsonite. In occurrence it is closely similar to that of smithsonite with which it is intimately associated. It is indeed very difficult and in some cases impossible to separate the two ores, so intimately admixed are they.

Calamine occurs in the residual clays, usually in the bottom portions, immediately on and next to the irregular weathered surface of the underlying limestone, as shown in figures 90 and 92. Beautiful white incrustations of the mineral presenting mammillary and stalactitic surfaces have been observed in places between layers of the more solid massive ore. Granular masses and honey-comb forms of calamine were quite common. Much of the calamine formerly mined at Bertha, in Wythe county, is reported to have been in sheet-form, rarely in contact with the limestone but concentrated several inches away from the limestone surface and having the intervening space filled with a mixture of loose powdery calamine and smithsonite.

The following chemical analyses of specimens of calamine from the mines of Wythe county, indicate the general character of the ore:

	I Per cent.	II Per cent.	III Per cent.
Zinc oxide	67.88	67.42	67.15
Silica	23.95	25.01	25.33
Water	8.13	8.32	7.47
Total	99.96	100.75	99.95
Specific gravity	3.338	——	3.40

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Calculated amounts of calamine and smithsonite from analyses made by F. P. Dewey on specimens of the ore from the Falling Cliff zinc mine at Bertha, Wythe county, gave the following results:

	Per cent.
Calamine	88.52
Smithsonite	3.26

"Buckfat"—"Buckfat" is the name applied by the miners to a mixture of clay with the minerals calamine and smithsonite. It is not a definite mineral but is a lean ore generally too low in zinc to be profitably used in the present practice of smelting. The zinc content shows wide variation, however, ranging oftentimes much higher than given in the analysis below. It is both hard and soft and is accordingly called by the miners "hard buckfat" and "soft buckfat." Its separation from the rich ores is effected by hand-sorting and by subsequent washing and jigging. The treatment practiced at the Bertha mines previous to the conversion of the ore into spelter consisted in violently washing "soft buckfat" in water and crushing and jigging the "hard buckfat."

Heyward gives the following analysis of a zinc-bearing clay from the neighborhood of the Bertha mines:

	Per cent.
Silica	37.38
Alumina	24.67
Ferric oxide	6.34
Zinc oxide	12.10
Magnesia	0.27
Potash	0.47
Soda	0.27
Water 100° C.—	6.69
Water 100° C.+	10.35
Total	98.54

Associated Ores.

Over the southwest Virginia area iron-ores and manganese-ores, especially the former, are very abundant in some of the larger zinc mines. The iron-ores have been somewhat extensively mined in some places and in several instances mines formerly worked for zinc ores are now being worked for iron. Pyrite is rather a frequent associate of galenite and sphalerite in some of the mines. It occurs in the fresh limestone below the belt of oxidation. It is by no means uniformly distributed through the rock, but in places it is sufficiently concentrated to be noticeable, and rarely, if ever, is it present in quantity large enough to be hurtful to the lead and zinc ores. Limonite comprises the principal iron ore mined in association with the zinc ores. Hematite is less common than limonite. Black oxide of manganese is a frequent associate in some of the mines.

Associated Minerals.

Named in the order of their importance, the associated minerals are dolomite, calcite, fluorite, quartz, and barite. Of these dolomite and calcite comprise the dominant minerals, with some barite and less fluorite. Fluorite and quartz make up the gangue minerals at the zinc and lead mine in Albemarle county. Calcite occurs only sparingly at this mine while fluorite is the dominant mineral. Over the southwest Virginia area dolomite and calcite fill fractures between the magnesian limestone fragments in the form of crystalline masses, forming a limestone breccia. The relative proportions of cement (recrystallized calcite and dolomite) to rock fragments vary widely. Numerous analyses of specimens of the calcite and dolomite collected over the southwest Virginia district gave nearly pure calcium carbonate for the former and a ratio of calcium to magnesium of 1:1 for the latter, which is the ratio of normal dolomite. The fluorite found at the Albemarle county mines is usually of white color though the violet shade is fairly common, which latter is sparingly found at several localities in the southwest Virginia zinc mines.

Alteration of the Lead and Zinc Ores.

The important secondary ores comprise calamine, smithsonite, and cerussite, which have been derived from the original sulphides, sphalerite and galenite, by the usual processes of weathering. Until recently only the oxidized or secondary ores have been mined, but preparation is now being made to mine the original sulphide ores in the fresh limestone.

Mode of Occurrence.

The sulphide ores.—The bulk of the sulphide ores belong to the disseminated replacement breccia type. As a rule the process of replacement has played an important part in the ore formation, but in some instances very little replacement of the limestone by the ore is indicated. In the latter case the ore would be more properly designated a straight breccia tpye in which practically no replacement has occurred. On the other hand the ore has originated at several places largely through a replacement process.

The breccia is usually made up of sharp-angled fragments of the country-rock, magnesian limestone, cemented by a matrix of white crystallized calcite and dolomite and blende, with or without replacement of the limestone fragments. The breccia-zones are associated with faulting and folding. Not all parts of the breccia-zones are mineralized, but the ore is distributed at somewhat irregular intervals. Where mineralized and so far as can be judged from developments the ore continues with depth.

When occurring in the same mine the blende and galenite are intimately admixed. Many parts of the limestone, both small and large, show all blende with only here and there sparing dissemination of galenite through the rock, closely intermingled with the blende. Other parts of the limestone usually much smaller in area show a preponderance of galenite with little or no disseminated blende. The same relation holds true for the very small amount of pyrite present in the rock which may be intermingled with the galenite or blende or both.

The oxidized ores.—Where sufficient developments have been made, as in the mines of Wythe county, the oxidized ores usually show much richness and they are often concentrated in massive form as large irregular masses and layers. This is especially true of the calamine which forms the dominant oxidized ore. So massive was the calamine in places in the old Bertha mines that blasting is reported to have been necessary at the time for its removal.

Concentration of the oxidized ores has taken place principally at and near the bottom of the residual clays, closely hugging the irregular weathered surface of the limestone, as shown in figures 90 and 92. Frequently several inches separate the massive form of the ores, calamine and smithsonite, from the limestone. This space is filled oftentimes with a loose, powdery mixture of the two ores. At times the partly decayed limestone in pulverulent granular form partly or entirely fills the space. Much galenite is intermingled in places with the concentrated calamine and smithsonite in the lower portions of the clays. Usually when associated with the oxidized ores in the way mentioned the galenite is observed to diminish in quantity upward more rapidly than the calamine and smithsonite.

Smithsonite, which is present in much smaller quantity than calamine, is ordinarily admixed with the calamine and the two concentrated in the basal portion of the clays next to the limestone surface. Cerussite occurs largely in stringer form penetrating the clays and as a coating on the nodules and masses of galenite. These stringers vary much in thickness and extent but in the larger ones a nearly vertical position in the clays is often assumed.

As a rule the residual clays are highly ferruginous. Limonite composes the principal part of the clays in some of the mines and it was derived in part at least from the oxidation of the original pyrite disseminated through the limestone in association with galenite and sphalerite. It is usually of good grade and several of the mines formerly worked for zinc ores are now being worked for iron ore. The relations between the ores, the limestone and the clays, as described above, are shown in figures 90 and 92.

Fig. 1.—View of limestone "chimneys" at Bertha zinc mines, Wythe county.

Fig. 2.—View in open cut, showing limestone "chimneys" at Bertha zinc mines, Bertha, Wythe county.

LIMESTONE WEATHERING, ZINC MINES, WYTHE COUNTY, VIRGINIA.

Relation of the Ores to Geologic Structure.

The lead and zinc district of the Great Valley region of Virginia-Tennessee is one of intense deformation—folding, faulting, and brecciation. Moreover, the localization and concentration of the ores follow closely these structural lines. Mineralization has not taken place through all parts of the breccia-zones which follow the anticlines, but only along some of the zones in places and at irregular intervals have the ores accumulated. Wherever the ores have been found they have been noted in some part of an anticlinal fold in or near a faulted breccia-zone. The ores are accordingly of the breccia type, as shown in figures 94, 95, and 96. At Austinville, Wythe county, the ores appear in well-defined ore-bodies which have resulted largely from a replacement process, mostly where the joint and bedding planes of the limestone intersect and on the limb of a faulted anticline.

Origin of the Ores.

The statements here made concerning the genesis of the zinc and lead ores apply only to the Great Valley region of Virginia and Tennessee. So far as known there are no igneous intrusions found within the limits of this region with which to connect the ores. There appears no good reason for regarding the ores as having been derived from profound depths as indeed the evidence is against this source of the material.

The field evidence favors the original deposition of the ores in the Cambro-Ordovician limestone in disseminated form, but so very sparsely disseminated as to render subsequent localization and concentration of them by underground waters along certain structural lines, previously indicated, in their present workable form. In some of the Virginia deposits the ores are intimately associated with the more carbonaceous layers of the limestone, which indicates that the ores were probably introduced as sulphates and were reduced by the organic matter in the limestone and deposited as sulphides.

In addition to the sulphide cycle, it seems probable that there was a second or sulphate cycle, in which the metals were transported as soluble sulphides and were deposited as such. This was probably the process of deposition at Austinville and in some other of the Virginia deposits. Many of the deposits show little or no replacement of the limestone substance by the ores. The mingling of the ore-bearing solutions with other solutions in the faulted breccia-zones, and the reaction of the ore-bearing solutions on the wall-rock, limestone, largely resulted in the precipitation of the ores, where not connected with reduction and precipitation by organic matter.

Description of the Mines.

The production of lead and zinc ores in the State has been almost exclusively from the Valley region of southwest Virginia. The ores have been worked in the following counties of the Valley region: Botetourt, Roanoke, Montgomery, Pulaski, Wythe, Smyth, and Russell. Of these Wythe has been the important producing county. Work in the other counties has been largely in the nature of prospecting.

THE GREAT VALLEY REGION.

Roanoke and Botetourt Counties.

Ores of zinc and lead have been opened at two places in the vicinity of Roanoke City, namely, on the Martin property 2¾ miles southwest of Roanoke City, in Roanoke county, and just across the county-line in Botetourt, a half mile northeast of Bonsack station. The openings on both places are of long standing and will not exceed 50 feet in depth. The developments here comprise some half dozen small openings in the limestone.

The Martin prospect.—An examination of the dumps at the openings showed the occurrence of the sulphides of lead, zinc, and iron in close association. No ore was seen in place.

The Bonsack prospect.—The development consists of a single shaft less than 50 feet deep. At the Bonsack prospect the dump showed some pyrite, a little chalcopyrite and sphalerite, the former predominating. No galenite was noted. Neither of these properties has passed beyond the prospecting stage.

Montgomery County.

More or less prospecting for zinc and lead ores has been done in a number of places in this county, but as yet no productive areas of the ores have been found. The localities at which prospecting has been done are as follows: In the extreme southwestern part of the county on Bony's creek; several miles southeast of Shawsville on the Langhorn estate; on the Walker and Vaughn properties south of the Norfolk and Western Railway between Shawsville and Big Tunnel; about 2 miles south of Christiansburg; and on the Cloyd property on New river, about 8 miles south of Blacksburg.

Pulaski County.

The known occurrence of zinc ores in Pulaski county is limited to the extreme southwestern part of the county, near the Wythe county line and in the vicinity of Allisonia and Delton along New river. The ore comprises zinc blende occurring in the unaltered limestone and the oxidized ores, calamine and smithsonite, concentrated in the residual clay derived from the limestone. Openings have been made at 3 places only, one of which has produced ore in sufficient quantity to be workable.

The Delton mines.—The Delton mines are located about one mile south of Delton and about the same distance west of New river, where crossed by the Cripple Creek branch of the Norfolk and Western Railway. These mines were opened by the Bertha Mineral Company in May, 1902, and were continuously worked until December, 1903, when it is claimed that the ore pinched out, about 8,000 tons of ore having been mined. The entire output from these mines was of the oxidized ores, comprising zinc silicate, calamine, and zinc carbonate, smithsonite. After concentration the product contained 40 per cent. metallic zinc, 0.5 per cent. lead, and 5 per cent. iron.

The Forney openings.—Two openings were made in the limestone, several years ago by Mr. B. S. Forney, on the opposite side of New river from each other and about one mile northeast of Allisonia. The opening on the south side was a shaft sunk to an unknown depth, and that on the north side of the river comprised a tunnel driven into the limestone slope at an elevation of about 300 feet above the river level. Beautiful specimens of light yellow zinc blende were noted on the dump at the tunnel. Zinc blende was observed in the limestone in the bed of New river, during the construction of a coffer dam across the river, at a position nearly opposite the shaft and tunnel on the two sides.

Wythe County.

Wythe county has been and is at present the main producing county of lead and zinc ores in Virginia. At least nine-tenths of the lead and zinc ores produced in the State has been from the Wythe county mines. The mines at Bertha and Austinville in the extreme southeastern corner of Wythe county have produced practically the entire output in these ores. It was here that the first mining of lead and zinc ores in the State was done, dating back more than 150 years. Until about 2 years ago the ores mined included the oxidized forms concentrated at only slight depths below the surface. Recent exploitation below this level has developed the presence of original sulphide ores in the fresh rock, which, at Austinville, appear to be sufficiently concentrated in places to be workable. At Cedar Springs, 22 miles west of Austinville, and in the southwest corner of Wythe county, zinc blende is being mined and milled.

The ores mined include calamine, smithsonite, sphalerite, galenite, and cerussite. Pyrite occurs sparingly in some of the mines in association with sphalerite and galenite.

The Bertha Zinc mines.—The old Bertha zinc mines, located about one mile south of Bertha, a station on the North Carolina extension of the Norfolk and Western railroad and 20 miles southwest of Pulaski, have produced a larger quantity of zinc ores than any other mines in the State. These mines were regularly opened in 1879 and were systematically mined for zinc ores until 1898, since which time the property has been worked for iron ores by the Pulaski Iron Company. The annual output in zinc ores from these mines was large and comprised only the oxidized forms, silicate and carbonate of zinc. Mining was confined entirely to the residual clays between and around the limestone chimneys, with a depth in some places of nearly 100 feet. (Figure 90.) Plate LXXVI, figures 1 and 2, are views of the limestone chimneys in the Bertha mines after the stripping of the residual clays. Figure 91 shows the relations of the soft ore to the limestone chimneys and the residual clay, and the method of mining the ore.

The Austinville Lead and Zinc mines.—The Austinville Lead and Zinc mines, owned by the Bertha Mineral Company, are located in the southeastern corner of Wythe county, 29 miles southwest of Pulaski by rail and 10 miles west of the Bertha mines described above. They are further located about a quarter of a mile south of New river on the limestone plateau, at an elevation of 290 feet above the river. These mines were first worked more than 150 years ago when lead ores were mined by Colonel Chiswell, in 1750. The ores occur in a metamorphosed zone along the southeast limb of an anticline, which trends northeast-southwest and is cut through by New river at this point. The limestone along this zone has been crushed and broken and cemented, and, in many places, recrystallized. So extensive has been this metamorphism in places that the original limestone bedding is obscured. In many places, however, the bedding planes are sharply defined, dipping on an average of 45° southeast. Jointing is rather strongly emphasized in the limestone at the mine openings.

Fig. 1.—View showing weathered limestone surface in open cut at Bertha zinc mines, Bertha, Wythe county.

Fig. 2.—Weathered limestone surface; bedding obliterated by recrystallization of limestone. Austinville lead and zinc mines.

LIMESTONE WEATHERING, ZINC MINES, WYTHE COUNTY, VIRGINIA.

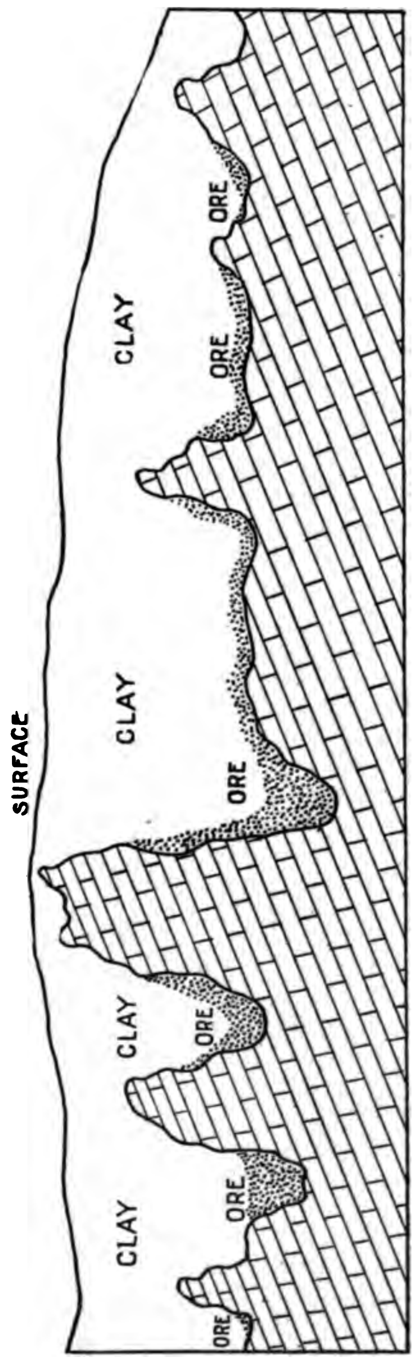

Fig. 90.—Section in open cut at the Bertha zinc mines, showing the relations of the soft ore to the limestone "chimneys" and the residual clay. Blocked area is limestone. Bertha, Wythe county.

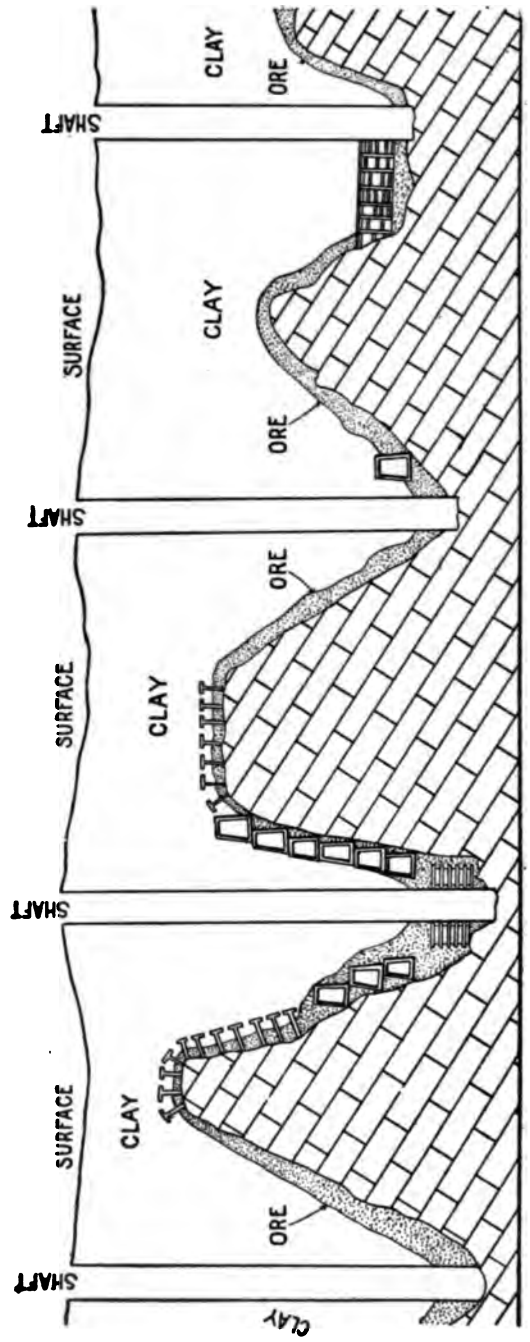

Fig. 91.—Section through the Bertha zinc mines, showing occurrence of zinc ore in relation to the limestone and clay; and the method of mining the ore. Blocked area is limestone.

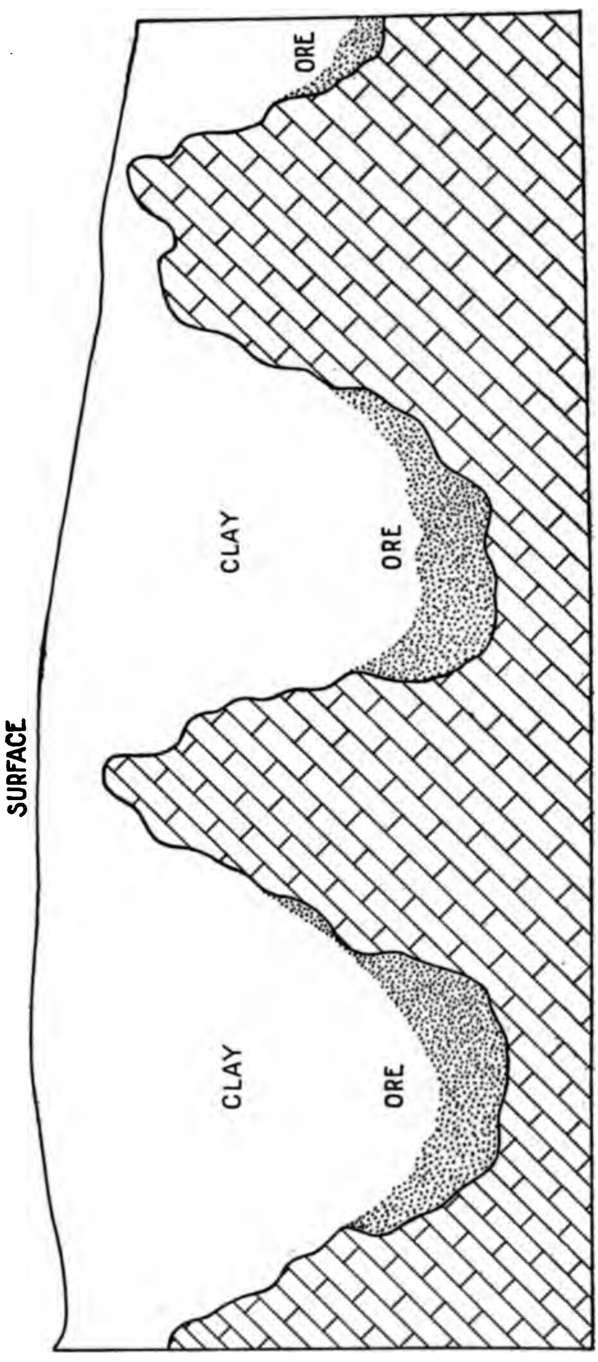

Fig. 92.—Section in open cut at the Austinville lead and zinc mines, showing the relations of the soft ore to the limestone "chimneys" and the residual clay. Blocked area is limestone. Austinville, Wythe county.

Until recently the ores mined at Austinville were of the oxidized type, concentrated for the most part near the bottom of the residual clays on the irregular surface of the limestone, as shown in figure 92. Plate LXXVII, figure 2, is a view of the weathered limestone surface at the Austinville mines, in which the bedding is obliterated by the recrystallization of the limestone. The soft ores mined included the silicate and carbonate of zinc and the carbonate of lead. Much galena, lead sulphide, was associated in places with the oxidized ores. During the early period of mining the ore was largely won by open cut mining. The lead ores were then followed down by stoping when found. At that time the zinc ores were discarded.

Considerable underground work has been done in the fresh limestone, and the Bertha Company has been largely engaged, during the past several years, in exploring and developing the original sulphide ores in the fresh rock. The sulphide ores include zinc blende, galena, and some pyrite, all more or less closely associated. In some places, zince blende predominates with a little galena and less pyrite, and in others, galena predominates with but little blende and pyrite. Pyrite, as a rule, is not abundantly distributed through the limestone and is not in quantity sufficient to be harmful to the ores of zinc and lead. The purity of the zinc blende at the Austinville mines is indicated in the following analysis, made by Mr. J. H. Gibboney, on selected pieces collected by the writer:

	Per cent.
Zinc	65.01
Sulphur	31.93
Iron	1.94
Lime	.08
Magnesia	none
Silica	.33
Total	99.29
Zinc sulphide	96.94

As shown in figure 93, a sketch map of the Austinville mines, mining of the ores has been by open cuts, shafts, and tunnels. The ores have been worked on 3 principal levels at the following depths below the surface: 90, 180, and 238 feet. An elaborate concentrating plant for milling the ores is in operation at the mines. In addition to this milling plant, oxide furnaces have been built, which utilize all tailings and low grade ores that formerly were claimed not to be usable, and therefore were discarded. The oxide furnaces supply a zinc oxide which averages from 70 to 80 per cent. zinc, used for charging in the smelting furnaces at Pulaski for making spelter.

Fig. 1.—Zinc milling plant of the Bertha Mineral Company, at Austinville.

Fig. 2.—Weathering of limestone into pinnacled surface, "chimneys," in iron-ore pits near Ivanhoe.

ZINC MILLING PLANT AND LIMESTONE "CHIMNEYS," WYTHE COUNTY, VIRGINIA.

Not only are the zinc and lead ores mined at Austinville, but the waste s washed for iron and the ore shipped to the iron furnaces, and the limetone of the chimneys of the open cuts is quarried and used for fluxing, hus utilizing practically everything.

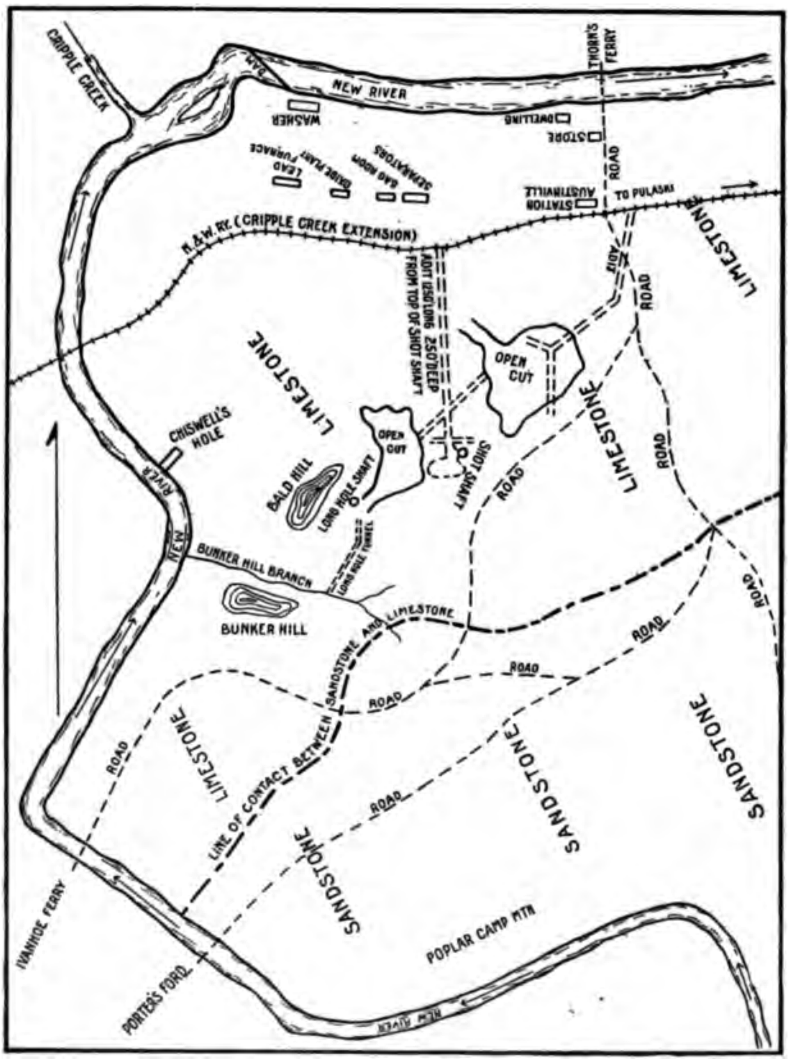

Fig. 93.—Sketch map of the Austinville lead and zinc mines, showing position and general character of workings, and line of contact between sandstone and limestone.

The New River Mineral Company's mines.—The mines of the New River Mineral Company, located near Ivanhoe, have been extensively worked for limonite or brown iron ore. Much zinc ore, comprising calamine and smithsonite, is reported to have been mined from these openings, from time to time, in winning the iron ore. Similar conditions are reported to have obtained in the Simmerman iron ore pits nearby. The zinc ores mined are reported to have been shipped to Trenton, New Jersey.

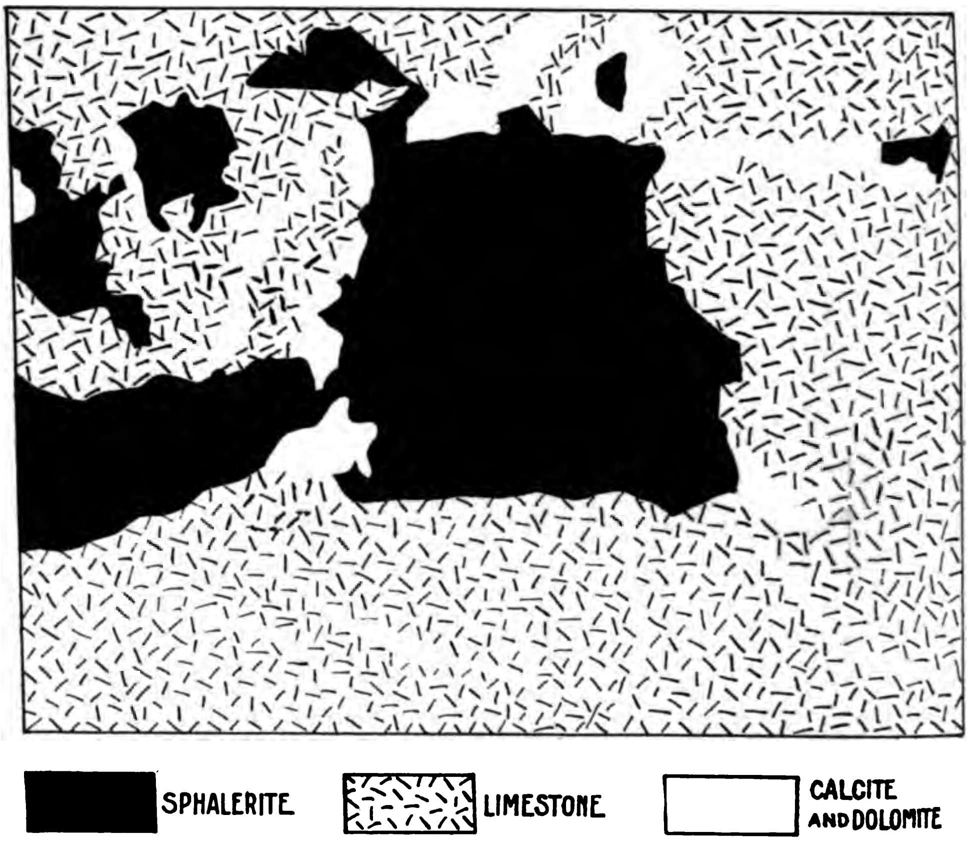

Fig. 94.—Limestone breccia from Cedar Springs, Wythe county, showing relations of sphalerite to calcite-dolomite filling and to the limestone. Some replacement of the limestone is shown. Natural size.

The Cedar Springs Zinc mines.—The mines of the Cedar Springs Zinc Mining and Development Company are located in the extreme southwest corner of Wythe county, about 5.5 miles south of Rural Retreat on the main line of the Norfolk and Western Railway. The property comprises 387 acres of land, located along the headwaters of Cripple creek, on which numerous openings are made, extending from Cedar Springs eastward for a distance of one or more miles. The openings comprise open cuts, shafts and tunnels, and in addition to these some drilling has been done, the deepest of which reached a depth of 250 feet. The ore is of the breccia type composed of zinc sulphide, practically, without galenite and pyrite. (Figures 94 and 95.) The blende is in massive form, of light yellow color, and is of exceptional purity, as shown in the analysis made by Mr. J. R. Eoff, Jr., on pieces collected by the writer:

	Per cent.
Zinc	66.76
Sulphur	33.44
Iron	.50
Insoluble matter, Calcium carbonate, Magnesium carbonate, Water 110° C.	trace
Lead, Cadmium	none
Total	100.70
Zinc sulphide	99.63

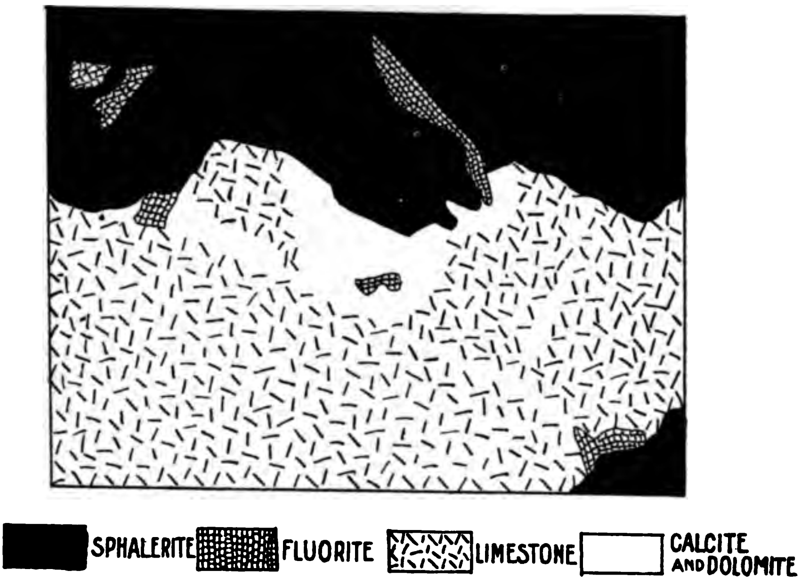

Fig. 95.—Limestone breccia from the Cedar Springs Zinc Mining and Development Company's openings, showing the relations of fluorspar to sphalerite, and to the calcite-dolomite filling. Natural size. Cedar Springs, Wythe county, Virginia.

A commodious concentrating plant has recently been built at the mines by the company for concentrating and milling the ore.

Smyth County.

Much prospecting for zinc ores has recently been carried on in Rye Valley in the south central portion of Smyth county. Operations have been almost exclusively confined along the South Fork of the Holston river in Rye Valley, extending in a general east-west direction.

The Rye Valley Mining Company's mines.—The largest operation in the county is that of the Rye Valley Mining Company, the mines of which

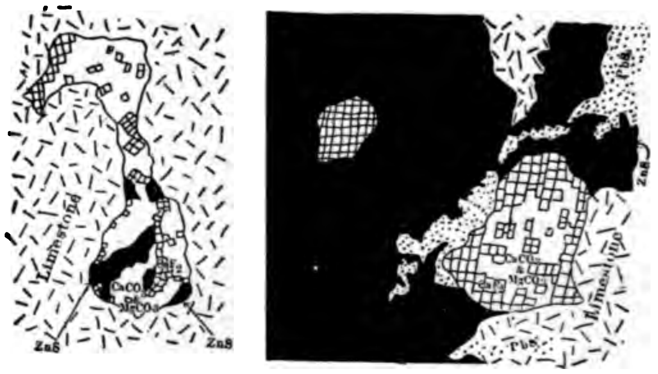

Fig. 96.—Sketch showing relations of sphalerite and galena to fluorspar and calcite-dolomite. Rye Valley Mineral Company, Sugar Grove, Smyth county, Virginia.

are located a quarter of a mile north of Sugar Grove post-office, and about 200 yards from and on the north side of the South Fork of the Holston river. The openings comprise 2 main shafts and a number of small test-pits. The depths reached by the shafts are 100 and 200 feet respectively, on the dip of the rock, 60° southeast. The shafts are connected underground by a drift at the 100-foot level. The ore is chiefly galenite, lead sulphide, with zinc blende in close association at the bottom of the 200-foot shaft. (Figure 96.)

The total production from this mine is reported at about 25 carloads of ore, which was hand picked, there being no concentrating mill on the property.

Other properties in Smyth county, which have been considerably prospected but which have not yet produced ore, are: *The Calhoun*, located about 2 miles west of Sugar Grove post-office; the *Virginia Lead and Zinc Company* on the Scott place, located about one mile south 80° west from the *Calhoun* openings; the *Livesay*, situated about 2.5 miles south 70° west from the *Scott* openings; the *McCarter place*, located about three-quarters of a mile southwest of the *Livesay* place; the *Martin prospect*, located about 4 miles north 80° west of the *McCarter* openings; and the *Van Hoy prospect*, located about one and three-quarter miles south 80° east of the *Martin* place.

The openings on the above places comprise in part shafts, open cuts, and pits, some of which have been dug to a depth of 50 feet and more. An examination of these during the spring of 1905 showed, at that time, fairly encouraging indications of workable zinc ore on several of the properties.

On the Scott place the blend closely resembles that described above at Cedar Springs, in Wythe county. An analysis of selected pieces of the ore from this place, collected by the writer, gave Mr. J. H. Gibboney the following results:

	Per cent.
Zinc	66.94
Iron	.30
Sulphur	33.26
Silica	.08
Lime	trace
Magnesia	trace
Total	100.58
Zinc sulphide	99.86

Russell County.

Zinc ores have been mined at only one locality in Russell county, namely, on Copper creek, about 7 miles south of Castlewood, a station on the Clinch Valley division of the Norfolk and Western Railway. Developments have thus far been entirely limited to the *Osborn place*, although ore is reported on several of the adjoining properties. The developments include one large main pit and numerous small test-pits, with an average elevation above Copper creek of about 350 feet. The property has been worked at several different times by different parties, and much money has been spent in developing it. The ore comprises calamine, sphalerite, and some admixed galena. The chief difficulty in mining this ore is the distance from the railroad and the rough mountainous area over which the ore must be hauled for shipping.

THE PIEDMONT OR CRYSTALLINE R

Albemarle County.

The single deposit of lead and zinc ores in Albem
only type of its kind yet known in the south. The
Albemarle Zinc and Lead Company, and is located 2

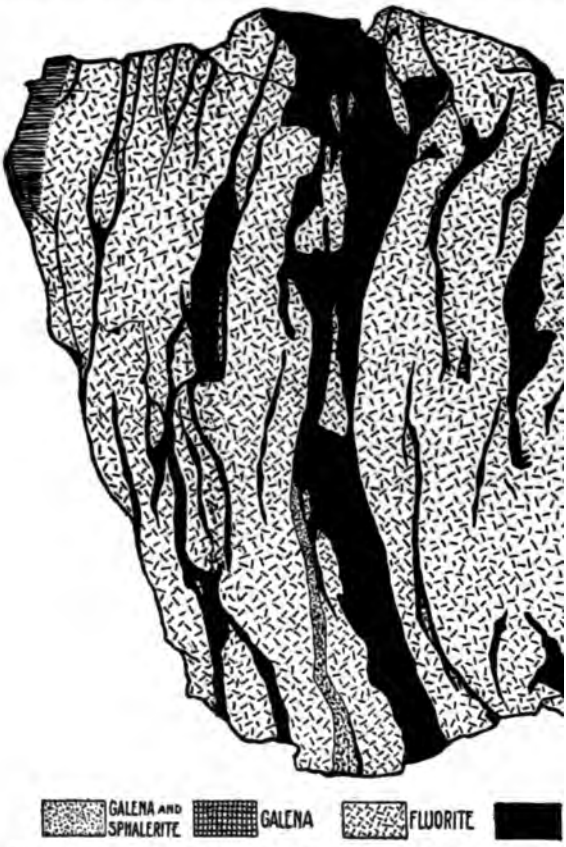

Fig. 97.—Specimen from fluorspar lens, showing distri
phide minerals, sphalerite and galenite. Albemar
Company's mine, near Faber. About one-third n

east of Faber, a station on the Southern Railway, in
foot-hills. The main developments comprise 3 shaft
depths of 25, 50, and 120 feet, and separated by a d
feet between the two extreme shafts. In addition t

level has been run into the ridge from the valley bottom, and a cross-cut run from the adit on and along the vein for a distance of 140 feet.

The rocks in which the lead and zinc ores occur are metamorphosed crystalline schists, cut by a series of basic igneous rocks of the diorite and diabase types. The metalliferous vein is traced for a distance of several miles. It is of variable width, with an average of 4 feet; the strike is north 45° east, exactly paralleling the diorite dike 25 feet distant, on the northwest side; and it dips 80° to 85° northwest. Where opened the vein is of the lenticular type, composed of bulbous bodies of fluorspar mixed with some quartz, through which the ore, blende and galena, is distributed.

The ore, consisting of blende and galena, occurs chiefly in the fluorspar lenses, although the schists next to the lenses is often more or less mineralized. Figure 97, a drawing of a large mass of the ore-bearing fluorspar-quartz broken from one of the lenses, illustrates the typical occurrence of the ore. Some chalcopyrite and smithsonite occur in addition to the principal minerals, blende and galena. Cerussite and azurite were reported some years ago from the dumps. The galena is argentiferous, and arsenic and antimony are reported in very small quantities. Fluorspar is the principal gangue mineral.

Specimens of the mineral collected by the writer gave Mr. J. H. Gibboney the following results on analysis:

	Per cent.
Zinc	62.11
Iron	3.44
Sulphur	34.45
Lime	0.05
Silica	0.26
Total	100.31
Zinc sulphide	92.70

The following analysis was made by Professor W. H. Seamon on a sample of the ore collected by him and believed to represent an average of the vein at that time:

	Per cent.
Zinc	32.00
Lead	4.02
Iron	1.88
Calcium	9.09
Insoluble residue	2 to 3 oz.
Copper	trace
Arsenic	trace

Through the kindness of Mr. Wilkens U. Greene, Mining Engineer in charge of the plant, several bags of the lead and zinc concentrates were sent to me and were separately analyzed with the following results:

	Lead concentrates Per cent.	Zinc concentrates Per cent.
Lead	63.05	6.02
Zinc	12.12	47.88
Iron	3.16	7.26
Copper	trace	0.94
Sulphur	19.32	29.52
Calcium fluoride	1.31	4.74
Insoluble residue	1.08	2.90
Total	100.04	99.26

Equipment and treatment.—The equipment includes a concentrating mill of 80 tons copacity per 24 hours, recently completed; 8 sets of dry jigs; crusher, dryer, rolls, and screens; and steam power of sufficient horsepower for operating the entire plant, including hoist, tram-cars, and cable for conveying the ore from the shaft to the mill. Compressed air drills are used in the underground mining.

The dry process for separating the ore is employed in milling, which differs essentially from the wet process in the form of jig used. The Krom jig is used, made of screens of different size meshes, substituting air for water. These can be set to 700 puffs of air per minute. At the Albemarle plant the ore is crushed and sized to pass a 16-mesh screen. All ore above this size is passed back to the rolls and crushed until properly sized. The ore goes thence to 4 rough jigs, and from here to 4 finishing jigs. It is claimed that the tailings are practically freed from all ore by this process. If not the jigs can be so regulated as to make a nearly complete separation. The trials so far made at the mill required the jigging process to be repeated several times on the same ore before a clean concentrate was obtained.

Methods of Mining the Ore.

Until very recently the mining of lead and zinc ores in Virginia was limited entirely to the surface belt of weathering—the residual clays. The mode of occurrence and the character of the ores to be mined demanded the employment of methods used in mining secondary concentrated ores. Accordingly, a system similar to that practiced in mining brown iron ores was employed, modifications being made to meet the changed conditions. Practically all the ores mined are oxidized forms, concentrated chiefly in the lower portion of the clays and are won within a depth of 100 feet. The mining has largely been by open cuts, tunnels and shafts. The open cut method differs from that of mining the iron ores in that the former is one essentially of stripping, while in the latter the ores and enclosing clays are mined together and sent to the washer for separation. The open cut method was later changed to that of shaft and drift as shown in figure 91, page 534.

The mining of sulphide ores in the fresh limestone has only recently begun at Austinville, in Wythe county.

Preparation and Smelting of the Ores.

The preparation and treatment of the ore can best be explained by outlining the method used at Austinville. The run-of-mine ore at Austinville averages in composition from 28 to 30 per cent. of metallic zinc, from 8 to 10 per cent. metallic lead, and from 8 to 10 per cent. metallic iron. The method of treating the Austinville ore from the time the ore is mined until it is ready for the furnace at Pulaski is, briefly, as follows:

The ore as mined, is carried by trolley to tipples, from whence it is carried by tram-cars to the mill, and dumped on a 4-inch grizzly; thence to a log washer, through a 9x24-inch Blake breaker set at 1.5-inch; and thence to a 14x24-inch corrugated rolls, set at 6 millimeters. From the corrugated rolls the ore is carried to a second log washer, thence to elevator and sizing screens of 6-mm., 2-mm., and 1-mm. mesh, respectively.

The oversize from the 6-mm. screen goes to smooth rolls, 12x18-inch in size, and is returned to the system or second log washer. The undersize from the 6-mm. on 2-mm. screen goes to the 4-compartment Cooley jigs; 1st hutch and side draw making clean lead; 2d hutch and side draw, middling, recrushed and returned to the system or second log washer; 3d and 4th hutches, clean zinc. Tails are passed to settling boxes; head of boxes reworked. Lighter material goes to the oxide furnace.

Undersize from 2-mm. on 1-mm. screen goes to the 5-compartment jigs; 1st and 2d hutches and side-draw making clean lead; 3d hutch and side-draw, middling; 4th and 5th hutches and side draw, clean zinc. Tails go to boxes.

Undersize from 1-mm. screen goes to 3-compartment classifier; 1st and 2d draw to 6-compartment jigs; 1st and 2d hutches and side draw, middling; 5th and 6th hutches and side draw, clean zinc. Tails go to boxes.

Third draw from classifier and overflow goes to the 3-compartment double jigs; 1st and 2d hutches clean lead; 3d hutch, middling, reworked. Tails go to boxes.

The middlings and tails from all jigs are treated in 4-compartment jigs as described above. The overflow from 1st and 2d log washer, except the lower end or lighter material, goes to settling boxes, 25 feet long and 8 feet wide; thence to the oxide furnace.

The lead concentrates, averaging lead, 57 per cent.; zinc, 4.8 per cent.; and iron, 3.29 per cent., go to the Scotch hearth furnace, which makes metallic lead and gray slag, the latter averaging lead, 31 per cent.; zinc, 25 per cent.; and iron, 13.3 per cent. This slag goes to the slag furnace, which makes metallic lead and slag, averaging 3.5 per cent. lead.

The zinc concentrates are carried by tram cars from the mill to the separators, where they are put through a revolving dryer to expel moisture and combined water to the amount of 7 per cent. Thence to a water-cooled scraper-conveyor to the top of the building by elevator to sizing screens of 0.5-mm., 1-mm., 2-mm., and 0.25-mm. holes. Oversize from 0.25-inch screen is returned to 12x14-inch rolls set close. Undersize re-enters the system. From screen to bins, four sizes.

The four sizes, which pass through screens, go to Wetherill magnetic separators, one 4- and one 6-magnet machine; the smallest sizes going to the smaller machine. Heads from separators, containing iron, 47 per cent., and zinc, from 5 to 7 per cent., are shipped to the iron furnace. The capacity of the mill is about 90 tons of raw ore per day of 10 hours.

Zinc oxide plant.—This plant, consisting of 12 furnaces, has only recently been added for the purpose of utilizing the low-grade ore and tailings, which were formerly discarded. The grade of ore, including tailings, used for making the oxide will average from 15 to 20 per cent. metallic zinc. The zinc oxide made is sent to the Pulaski furnaces where it is used for making spelter. The oxide made is white, and contains about 4 per cent. of lead, and averages from 70 to 80 per cent. of metallic zinc. The successful operation of this plant at Austinville is of great importance, since it furnishes a ready method for utilizing low-grade zinc ores, which have elsewhere been claimed not to be profitable for making spelter.

The Bertha Zinc Smelting Plant.

The only zinc smelting plant in the south, located at Pulaski, Virginia, is owned and operated by the Bertha Mineral Company. This plant was built shortly after the beginning of zinc mining at Bertha, Wythe county, Virginia, in 1879. It was remodeled and enlarged in 1886, and, at present, it consists of 10 large smelting furnaces, ore-sheds or bins, refiners, coal-pit, engine room, pottery, metal storage houses, and a roasting furnace. Suf-

Fig. 1.—General view of zinc smelting plant of the Bertha Mineral Company, Pulaski.

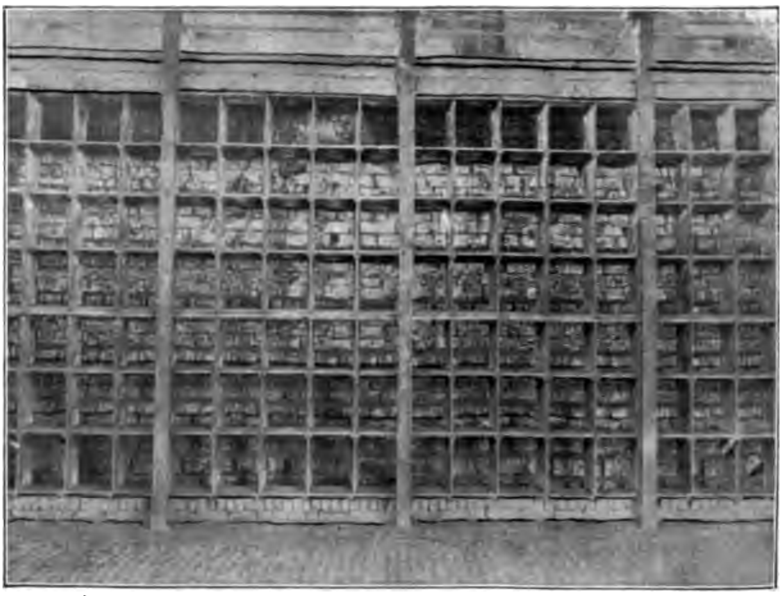

Fig. 2.—View of dismantled zinc furnace, Bertha Mineral Company, Pulaski.

ZINC SMELTING PLANT AND FURNACE, PULASKI, VIRGINIA.

ficient railroad trackage is in operation around the plant for shifting the cars; and a narrow-gauge road is operated between the plant and the company's coal mine at Altoona. Plate LXXIX, figure 1, is a view of the smelting plant.

Spelter.

The high grade spelter made by the Bertha Mineral Company, at Pulaski, has a world-wide reputation. Three grades of spelter are made, branded according to purity: "Bertha Pure Spelter," "Old Dominion," and "Southern." The "Bertha Pure Spelter" is sold under a guarantee of 99.98 per cent. of metallic zinc. The following analysis gives an idea of the composition of this grade of spelter:

	Per cent.
Zinc	99.981
Iron	0.019
Lead	trace
Sulphur	trace
Silicon	none
Carbon	none
Arsenic	none

The "Old Dominion" brand of spelter contains from 0.2 to 0.4 per cent., and the "Southern" brand from 0.8 to 1 per cent of lead.

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IV. GOLD AND SILVER.

Historical.

The earliest reference to gold in Virginia, so far met by the author, is by Thomas Jefferson, in 1782, in which he describes a lump of ore weighing about 4 pounds, taken from the north side of the Rappahannock river, about 4 miles below the falls. The lump is reported to have yielded 17 pennyweight of gold. Jefferson heard of no other indications of gold in the neighborhood.

The first discovery of gold in Virginia, after the date of Jefferson's note referred to above, is reported in 1831. The Virginia Mining Company of New York, operating between the years 1831 and 1834, the Grasty tract of land in Orange county, was the first gold mining company incorporated in Virginia. The date of the incorporation was March 10, 1832. The Orange county, Virginia, deed books show that a one-half interest in a 20-year lease on the 5-acre mining tract, dated 1829, was purchased in 1831 for $30,000 in cash. In 1836 there was considerable activity in gold mining in the State, and the production was reasonably steady from the rediscovery in 1831 to 1850, the annual value being given between $50,000 and $100,000. Increased activity in gold mining in the State was manifested in the early fifties, but the Civil War almost completely stopped mining operations both in Virginia and in the South generally.

The first mint returns from Virginia date from 1829. Considerable activity was again manifested in the Virginia gold fields after the close of the Civil War, and milling and reduction plants were erected at various points. Many of these attempts met with only small success and in most cases they were abandoned, not because of the lack of ore but because, largely, of bad management and inexperienced mining, together with the refractoriness of the Virginia ores.

Distribution.

Map, figure 98, shows the location of principal areas in Virginia from which gold has been mined. The principal gold deposits of Virginia are found east of the Blue Ridge and occur in the crystalline rocks of the Piedmont plateau. These are arranged in a belt which begins in Montgomery county, Maryland, and extends across Virginia in a southwesterly direction to the North Carolina line. The belt varies in width from 15 to 25 miles and is 200 miles long, covering an area of some 4,000 square miles, with its best developed portion in Fauquier, Stafford, Culpeper,

Fig. 98.—Map of Virginia showing the principal gold ore areas.

Orange, Spottsylvania, Louisa, Fluvanna, Goochland, and Buckingham counties. Gold is also found in Appomattox, Prince Edward, Charlotte and Halifax counties, which mark the southwest extension of the principal belt. Excepting Halifax no developments have yet been made in these last named counties. Gold is found in Franklin county between Pig river and Rocky Mount in quartz veins enclosed in micaceous schists. Some alluvial gold has also been noted.

A smaller belt is situated on the west side of the Blue Ridge in Montgomery, Floyd, and Grayson counties, but as yet it is undeveloped and has proved of little economic importance. The work in Montgomery county has been mostly in the nature of sluicing and panning.

Many of the mines in the principal belt have produced large quantities of gold, as shown in the United States mint returns tabulated below, and have been rather extensively worked. So far as is known at present very few of the mines are actively producing, although considerable prospecting is in progress and at some, extensive preparations for mining are being made.

The mines in Fauquier, Stafford, Culpeper, Orange, and Spottsylvania counties are grouped about and near the junction of the Rappahannock and Rapidan rivers in a belt about 15 miles wide. This principal belt is crossed by innumerable streams bordered by placers.

General Geology.

The country-rocks.—The principal rocks of the Virginia gold belt are micaceous schists and gneisses, often garnetiferous and chloritic, and in places hornblendic. They include both altered sediments and igneous masses. The prevailing strike is north 20°-30° east and the dip is toward the east and southeast at varying angles, frequently steep, and in many cases nearly vertical. Granite masses and dikes of basic igneous rocks occur in the region, sometimes sheared from dynamic causes.

The veins.—The gold-bearing veins are quartz, which vary in texture from large crystalline masses to very fine saccharoidal grains. In structure they vary from massive to thin platy or schistose bodies, both usually penetrated by closely spaced irregular fractures. The principal metallic content is auriferous pyrite which, at times, is copper-bearing and contains more or less admixed chalcopyrite. Within the weathered zone, which extends from the surface down to local water level and accordingly is variable in depth, the quartz is rendered more or less porous or cellular and discolored or stained with iron-oxide from the oxidation of the sulphide minerals, and the liberation of free or elementary gold. T degree of porosity and staining is proportional to the amount of sulphide minerals present and the stage of oxidation. Below the le water level the veins are fresh, the sulphides are unaltered, and element gold is less frequent in occurrence.

From the general descriptions of the mines given below, it will observed that the principal and early operations were confined larg to the oxidized portions of the veins, which yielded a free milling that was easy of treatment. Since then operations include the mining sulphurets or the sulphide bodies, which require a different metallurgi treatment of the ores, in order to extract and recover the gold. The g occurs both as free milling ore within the weathered zone and as s phurets below the local ground water-level.

The auriferous quartz veins conform in the main to the structu strike and dip, of the enclosing rocks; a fact which has caused vario explanations to be advanced by different observers. They were regard by some as contemporaneous with the formations in which they occur; others as true veins of injection, and formed subsequent to the schistos of the enclosing rocks; by still others as beds; and lastly by some veins of segregation. As pointed out by Professor W. B. Rogers, in 18 that although in the main the dip and strike of the veins conform w those of the enclosing rocks, the correspondence is far from being exac for they frequently cut the schists at small angles both in dip and strike This evidence is sufficient to establish the fact that the formation of the veins post-dates the schistose structure of the enclosing rocks.

The vein structure is irregular lenticular, varying in width from a few inches to as many feet. Often the lenticular stringers are discontinuous. One stringer may dwindle to a thread or disappear and is replaced by another or by others. Some of the veins are remarkable for their persistence and continuity, conditions best illustrated perhaps by the Fisher lode in Louisa county, which has been opened along the strike for a distance of some 5 miles and to a maximum depth of 250 feet, by at least 5 mines.

The gangue minerals.—Excepting quartz and pyrite, the gangue minerals in the gold veins of Virginia comprise the following species: Chalcopyrite, native copper, galena, mispickel (arsenopyrite), pyromorphite, tetrahedrite, tourmaline, vanadinite, sphalerite, pyrrhotite, and siderite. According to S. F. Emmons the telluride of bismuth, tetradymite, is found in several of the Virginia gold mines. So far as the gangue minerals are

concerned the Virginia gold ores are entirely typical in character. The ores are quartzose deposits in which pyrite is usually present, chalcopyrite common, galena, mispickel, and sphalerite are not rare.

DESCRIPTION OF MINES.

Fauquier County.

Map, plate LXXX, shows the location of the known mines in the principal gold belt of Virginia. The mine description which follows below by counties amounts, in most cases, to hardly more than the naming and location of the known gold mines in the State. This is made necessary because of the fact that a majority of the openings are of very long standing, and are at present in such condition that the geological relations are practically obscured.

The gold mines are located in the southern part of Fauquier county, near Morrisville, about 8 miles southeast of Bealeton, a station on the main line of the Southern Railway. The principal mines are the *Wykoff, Kelly, Bancroft, Franklin,* and *Kirk*. Of these, the *Franklin* mine was the most extensively worked and comprised a 20-stamp mill. An average of 10 assays of samples of ore taken from this mine gave a reported gold value of $24.24 per ton. In 1901 and 1902 about 1,000 tons of tailings were reported cyanided from this mine, but a satisfactory extraction was difficult, presumably, because of the presence of selenium. According to Lindgren, the deposit is a strong fissure in diorite, accompanied by an intrusion of diabase, and was worked to a depth of 80 feet for a continuous length of 700 feet. The *Kelly* and the *Kirk* mines both operated 10-stamp mills.

Stowe described 3 veins at the *Wykoff* mine, one of which, known as the "Mill-House," is given as 20 feet thick. The assay values of the 3 veins are given as follows: "Mill-House," $41.28 per ton; "Tunnel" vein, same value as the "Mill-House"; "Slate" vein, $89.19 per ton. An assay of a sample of ore taken from still another outcrop gave $30.00 per ton. None of the Fauquier county mines were operating in the summer of 1906. The *Kelly* mine is reported to have been the one most recently worked. The Virginia Mining and Development Company is working the *Liepold* mine. Preparatory to opening the mine, a 10-stamp amalgamation mill was worked on the property.

Stafford County.

The principal mines are located in the western part of the county near the Rappahannock river. The *Eagle* mine, located 12 miles northwest of Fredericksburg, was extensively worked until 1894 by the Rappahannock Gold Mining Company. Its length of workings is 600 feet and its greatest depth is 250 feet. The *Monroe, Lee,* and *Rattlesnake* mines are in the same vicinity; the *Monroe* and *Rattlesnake* mines adjoin the *Eagle* on the northwest. The *Rattlesnake* mine was worked as a placer and large quantities of nuggets are reported to have been taken from it, which weighed from one-half to 5 dwts., and some ranging as high as 125 dwts.

The *Rappahannock* mine, 14 miles northwest of Fredericksburg, is situated in the Hartford district, near the Rappahannock river, and was operated both before and after the Civil War. This mine was worked to a depth of more than 200 feet.

Culpeper County.

The *Culpeper* mine is located on the Rapidan river, 18 miles west of Fredericksburg. In a report made by Professor Silliman in 1836 it is stated that the average value of this ore was $25.00 per ton. Other mines in the district are the *Richardville* and *Ellis*. The Powhatan Land and Mining Company operated a mine in Culpeper county in 1894, treating the ore in Crawford mills and a 10-stamp mill in connection with Frue vanners.

Spottsylvania County.

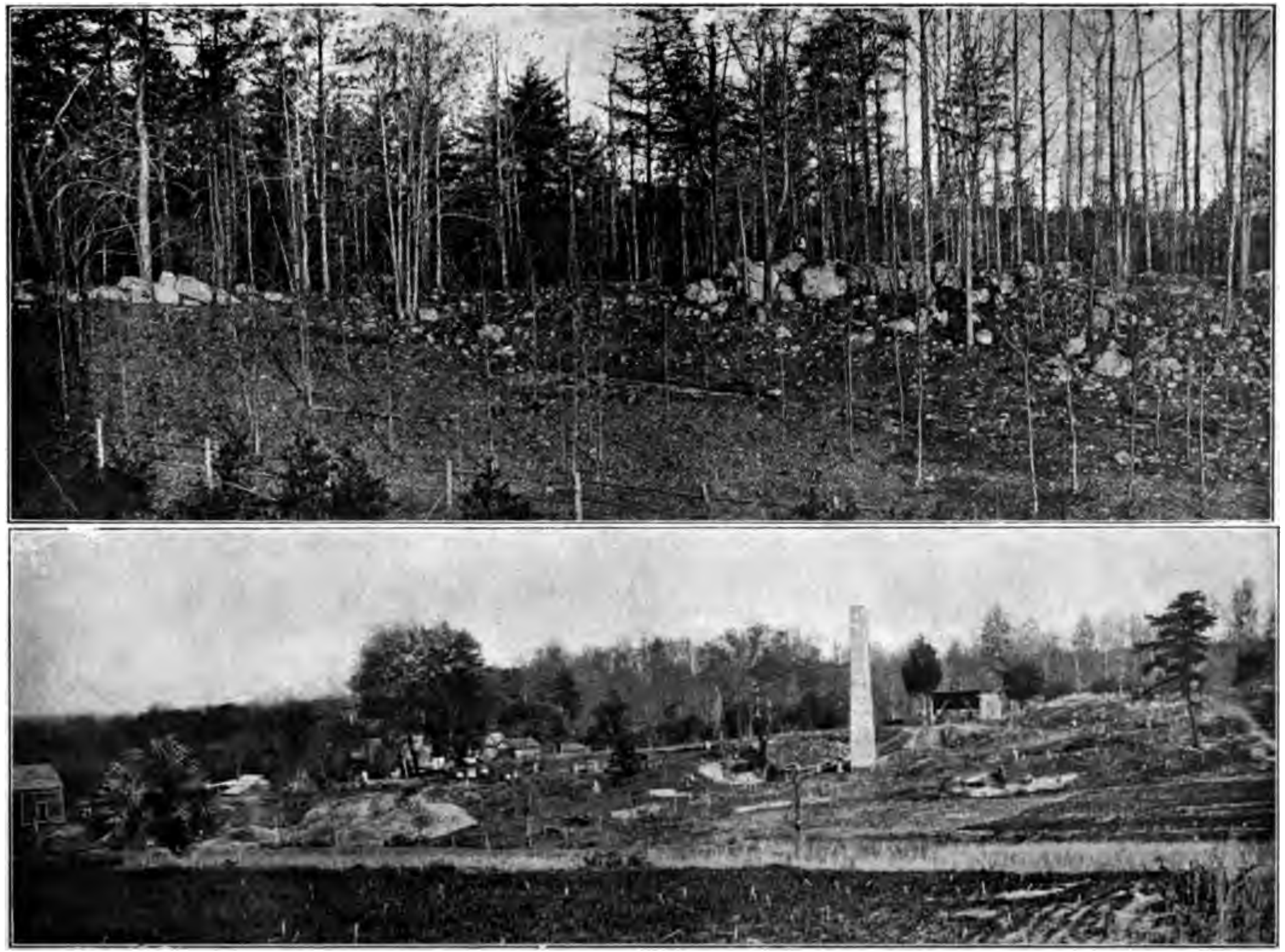
The oldest mines worked in this county were those operated by the United States Mining Company, located near the Rappahannock river, in the extreme northwest corner of the county. A 2-foot vein was operated by adits and shafts, the deepest of which was 80 feet. The value of the ore mined was reported to have been $25.00 per ton and the cost of milling 80 cents per ton.

The following description of some of the earlier milling methods, as practised at the mine near the Rappahannock river, is taken from a report of the Supervising Committee of the United States Mining Company in 1835, as quoted by *Nitze and Wilkens in Bulletin No. X of the North Carolina Geological Survey*: "The plant consists of a crushing (rolls) and a vertical mill (stamping-mill) in a building 26x36 feet. Both mills are located on the ground floor and are propelled by a water-wheel 11 feet in diameter, with a 11-foot face. The crushing-mill has 3 sets of cylinders 2 feet in length and 15 inches in diameter, the first or upper set fluted, the other smooth. The ore is thrown into a hopper on the upper floor, from which it is conducted over an inclined shaking-table to the fluted cylinders by which it is crushed to a size from 1/4 to 1 inch in diameter. The crushed material is equally divided and goes to the two

EXPLANATION OF PLATE LXXXI.

Figure 1.—Portion of a huge quartz vein outcrop on the former "Clark Tract," a short distance south of the former Chicago-Virginia Company's "upper" shaft. The large boulders seen on the surface are blocks of vein quartz. Orange county, Virginia. (The Piedmont Mining and Metallurgical Corporation.)

Figure 2.—View of gold-bearing quartz veins. Represents a length of 440 feet along Ledge No. 1, and includes a portion of the "Smoke House Ledge." The chimney was built by the Virginia Mining Company in 1832, and is almost as good as when first completed. It is a monument to the first scientifically practical attempt at extracting gold from gold-bearing quartz in the United States. To the left of the chimney is the site on which the reduction mill was erected at that time. Orange county, Virginia. (The Piedmont Mining and Metallurgical Corporation.)



GOLD-BEARING QUARTZ VEINS, ORANGE COUNTY, VIRGINIA.

sets of smooth cylinders. By them it is further greatly reduced, ranging from impalpable powder to grains as large as coarse hominy. From these cylinders it falls into a sifter having the fineness and motion of the common meal-sifter, from whence the material which passes through is conducted to 12 amalgamators, constructed upon the principle of the Tyrolese bowls, making from 90 to 100 revolutions per minute. They perform the office of washing and amalgamating. The sand discarded by them, after being washed, is conducted through troughs to the vertical mill, where, being reduced to an impalpable powder, it passes in the shape of turbid or muddy water to another set of amalgamators similar to those above-mentioned, and thence to the river. The portion of the ore reduced by the cylinders which pass over the sifters is conducted to the vertical mill, and is treated in the same manner."

West of the central portion of the county is a group of mines among which the *Whitehall* is the most prominent. Gold was first found at the *Whitehall* mine in 1806, and it was worked from 1848 until just before the Civil War and subsequently as late as 1884. Returns from the Philadelphia mint show that this mine produced $1,800,000 in gold from the beginning of operations down to 1881. At a depth of 28 feet a pocket 3 feet square is reported to have yielded $160,000 of gold. Some of the ore from the shaft of the *Chicago-Virginia* mine assayed $30.00 per ton in gold. An average assay value of 12 samples was $14.00 per ton. Prior to 1880 considerable placer work was done. Other properties in this group are the *Higgins, Johnston, Pulliam,* and *Grindstone Hill* mines.

Farther south on Pigeon Run are located the *Mitchell* and the *Goodwyn* mines. In the earlier days considerable placer work was done along Pigeon Run. The placer workings of the Pocahontas Gold Mining Company at Andrews in the south central part of the county comprised 150 acres in the eighties.

Orange County.

The gold mines of Orange county are located in the northeast corner of the county, near the Rapidan river, and along and north of the narrow-gauge railroad, operated between Fredericksburg and Orange. The first gold mining company incorporated in Virginia was the Virginia Mining Company of New York, operating between the years 1831 and 1834 on the Grasty tract, near St. Just post-office in Orange county.

The *Vaucluse* mine, discovered and opened in 1832, is the most prominent one among the mines of Orange county. In 1843 its plant was valued at $70,000. A description of the milling practice at this mine in

1847 is quoted from *Bulletin No. X of the North Carolina Geological Survey*: "The machinery consists of a condensing Cornish mining engine of 120 horse-power; the mill-house contains 6 large Chilean mills; the cast-iron bed-plate of each is 5 feet 6 inches in diameter, and on it are two cast-iron runners of the same diameter, the total weight of the mill being 6200 pounds. The ores, on arriving at the surface, are divided into two classes: 1. The coarse and hard ore for the stamps; 2. Slate and fine ore for the Chilean mills. This is done by means of a large screen. The very large pieces are first broken by a hammer before they are fed to the stamps. All of the ores are ground with water, each mill being supplied with hot and cold water at pleasure. Twelve inches from the top of the bed-plate there is a wide, open mouth, from which the turbid water escapes to tanks. On the south side of the steam engine is the stamp house and amalgamation mill, containing 6 batteries of 3 stamps each; these stamps, with the iron head of 125 pounds, weigh 350 to 380 pounds each. Each battery is supplied with water, and at each blow of the stamp a portion of the fine ore passes out of the boxes through the grates to the amalgamation room. Here are stationed 18 small amalgamation bowls of cast iron, 30 inches in diameter. The bowls are supplied with runners which move horizontally; in the center of these runners is an eye or opening like that in the runner of a corn-mill. The ground or finely-stamped ore, gold and water pass into this eye, and by the rotary motion of the same are brought into contact with the quick-silver deposited in the center, forming amalgam. From the amalgamators the pulp passes through 3 dolly-tubs or catch-alls, acting as mercury and gold tubs. After this the whole mass passes to the strakes or inclined planes, where the sulphurets are deposited and the earthy matter washed away. These sulphurets were formerly treated in two heavy Mexican drags or arrastras; but not answering so good a purpose, they have been altered into three heavy Chilean mills."

A 14-foot vein at the 60-foot level was reported in 1880 at the *Chicago-Virginia* mine at Mine Run. Other mines in the vicinity are the *Randolph, Orange Grove, Greenwood, Melville,* and the *Grasty.*

The Piedmont Mining and Metallurgical Corporation of Philadelphia, Pennsylvania, incorporated under the laws of Virginia, recently obtained 930 acres of the desirable gold-bearing lands, stretching northward from St. Just post-office, near Clark's Mountain and about 8 or 10 miles west of the *Vaucluse* mine, in Orange county. Several of the tracts included in this property were extensively worked and were large producers in the early days of gold-mining in Virginia. One of these, the *Grasty tract,* was

Fig. 1.—Exposure of large gold- and copper-bearing veins near the northern part of the "American Tract," on Ledge No. 1, about ¼ mile south of the "North-East" shaft. Chimney of the old Virginia Mining Company's mill, built in 1832, shown in the background. Orange county. (The Piedmont Mining and Metallurgical Corporation.)

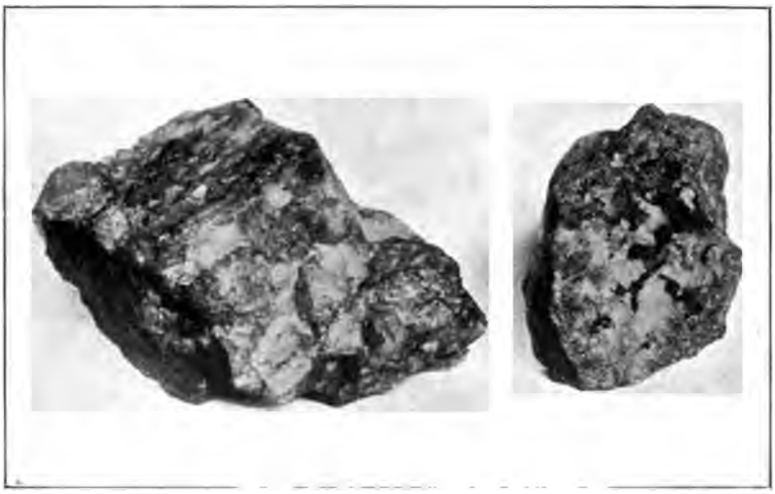


Fig. 2.—Specimens of gold- and copper-bearing quartz ore (sulphides), from Orange county. (The Piedmont Mining and Metallurgical Corporation.)

GOLD- AND COPPER-BEARING VEINS AND ORE, ORANGE COUNTY, VIRGINIA.

the first gold mine incorporated in Virginia. Five different mining companies formerly operated on 3 of the tracts now owned by the above corporation. These were: The *Virginia Mining Company* of New York, operating between the years 1831 and 1843; the *Chancellorsville-Freehold Gold Mining Company* of London, England, operating between the years 1853 and 1857; the *Chicago-Virginia Gold Mining Company,* operating between the years 1879 and 1881; the *American Gold Mining Company,* operating between the years 1881 and 1883; and the *Gold Run Mining Company* of New York, which sank the shaft north of the branch on Mine Run. The mining work done by these companies comprised a total of 578 feet of shaft-sinking, 11 shafts of which were on the *Grasty tract,* 3 on the *Chicago-Virginia tract,* and 1 on the *Dickey tract;* more than 1.000 feet of drifting on the veins; and about 400 feet of underground cross-cutting, tunnelling and surface open-cut work, the largest part of which was on the *Grasty tract.* This work proved all the veins to be gold-bearing, of good width, and carried good ore values.

It is reported that the above mining companies mined several thousand tons of ore during the time of their operations, which embraced several periods of workings between 25 to 75 years ago. The reported gold values of the ore mined varied from $6.00 to $32.00 per ton. Recent development work on these properties, to a depth of 40 feet, by the Piedmont Mining and Metallurgical Corporation, show gold values made on many tons shipped to reduction works ranging from $4.13 to $201.67. Sorted ores gave assay values as high as $41.34, while concentrated ores ran as high as $103.00. The estimated probable cost of mining and milling these ores will not exceed $2.25 per ton, in a 100-ton per day plant.

Louisa County.

The gold-bearing rocks of Louisa traverse the central portion of the county, in a southwesterly direction, in the form of a narrow but well-defined belt. Near the center of the county and in the gold belt, 2 to 5 miles northeast of Mineral, are the famous Louisa county pyrite mines described on pages 198-202 of this volume. These large bodies of pyrite are probably contemporaneous in origin with the gold veins. The ore lenses of pyrite and the quartz veins carrying gold observe similar strike, dip and pitch. Traces of gold are found in the pyrite and small gold-bearing quartz veins which, according to W. H. Adams, formerly manager of the Arminius mines, are gold-bearing to the extent of from $4.00 to $15.00 per ton, are reported encountered in the mines on the hanging- and foot-wall rocks.

The *Tinder Flat* placer deposits, located along and on both sides of North Contrary creek, at the north end of the pyrite mines, were perhaps the best known and most productive source of placer gold in the early days of Virginia gold-mining. These placer bottoms were tested again in 1895 with a view to putting in the necessary modern machinery for working them on a large scale. The silver content of the *Allah Cooper* mine, 2 miles northeast of the *Tinder Flats,* is reported to have been unusually large. A half-mile southwest of the Arminius pyrite mine and on the same line of strike is the *Walton* gold mine. According to Nitze and Wilkens this mine produced some very rich ore from a shoot or chimney developed to a depth of 150 feet. No recent mining has been done as the mine has been tied up for many years in litigation.

The *Walton* mine is located south 10° west about half a mile from the Arminius pyrite mine. Considerable pit prospecting has been done on the property and one shaft has been worked to a depth of 150 feet. The country rock is mica schist of the same character as that enclosing the pyrite lenses at the Arminius pyrite mines. This mine has not been operated for some years, but during the period of its operation, its is reliably reported to have been one of the best producers in the area. A most creditable exhibit of the ores from this mine was made at the Philadelphia Centennial.

The *Cooper* mine, located about a quarter of a mile south 10° west of the Arminius pyrite mines, is developed by a principal shaft about 100 feet deep sunk on an incline of 56° south 80° east. The property has been further prespected quite extensively by numerous open pits. The country-rock is the same as that at the Arminius pyrite mines. It contains thin quartz stringers which in turn contain some admixed calcite with pyrite, and a little chalcopyrite. Work was suspended here in 1903.

The *Luce* gold mine is located about one mile south 25° east of Mineral and about a quarter of a mile south of the Chesapeake and Ohio Railway. The country-rock is a crinkled mica schist containing some garnets. The property has been developed by 2 shafts about 300 feet apart and aligned along a north 30° east direction. These shafts dip 60° and 70° nearly southeast. Numerous smaller openings are made over all parts of the property. A 20-stamp mill was operated at this mine, but from neglect it is rapidly going to wreck and ruin. Indications point to a period of considerable activity at this mine some years back. Much ore was mined and milled. It was probably the most extensive gold operation in the district.

The *Chick* mine, situated about 1.5 miles east of Mineral, is a recent development in the district. At the time of my visit in July, 1906, operations had been suspended and the development work comprised an open cut and tunnel about 50 feet long and 10 to 15 feet wide. This opening is made in a garnetiferous mica schist, the schistosity of which strikes north 15° east and dips nearly vertical. The vein where exposed consisted of thin stringers of quartz interleaved with the schist, the thickest one of which did not exceed 4 feet. A 2-stamp mill had been built and the total production was $65.00.

Two miles east of and parallel to the pyrite ore-bodies, and about one mile east of Mineral, the veins known as the *Fisher lode* have been opened and developed by the *Harris, Luce, Slate Hill, Louisa,* and *Warren Hill* mines. The *Luce and Slate Hill* mines were operated as late as 1895. The *Luce* mine was developed to a depth of 200 feet with the total length of drifting on the vein more than 1,000 feet. Width of the vein is from 3 to 8 feet. A 20-stamp hand-feed mill was operated at the mines. The *Slate Hill* mine was first opened in 1850 and was extensively worked for a while. It joins the *Luce* mine on the southwest, of which it formed a part. Two veins were developed to a depth of 150 feet. According to a report made in 1853 the average value of the ore is given at $4.00 per ton and the cost of mining and milling at $1.40 per ton. In 1895, a Huntington mill had been erected and the mine was being developed in the lower levels.

Fluvanna and Goochland Counties.

The gold belt traverses the boundary of Fluvanna and Goochland counties, crossing the James river at Bremo Bluffs into Buckingham county. Some of the mines in this belt are located partly in both counties, and for this reason the two counties are treated together. Among the principal properties are the *Tellurium, Bowles, Payne, Page, Hughes, Moss, Fisher, Busby, Taugus, Gilmore, Collins, Snead, Marks, Eades, Bertha and Edith, Walters, Manning, Big Bird,* and the *Belzora.* From 1830 to 1860 this belt was extensively operated but at present the district is comparatively quiet and but little work is in progress.

The *Tellurium* mine, located 6 miles from Columbia, lies partly in Fluvanna and partly in Goochland counties. It was discovered in 1832 and was continuously worked until 1857. It was operated again as late as 1886 and during its several periods of activity is reported to have yielded $1,000,000.00 Three gold-bearing veins, the "Big Sandstone," "Middle," and "Little," trending northeast-southwest and dipping 20° to 30° east have been traced for a distance of more than a half mile. It is reported that the average value of the ores mined from the "Little" and "Middle" veins during the 14 years was $100.00 per ton, the minimum being $5.00 and the maximum $300.00 per ton. The value of the ore mined from the "Big Sandstone" vein during the 9 years of operating is estimated at $20 per ton. This vein was developed by numerous shafts, the deepest one of which is reported to have been 120 feet. A 10-stamp mill was operated at the mine.

The *Bowles* mine adjoins the *Tellurium*. Lying partly in Fluvanna and partly in Goochland county, within a half mile of the *Tellurium* and *Bowles* mines are the *Fisher*, *Moss*, and *Busby* mines, all on the same lode. In 1882, the *Bertha and Edith* mine was worked chiefly as a placer deposit. The *Snead* mine, located 2 miles north of Fork Union, Fluvanna county, has not been worked for 20 years.

The *Fisher* mine was opened in 1860 and in 1895 had been developed by a 40-foot shaft and 175 feet of levels. The vein varies from 3 to 15 inches in width but carries reported values of from $25 to $300.00 per ton. One mile northeast of the *Fisher* is the *Moss* mine, which was discovered in 1835. It was worked to a depth of 65 feet and the vein, which according to Nitze and Wilkens is 2 feet in places, carries values from $15.00 to $65.00 per ton. This mine is located 2 miles west of Caledonia, Goochland county, and is leased by the Telluric Gold Mining Company. Recent developments at this mine have been very encouraging.

Two veins traverse the *Moss* property for a distance of about 2,500 feet along the strike. One of the veins is described as composed of lenticular masses of highly laminated quartz enclosed by micaceous schists and dipping about 45° southeast. The ore is practically free-milling down to a depth of 130 feet on the dip, when the sulphides appear. Recent sampling of the workings is reported to have given an average value of $16.00 per ton. Recent developments comprise 2 shafts, one of which is 118 feet deep on a 55° dip, with a total of 285 feet of drifts in ore milling $15.00 per ton. A small shoot was cut in the west level which averaged about $150.00 per ton of gold and 40 ounces of silver. The second shaft is down 130 feet with 60 feet of drifts in ore yielding $14.40 per ton. A milling plant is in operation.

Work at the *Busby* mine a half mile northeast of the *Moss* has been of a superficial nature. According to an early report by Professor Silliman this ore gave values of $160.00 per ton. The *Page* mine is located a half mile west of Wilmington on Long Island creek in Fluvanna county.

GOLD MILLING PLANT AND OPEN CUT, VIRGINIA.

Figure 1.—General view of the Hughes Gold Mining and Milling Company's plant, near Fork Union, Fluvanna county, Virginia.

Figure 2.—Open cut a few feet south of the old Virginia Mining Company's main shaft. The gold-bearing quartz ledge No. 1 is shown at the rear end of the open cut. The Piedmont Mining and Metallurgical Corporation, Orange county, Virginia.

GOLD MILLING PLANT AND OPEN CUT, VIRGINIA.

Mining of the quartz vein was begun in 1856 and an 8-stamp mill was built. Considerable prospecting work was reported in progress prior to 1895.

The *Hughes* mine, owned and operated by the Hughes Gold Mining and Milling Company, comprises a tract of 275 acres, located 5 miles north of Bremo, a station on the Chesapeake and Ohio Railway. This mine was first opened in 1836. Operations conducted by the Hughes Gold Mining and Milling Company for the past several years have been very encouraging.

The developments comprise shafts, drifts and open-pit work. Shaft No. 1 is sunk to a depth of 40 feet on the large ore-body. A level is driven southwest for a distance of 140 feet from the bottom of the shaft and more than 50 feet of ore have been stoped and milled above this level. Test-pits sunk to the northeast of the shaft have proved the vein for a distance of 1,500 feet, with a thickness of from 1 to 5 feet. According to the general manager, Mr. William Bugbee, a mill run on 585 tons of ore stoped from this vein gave a gross value of $9.00 per ton of gold.

Shaft No. 2 is sunk on a second vein 800 feet southwest of the former one to a depth of 110 feet. Two levels at depths of 60 and 110 feet, respectively, are driven from this shaft. The ore-body stoped out from the surface to the first level, 60 feet, varied from 1 to 3 feet in width and showed an average value of $20.00 per ton. Some favored spots are reported to have averaged as high as $711.00 per ton. This ore-body has been opened for a distance of about 230 feet and shows an average thickness of 2 feet, varying between 1 and 4 feet. The average value of the ore is given at $13.00 per ton of gold, based on most careful sampling and assaying.

In addition to these, pits have been sunk on 4 other gold-bearing leads, 3 of which are from 2 to 3 feet thick and assay at or near the surface about $5.00 in gold per ton. The fourth is a 15-inch vein which assays $23.00 per ton of gold at a depth of 18 feet.

The milling plant, comprising stamp mill, concentrating, cyaniding, and furnace departments, is commodious and modern in all respects. The 3 following facts have been demonstrated by Mr. Bugbee: (1) That more than 90 per cent. of the gold in the ore can be saved. (2) That the ore will average nearly $11.00 per ton of gold. (3) That the total cost of mining and treating the ore is a fraction over $4.00 per ton based on the present capacity of the plant.

The *Belzora* mine, discovered in 1832, is located 7 miles from Columbia, in Goochland county. It was worked by surface washings until 1849, after which time the veins were opened. Adjoining the *Belzora* are the *Marks, Collins, Eades* and *Big Bird* mines.

Buckingham County.

Buckingham is the most southwesterly county of the Virginia gold belt in which mines have been actively worked. As stated above, the occurrence of gold is known still farther to the southwest in Appomattox, Prince Edward, Charlotte, and Halifax counties but, as yet, no developments have been made, except in the last named county, Halifax.

The principal mines operated in Buckingham county were the *Booker,* sometimes called the *Morrow; London and Virginia, Buckingham, Garnet ond Mosely, Morton, Ford, Philadelphia, Willis Creek, Piedmont, Apperson, Duncan, Anaconda,* and the *Lightfoot.* All of these were actively worked at one time. The largest ones were operated extensively before the Civil War and are reported to have produced large amounts of gold. Some of these have been worked since the War and a few within recent years.

The *Booker* mine is located 4 miles southwest of Dillwyn and was extensively worked prior to the Civil War by an English Company. The mine is developed by numerous shafts and drifts, the deepest of which is 106 feet. The work is of such long standing and the dumps so entirely cleaned up that very little could be seen at the time of my visit in August. It is reported that the ore was treated in a Howland mill and yielded $13.00 per ton.

The *London and Virginia,* and the *Buckingham* mines join each other and the openings extend from one on to the other, along a north 40° east direction. These mines are located one mile northwest of Dillwyn. They were developed by shafts and open-cuts, the deepest of which will not exceed 160 feet. The principal opening is a cut which extends nearly entirely across both properties. It is variable in both width and depth, with a probable average of about 12 feet wide and from 20 to 80 feet deep. It follows the dip and strike of the vein which closely conforms with the structure of the enclosing mica-schists. The schists vary from biotite-muscovite to sericite and finely laminated quartzose rocks. These properties were large producers before the Civil War, but at the beginning of the War they were closed down and practically no work has been done since. Some placer gold was mined in the early days in the vicinity on Turpin's creek.

At the *Anaconda* mine, three-quarters of a mile southwest of Johnston, development work on a small scale was in progress in August, 1906, by the Anaconda Gold Mining Company. This property was worked as a placer deposit some years ago.

The *Lightfoot* mine, situated 2 miles northwest of Arvonia, on the east side of the Slate river, was worked in 1861 and again developed by an 85-foot shaft and drifts some 5 or more years ago for copper. Preparations are now in progress for the further development of this mine.

The *Apperson* mine, 12 miles southwest of New Canton and 10 miles northeast of Buckingham court-house, comprises 3 veins, one of which measured 10 to 15 feet wide of gold-bearing rock.

Halifax County.

In the Virgilina copper belt of Halifax county, gold-mining is engaged in and 2 mines have been opened up, situated close together, about 6 miles directly north of the town of Virgilina. One of these, the *Goldbank* mine, incorporated under the name of the *Virgilina Gold Mining Company,* is an active producer of gold at the present time.

The vein is parallel and similar to the numerous other veins in the district worked for copper, except that besides a little copper its chief value is in gold. The vein material is quartz enclosed by highly altered andesite, resembling somewhat a sedimentary slate. It is nearly vertical, and has a nearly due north-south strike. The elementary gold is very finely divided and is contained in both the quartz-filling and the enclosing country-rock. Sulphides of copper occur in subordinate amount but no attempt is made to save them. The value of the vein is said to average $8.00 per ton of gold across its width of 6 feet.

A vertical shaft has been sunk to a depth of 160 feet and drifts have been run along the vein at this level for a distance of 100 feet to the north and 300 feet to the south, taking out the entire width of the vein. A mill containing 2 batteries of 5 stamps each is operated at the mine. Two more batteries are contemplated. The stamps weigh 750 pounds each. No attempt is made to save or treat the tailings which are known to be rich in gold. During 1906 about 10 tons of ore per day were being milled.

The *Howard* gold mine, located only several hundred yards from the *Goldbank* mine of the Virgilina Mining Company, has temporarily suspended operations. A milling plant has been built at the mine carrying a battery of 5 stamps. The underground developments comprise some shaft and drift work.

Montgomery and Floyd Counties.

On the west side of the Blue Ridge and at the southeast base of Pilot Mountain, placer deposits were opened in 1879 along Brush and Laurel creeks, in Montgomery and Floyd counties. Most of the tributaries to Brush and Laurel creeks show some gold and prospecting has extended over an area 20 miles wide by 4 miles long, a total of 80 square miles. The area is further traversed by numerous white and mottled gold-bearing quartz veins.

According to Professor Fontaine, the average yield for the best of the earth in 1882 was about 5.5 grains of gold per pan of 25 pounds of earth. The gold contains about 32 per cent. of silver. The quartz veins and stringers charged with pyrite are in gneiss and specimens of the vein and of the gneiss were sampled by Professor Fontaine and separately assayed with the following results:

Veins.......64.6 grains per ton of which 27.1 grains were silver.
Gneiss...... 5.7 grains per ton of gold and silver.
Gneiss...... 6.4 grains per ton of gold and silver.

In 1880, $2,500 worth of gold is reported panned out in 2.5 months. One assay is stated to have yielded $94.00 per ton of gold and $3.00 of silver. Nuggets were taken from the loose deposits that sold for $2.00 and more a piece. An analysis made by Mr. Porcher of a specimen of native gold from the workings in Montgomery county gave:

	Per cent.
Gold (by cupellation and parting)	65.31
Silver (by cupellation and difference)	34.01
Copper	0.14
Iron	0.20
Quartz	0.34
Total	100.00
Specific gravity	15.46

Gold occurs in Patrick, Carroll, and Grayson counties in small quantity in association mostly with copper ores.

Production.

Records of actual production from mining operations in Virginia date from 1829. The U. S. Mint returns from 1829 to 1854 show that nearly one and a half millions of gold were deposited during that period from Virginia mines. The following tables are compiled from the production reports of the U. S. Mint. The figures represent not only the amounts deposited at the U. S. Mint and Assay Offices but such other amounts as were produced and not turned into the Mint of which records could be obtained:

Production of gold and silver in Virginia by years.

Year	Value	Year	Value
1799-1879	$3,091,700	1893	$ 6,190
1880	11,500	1894	7,643
1881	10,000	1895	6,325
1882	15,000	1896	4,466
1883	7,000	1897	not given
1884	2,500	1898	4,500
1885	3,500	1899	7,160
1886	4,000	1900	3,200
1887	14,600	1901	5,720
1888	7,500	1902	6,227
1889	4,113	1903	18,630
1890	6,496	1904	7,686
1891	6,699	1905	5,122
1892	5,002		

The following results show the U. S. Mint returns for the first 5 years of production of gold in Virginia, from 1829 to 1833, inclusive:

Year	Value
1829	$ 2,500
1830	24,000
1831	26,000
1832	34,000
1833	104,000

The following table shows the distribution of gold and silver in Virginia, annually, as to sources of production, from 1900 to 1905, inclusive:

Year	Gold		Silver	
	Quartz Fine ounces	Placer Fine ounces	Quartz Fine ounces	Copper ores Fine ounces
1900	78	94	96	——
1901	185	128	617	427
1902	181	27	—	1,344
1903	216	—	—	17,073
1904	—	—	—	——
1905	202	39	173	——

In 1904, the production of gold and silver in Virginia was contributed to by eleven counties. From the U. S. Mint returns for 1905, Lindgren estimates that for Virginia, gold increased in value over 1904, $1,182; and silver decreased $3,779. In 1905, 7 mines were reported producing, 3 of which were placer mines. According to Lindgren the 4 deep mines yielded an estimated tonnage of 800, giving an average of $5.35 per ton in gold and silver.

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V. TIN.

Mineralogical and Chemical Character.

The tin-bearing mineral, cassiterite, is an oxide corresponding to the formula SnO_2 and contains theoretically 78.6 per cent. of metallic tin. When pure, cassiterite is nearly white, but it usually contains more or less ferric oxide which imparts a reddish to brown or black color, proportionate to the percentage of iron present. The mineral sometimes occurs in prismatic crystals of Tetragonal form, though when found in commercial quantity it is more often granular and in rough masses. Three varieties of the mineral are recognized: (1) ordinary or tin-stone obtained directly from the vein; (2) wood-tin having the color and appearance of dried wood and of botryoidal and reniform shapes; and (3) stream-tin found along stream courses in the loose sand and gravel deposits.

Historical.

The existence of tin ore on Irish creek, in Rockbridge county, was known for a long time prior to the first prospecting in 1883, when active operations were begun. The tin ore from this locality was first tested by Professor Armstrong of Washington College, Lexington, in 1846; he claimed that the specimen contained both tin and silver. Only two openings had been made prior to 1883. Since that time prospecting for tin ore has been reported along the eastern edge of Rockbridge county, extending parallel to the Blue Ridge, from a few miles north of the James river into Nelson county. Thus far the most favorable portion of the region in which tin has been found is that known as the Irish creek area, located in the northeastern corner of Rockbridge county, in the crystalline rocks of the Blue Ridge, about 7 miles distant from Vesuvius, a station on the Shenandoah division of the Norfolk and Western Railway, and at an average elevation of about 2,800 feet. A company known as the Virginia Tin Mining and Manufacturing Company was organized in 1883 for the purpose of working the tin deposits along the headwaters of Irish creek. The work of sinking a shaft commenced in November, 1884.

Occurrence.

The Irish creek area is about 4 miles long in a northeast-southwest direction and is 3 miles wide, embracing a total area of 12 square miles. The immediate rocks of the area are crystallines, of granitic composition, composed principally of a coarse aggregate of quartz and feldspar (orthoclase and acid-plagioclase, albite), with hornblende. The rock is porphyritic in places, the large feldspar crystals measuring as much as an inch and more in length. The coarse granite enclosing the tin veins is reported to be often rich in tourmaline. The granitic rock is generally much decayed at the surface to a mottled clayey mass which is as much as 50 feet thick. A finer textured facies of the granitic rock is quite common. Further variation is shown in lenticular masses of a flesh-colored granitoid facies of the rock, consisting of orthoclase, quartz and epidote, which closely resembles unakite and has been so designated by some.

Dikes of fine-grained altered diabase traverse the granitic rock in all directions and apparently they are frequently associated with the veins of tin ore. Sedimentary rocks are commonly developed along the western flank of the ridge and lower down the slope they pass beneath the Valley limestone.

The tin ore occurs principally in well-defined quartz veins which traverse the granite in all directions and have steep though varying dips. The veins are banded and contain pyrite and arsenopyrite in addition to cassiterite. The walls of the enclosing granite are changed to greisen (quartz and fine scaly muscovite) containing a small amount of cassiterite. The veins are usually narrow not exceeding a foot and less though a greater thickness is frequent and some of the veins measure several feet across. In the veins proper, the gangue is quartz in which the cassiterite occurs as crystals, nodules, and stringers. According to Winslow, the general character of the gangue is a dark earthy rock, composed largely of quartz with pyrite, mica and various earthy minerals, among which cassiterite is disseminated in small crystals and in fine grains indistinguishable to the naked eye.

Near the surface, the vein rock is much altered and softened from weathering and is of a reddish to yellow-brown color from the oxidation of the iron-bearing minerals. In its undecomposed or fresh condition it is readily distinguished from the enclosing country-rock. The location and character of the veins have been proved by numerous openings usually of shallow depth. Analyses have proved nearly every vein to contain tin but in many cases the quantity is reported to be very small. On the other hand many of the veins show rich returns. Through some of these, veinlets of solid cassiterite an inch or more thick and pockets composed of nodules of tin-stone are reported. Winslow describes numerous nodules of cassiterite the size of a hen's egg; and in one of the veins at a depth of 6 feet below the surface, he describes a block about a foot in diameter of nearly pure cassiterite.

The associated minerals so far discovered comprise wolframite, mispickel (arsenopyrite), pyrite, and beryl. In addition to these, siderite, limonite, chlorite, muscovite, damourite, and fluorspar have been reported found. The mispickel is reported by McCreath to contain both gold and silver.

Opening No. 1 on the Cash lands of Irish creek showed the crystalline rocks to dip nearly vertical, consisting mostly of an aggregate of quartz, feldspar and hornblende and, in places, mica-schist. The vein was composed of white quartz with tin ore, the largest piece of which did not exceed 2 inches in thickness and much of it was not over 1 inch. The samples assayed, showed an average of 31.60 per cent.

According to the prospectus of the Virginia Tin Mining and Manufacturing Company, there is a continuous and well-defined vertical vein of crystalline cassiterite, averaging 1 inch in thickness, in one of the two trenches at opening No. 1 on the Cash lands. About a ton of ore was reported removed which yielded on assay about 75 per cent. metallic tin.

According to Professor Henry D. Campbell, who visited the Martha Cash mines in 1883, secured a specimen from one of the veins, which he analyzed with the following results:

	Per cent.
Tin (metallic)	63.583
Iron (metallic)	1.680
Silica	.415
Sulphur	0.066
Arsenic	0.301
Titanium	distinct trace

In 1885, Massie described the character of the ore on the Cash lands as occurring in the form of cassiterite or black tin in sheets, strings and nodular masses, in the gangue of veins. The color of the cassiterite is from light yellowish-brown to dark brown and the ore is free from injurious minerals.

Operations stopped in the Irish creek area as early as 1886, owing to the tin lands becoming involved in litigation. In 1889, a party of Boston capitalists obtained control of the Cash mines and, in 1890, they began operations by erecting a small concentrating plant, Sturtevant mill, a set of jigs and a vanner. At the close of 1891, the mill, located near Vesuvius, on the Norfolk and Western railroad, which cost $50,000.00, was ready. At the same time the development work put about 290 tons of rock, averaging about 3.3 per cent. of metallic tin, on the dumps. About 240 pounds of the black tin concentrates were shipped to Boston to be smelted. These are reported to have averaged only 43 per cent. of metallic tin because of the arsenopyrite and ilmenite. The property again became involved in litigation and operations were again suspended. The vein from which the ore was obtained by the Boston parties for the above tests was 6 to 8 feet wide. The tin ore impregnates the granite on the two sides of the vein but in such small quantities as not to be workable.

The late Major Hotchkiss examined the Irish creek tin area for the Lexington Tin Company in 1885. A part of his report follows which is quoted from the Mineral Resources of the United States for 1885:

"The tin ore of this region is found in the form of crystals, threads, or stringers, and in masses of varying size, disseminated in fissure veins traversing, in all directions, the granitic and other Archaean rocks that here constitute the crest and the immediate westerly slope of the Blue Ridge, and that disappear beneath the Potsdam rocks 1 or 2 miles to the northwest of the tin-bearing field.

"The tests to prove the existence of these ores were made by sinking, driving, or cutting pits, trenches, shafts or tunnels, at the points indicated, as hereinafter described in detail, mainly in a territory about 1½ miles long and 1¼ miles wide. At other points, outside of this territory, the existence of tin ore has been proved. The character of these test works and of the ore found at each, and therefore the present condition of information about these tin ores, based on what has been actually ascertained about them, can best be learned by a brief statement about each of these trial works.

"No. 1. This is known as the "Cash No. 1 mine," as it is at the point on the Cash land where tin ore was first found in this region. This is an open cut about 60 feet long and from 3 to 10 feet deep, driven into the base of the spur of Cash Mountain a few feet above the level of Painter branch. The tin-bearing vein here has an average thickness of about 84 inches; this consists of tin-stone disseminated in small grains and small pockety masses throughout a gangue of quartzose and micaceous rock that can be easily mined and crushed, and next to the wall, a persistent vein of solid tin-stone, or cassiterite, that averages one inch in thickness, and is sometimes 6 inches thick. Several branchings of veins from the main one, penetrating the crevices of the adjacent rocks, have also been discovered here. Portions of this large vein are occupied by massses of quartz rock.

"Professor Campbell sampled 72 inches of the thickness of this vein, including the wall rock involved with the ore, and found it to contain 66 pounds of metallic tin to the ton. Mr. McCreath analyzed a sample of this ore selected by Mr. Rittenhouse 'representing all grades, from pure tin crystals to quartz and rock containing little or no tin,' and found in it an average of 3.160 per cent. of metallic tin. The cassiterite will yield, by itself, from 65 to 70 per cent. of metallic tin.

"No. 2 embraces four openings; the second opening is a shaft 40 feet deep, said to include a vein of tin ore that is 36 inches thick at the surface and 120 inches thick in the bottom of the shaft where sinking was suspended. Mr. Cabell Whitehead found in an average sample of the ore of this vein, representing its whole thickness, after repeated assays, an average of 5 per cent. of metallic tin, or from 125 to 130 pounds of tin to the ton of ore. Professor Campbell made the percentage larger.

"About 3,000 pounds of the ore from this shaft were sent to England as a trial lot; the purchaser reported a considerable yield of metallic tin. I requested Mr. Massie, who selected the ore for that shipment, to sample the ore lying scattered around this shaft for me, so as to give me what would fairly represent the ore that was shipped to England. I witnessed the sampling, and am satisfied that it was fairly done. This sample of several pieces I submitted to Dr. Frank W. Traphagen, analytical and consulting chemist of the Staunton Male Academy, and he found in it, after repeating his analysis, 17.54 per cent. of binoxide of tin, or 13.79 per cent. of metallic tin. Nodules of cassiterite, from small sizes up to some 12 inches in diameter, have been found in this vein; there is no question about its richness. This shaft is on the slope of Painter mountain, and more than 400 feet above the level of Irish creek at the foot of the mountain to the north. No. 2a is a pit uncovering a large bowlder of quartz that is veined with crystals of tin-stone; that will probably yield as well as the vein at the shaft, or No. 2, which is 70 feet above this in altitude, the intermediate ground being strewn with tin ore. No. 2b is an open drift, at a level 90 feet below No. 2, cut for 60 feet into the slope of the mountain, ending there about 15 feet deep, where a vein of tin ore, apparently averaging with that at No. 2, had been cut and found 108 inches thick. No. 2c is a trench on a tin-ore vein of about the same character as the preceding.

"No. 3 is some 500 feet above the level of the creek opposite, is a long trench, about 6 feet deep, exposing some 10 feet of a vein of tin-stone that is 48 inches thick. An average sample of this ore, assayed by Prof. H. D. Campbell, yielded 0.292 per cent. of metallic tin; a sample assayed by Prof. M. B. Hardin, at Virginia Military Institute, yielded 0.41 per cent. A quartz vein is exposed near this, resembling the one near No. 2. Traces of ore extend from this to No. 2.

"No. 4 is a shallow cut, about 1 foot deep, exposing a tin vein 12 inches thick that yielded 0.19 per cent. when assayed by Prof. M. B. Hardin.

"No. 5 consists of three pits connected by a trench. The tin vein in the middle pit is 18 inches thick; samples from this yielded 5 per cent. metallic tin in an analysis by Professor Hardin. A sample from the upper cut, or pit, an average of the ore from 6 feet of length of vein, gave 0.799 per cent. of binoxide of tin on analysis by Prof. H. D. Campbell. In the upper cut the vein is one-half inch thick at the depth of 10 feet; it becomes thicker as it goes down, and will average 7 inches. A good many crystals of tin-stone are found here.

"No. 6 is a pit exposing a vein 12 inches thick; it widens in going down. An average sample yielded 0.28 per cent. of metallic tin as analyzed by Professor Hardin.

"No. 7 is a pit showing a vein 18 inches thick; it is much like No. 6 but poorer.

"No. 8 is a pit showing a vein 36 inches thick of lean ore.

"No. 9 is a pit showing a vein 4 inches thick; ore not assayed.

"No. 10 is a shaft 40 feet deep, sunk on a vein 36 inches thick. A sample taken at the depth of 3 feet, before the shaft was sunk, representing an average of the exposed vein, yielded 1.12 per cent. of metallic tin to an assay by Dr. Dabney, of North Carolina; at a depth of 10 feet, 2 per cent. of cassiterite was found in an assay of the vein by Mr. A. D. Robertson. This vein is in trap rock. Three or four threads of ore come together in the bottom of the shaft.

"No. 11 is a pit exposing a vein 43 inches thick containing a trace of tin.

"No. 12 exposes a vein 12 inches thick containing a trace of tin.

"No. 13 exposes a vein 8 inches thick containing a trace of tin.

"No. 14 is a vein 48 inches thick of lean ore between trap and granite.

"No. 15 is a trench exposing a 6-inch vein in quartz in which crystals of tin-stone are found.

"No. 16 is a tunnel in rotten granite 30 feet long, cutting a vein of lean ore from 3 to 12 inches thick.

"Nos. 17, 18, 19, and 20 are pits exposing a 6-inch vein of lean ore.

"No. 21 is a tunnel driven in rotten granite some 60 feet along an 18-inch vein. Professor Hardin assayed picked samples from this vein and obtained 3¼ per cent. of metallic tin. Professor Campbell assayed a sample, averaging 25 feet of the length of the vein, and obtained 0.582 per cent. of metallic tin. In a pit sunk above this tunnel this vein is also 18 inches thick.

"No. 22 is a vein exposed by the roadside that is from 3 to 4 inches thick in solid rock; it is regarded as an offshoot thread from No. 21.

"No. 23 is a pit and a short tunnel on a lean 10-inch vein.

"No. 24 consists of two parallel veins about 10 feet apart, from 3 to 6 inches thick, which meet No. 25; this ore assays next to that of No. 21.

"No. 25 is a vein about 12 inches thick, which crosses and dips towards No. 24; it assays about 0.25 per cent.

"No. 26 is a tunnel about 30 feet long in a vein 24 inches thick in places; this assays 0.10 per cent.

"No. 27 is a pit exposing two parallel veins about 6 feet apart, one 4 to 6 inches and the other 12 inches thick of lean ore.

"No. 28 is a pit exposing a 24-inch vein of lean ore.

"No. 29 is a drift cut some 30 feet long and over 30 feet deep at the end, exposing a vein of lean ore averaging 24 inches thick. Assays 0.10 per cent. This vein has been exposed for 400 yards, to the top of the mountain, where it is 120 inches thick; in places in the drift below it is 240 inches thick. The tin-stone here is associated with quartz and iron pyrites. It is believed that this and Nos. 30, 31, and 32 will finally come together.

"No. 30 is a vein 12 inches thick in very hard rock; an assay of a sample gave 1 per cent., but the average will be less.

"No. 31 is a vein averaging 24 inches in thickness (36 in places). Professor Hardin obtained 0.17 per cent. of tin from an average of the whole vein. It also carries $1.86 of gold to the ton.

"No. 32 is a vein 48 inches thick, averaging in richness between Nos. 30 and 31.

"Nos. 33 and 34 are cuts on a quartz and pyrites vein containing traces of tin.

"No. 35 is an outcrop of veins from which an 8-inch cubic block of crystals of tin-stone was obtained. Not opened as yet.

"No. 36 is a quartz vein 60 inches thick that yielded an average of 0.12 per cent. of metallic tin to assay of Mr. A. D. Robertson.

"No. 37 is a vein 36 inches thick, on Mount Nettle, some 1,200 feet above Irish creek, in micaceous granite.

"No. 38 is a 10-inch quartz vein containing iron pyrites and a trace of tin.

"In the above notes the measurements of Messrs. Winslow and Robertson have been accepted and used, and the assays of Messrs. McCreath, Campbell, etc., as reported in published articles and as furnished to Mr. Robertson.

"The forty odd testing pits, trenches, shafts, tunnels, etc., above mentioned, are distributed over a territory nearly 10 miles wide and 4 miles long in the north and middle spurs, Mount Maria, Cash mountain, Painter mountain, Mount Elizabeth, Little Hill and Big Hill, and Mount Nettle, all spurs of the Blue Ridge projecting between the northeasterly and the easterly head branches of Irish creek. In all of these more or less metallic tin has been found, ranging from "traces" up to 70 per cent. Those that have been assayed may be recapitulated as follows:

"No. 1, 0.292 to 65 or 70 per cent., 66 pounds to the ton average.

"No. 2, 5 to 13.79 per cent., 125 to 130 pounds to the ton.

"No. 3, 0.292 to 0.41 per cent.

"No. 4, 0.19 per cent.

"No. 5, 0.799; 17.58 pounds of "black" tin to the ton.

"No. 6, 0.28 per cent.

"No. 10, 1.12 to 2. per cent., 35 pounds of "black" tin to the ton.

"No. 21, 0.582 to 3.25 per cent., 18 pounds of "black" tin to the ton.

"No. 25, 0.25 per cent.

"No. 26, 0.1 per cent.

"No. 29, 0.1 per cent.

"No. 31, 0.17 per cent. of tin and $1.86 of gold to the ton.

"No. 36, 0.12 per cent.

"The localities of the above and the per cents. of tin are:

"No. 1, on Cash mountain, 31.60 to 70 per cent.

"Nos. 2 and 3, on Painter mountain, 0.292, 0.41, 13.70 per cent.

"Nos. 4 and 5, on Mount Elizabeth, 0.19, 0.799 per cent.

"No. 6, on Little mountain or hill, 0.28 per cent.

"No. 10, on Big Hill, 1.12, 2 per cent.

"Nos. 21, 25, 26, 29, and 31, on Mount Maria, 0.17, 0.25, 0.582, 0.1, and 3.25.

"No. 36, on North Spur, 0.12 per cent.

"Omitting from the above the deposit on Cash and Painter mountains assays Nos. 1, 2, and 3, the averages of yields from the other localities do not vary greatly among themselves, showing that these ores range in richness from 0.1 to 3.25 per cent.; the eleven assays of these localities averaging 0.805 per cent., or nearly 18 pounds of "black" tin to the ton. I see no reason why an abundance of ore should not be had from these, Mount Elizabeth, Little mountain, Big Hill, Mount Maria, and North Spur veins, that will yield this average result.

"The assays of the Cash and the Painter mountain ores range in richness from 0.292 to about 70 per cent., making an average for the five given of 23.218 per cent. This is probably too high an average for all the well-picked tin stone that could be obtained from these localities; and yet it would not, in my opinion, be very difficult to obtain from them a large quantity of ore that would run such an average. The prospecting that has been done, the condition of the veins as exposed, and their richness in metallic tin, I think, warrant the conclusion that an abundance of high-grade ore can readily be obtained from these localities.

"While the developments that have been made here are by no means extensive, and are not such as one would like to see, still they cover a very considerable area and fairly well expose the tin veins from the surface, and so that their character can be s than this, the openings that have been made are so l expose to inspection fully 600 feet of the vertical de of this region, some of them having been made nea creek and others near the top of the spurs more than level; horizontally these openings are many of them apart; consequently, it is fair to say that we have and steeply eroded or naturally trenched region, the of varying depths, up to over 600 feet in a level co numbers 1 and 2 are but 1,600 feet apart horizontal over 300 feet apart vertically. It is considered that their surroundings there are nearly the same data for be obtained if the shaft at No. 2 were sunk to a dep same may be said of the other localities where the posed. This knowledge has led me to the favorable pressed in reference to the quantity and the quality o

"The geological and mineralogical conditions of bearing region are similar to, if not even identical Cornwall (England) and other noted tin-producing the same crystalline and metamorphic rocks, broken, by dikes of trap, basalt, and other igneous rocks, th conditions for the formation of true, profitable, metall such as are caused by profound movements of the ear veins as those in which stanniferous ores of the Iri found.

"The exposure of the Irish Creek tin veins, both r unmistakably leads to the conclusion that these veins character, extent, thickness, and richness in metallic with those of the famous Cornwall district of Engla conditions are better. I may add that no region ca vantages for extensive mining and metallurgical ope is all the year round salubrious and favorable for w proper of Virginia, unlike most mountain chains, fertility and varied productiveness, and the same may Virginia, that flanks it on the east, and of the famous flanks it on the west. The forests of this region for charcoal; and it is not far by direct railway to th and coking coals in the United States.

"In conclusion, this report is emphasized by the opinion that this Irish Creek tin-bearing district, as above described, will prove abundantly productive in tin."

Other Localities.

The occurrence of tin is reported from Nelly's Ford, near Rockfish river, in the northern portion of Nelson county. No prospecting has yet been attempted.

Bruce in his book entitled, *Southwest Virginia and Shenandoah Valley,* published in 1891, makes the following statement concerning tin in Clarke county (pages 234-5): "Along the foothills of the Blue Ridge, in this county, fine specimens of copper and lead have been discovered east of the Shenandoah river, and tin has been reported to have been found on the Capon Springs property by Mr. Bale, who shipped a cargo of the ore to Wales."

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VI. NICKEL AND COBALT.

General Statement.

Nickel and cobalt can best be treated together, for most of the ores containing one are apt to carry some of the other. Virginia has not, as yet, produced any appreciable quantity of either of these metals, but there are occurrences in certain localities of the State which afford promise of commercial quantities of the metals, especially nickel.

The existence of nickel in Virginia has been reported from a number of localities in the Piedmont region or crystalline area, especially in association with many of the extensive pyrrhotite bodies of the Floyd-Carroll-Grayson plateau in southwest Virginia (map, figure 29), and in Amherst county near and to the east of Lynchburg. In Amherst county the pyrrhotite is somewhat sparingly developed as small grains and moderate size granular masses, in crystalline schists, partly hornblendic, of doubtful origin. More recently, nickel, in association with peridotite masses, has been reported from near Broadrun station, in Fauquier county, northern Virginia; but this locality has not yet been investigated.

Reliable analyses of the southwest Virginia pyrrhotite bodies, giving the exact percentage of nickel and cobalt, are unfortunately not available. Recent developments in northern Floyd county, near the boundaries of Montgomery and Roanoke counties, give very encouraging results of the existence of nickel in commercial quantities. This area is described below in some detail.

In addition to the above occurrences and associations, cobalt is found in association with some of the impure earthy manganese (wad) deposits of the Valley region, especially on the east side of the Valley along the western base of the Blue Ridge. The following analysis of manganese ore from the Church Mountain mine in Rockingham county, made by Professor

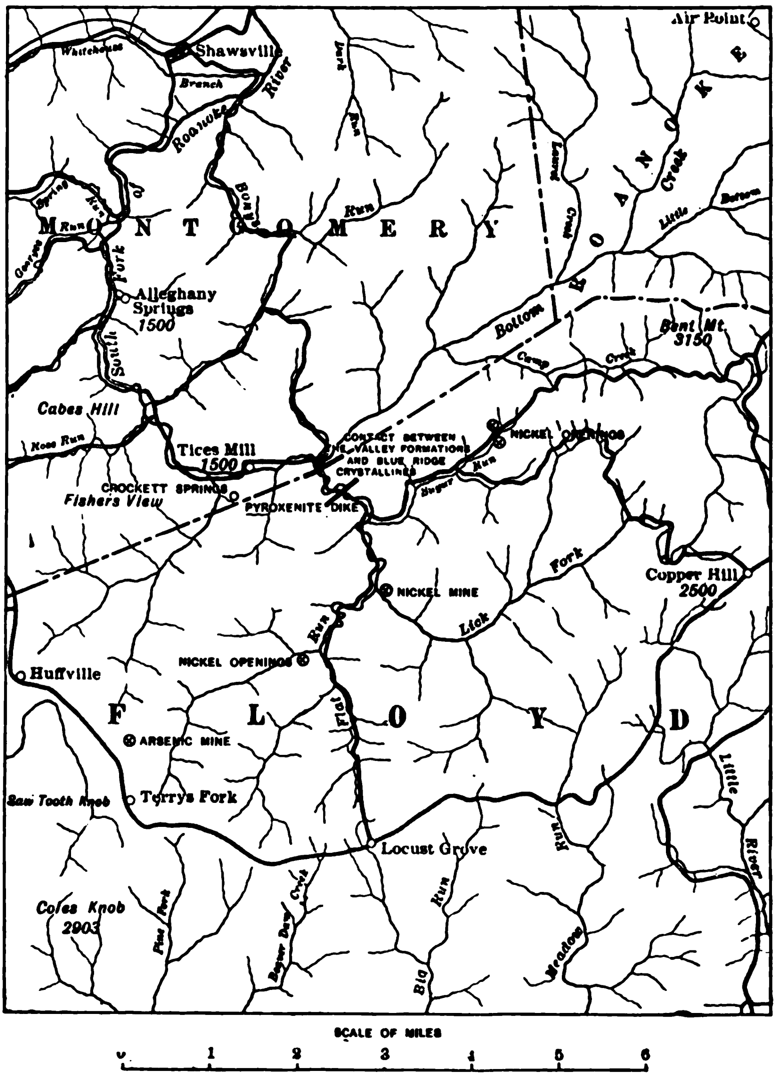

Fig. 99.—Map showing location of nickel and arsenic mines in Floyd county, Virginia.

F. W. Clarke of the U. S. Geological Survey, shows a noteworthy percentage of cobalt:

	Per cent.
Metallic manganese	39.20
Cobalt	2.48
Iron and aluminum oxides	5.14
Insoluble matter	22.11
Ignition	11.30

The Floyd County Area.

The property, controlled by the Virginia Nickel Corporation, as indicated on the accompanying map, figure 99, is located in the extreme

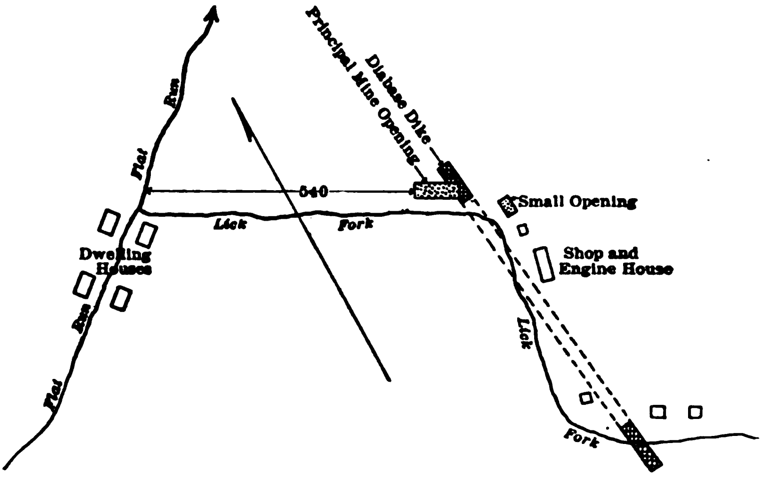

Fig. 100.—Ground plan showing location of openings at nickel mine on Lick Fork, near Hemlock, Floyd county, Virginia.

northern part of Floyd county, along the boundaries of Montgomery and Roanoke counties. The openings thus far made are wholly in Floyd county, the principal ones being directly on Lick Fork, within a few hundred feet of its confluence with Flat Run (figure 100), southeast headwaters of the South Fork of the Roanoke river. The Lick Fork openings are further located in a direct line from Shawsville, the nearest railway station, 7 miles nearly south-southeast.

From 1904 until recently, the Virginia Nickel Corporation exploited the area under the name of Fidelity Exploration Company. Openings have been made at four different places, aligned along a nearly northeast-southwest direction, for a distance of about 4.5 miles. Some of these are in schists and contain pyrite instead of pyrrhotite as the ore.

At the Lick Fork openings, the principal ones in the area, the ore is chiefly pyrrhotite with some intermingled chalcopyrite. This occurrence of pyrrhotite has been known for many years. The ore was dug and copperas made from it in a very crude way before the Civil War. The Lick Fork openings, shown in figure 100 and comprising shafts and drifts, were begun in the hard rock out-crops at the base of a high and steep ridge, a few feet above the stream level. At the time of my visit, in May, 1907, a large amount of ore on the dumps was reported to average by actual assays not less than 1.75 per cent. of nickel, and a fraction of 1 per cent. of copper. As much as 0.4 per cent. of cobalt was reported, but the average is

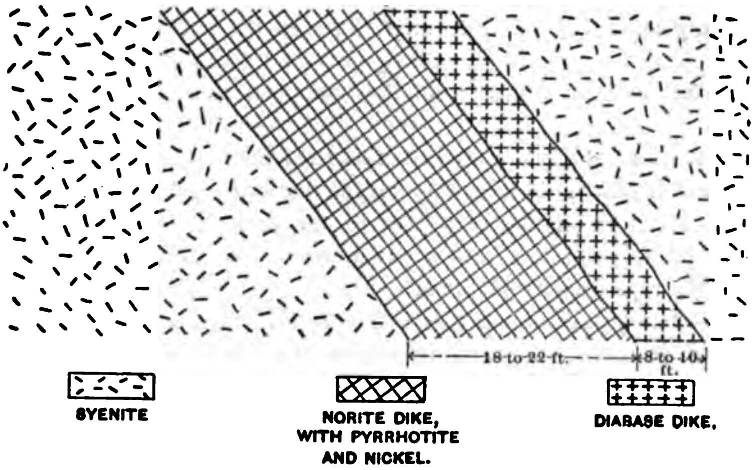

Fig. 101.—Section showing structural relations of the rocks at nickel mine, near Hemlock, Floyd county, Virginia.

considerably less. Assays of the pyrite from other openings in the area are reported to yield from 3 to 4 per cent. of nickel.

Arsenopyrite (mispickel), pages 210-211, is mined less than 4 miles southwest of the Lick Fork openings, but numerous analyses made of the ore do not show the presence of either nickel or cobalt.

The area is composed exclusively of crystalline metamorphic rocks derived in part from original sediments and in part from igneous masses. The country-rock is chiefly made up of a complex of micaceous quartz-schists and gneisses of variable composition, and usually of a pronounced thinly foliated type. The rocks immediately associated with the ore are without exception of igneous origin, and range in composition from a pyroxene syenite to a very basic gabbro. These comprise pyroxene syenite, diabase, and gabbro. They are intruded into the schists and gneisses. The gabbro and diabase penetrate the pyroxene syenite i are accordingly younger in age. The structural rel diabase, and gabbro, as indicated in the larger openi shown in figure 101. The diabase is in direct conta with the gabbro, has an average thickness, so far as in depth, of from 8 to 10 feet, and an outer contac its own hanging-wall.

The mica gabbro is the ore-bearing rock, has an present main opening on Lick Fork of from 18 to diabase dips from 45° to 60° east-southeast. The rhotite chiefly and some chalcopyrite, is quite freely out striking regularity or uniformity, through the ga of the gabbro, the proportion of sulphides is very s make up 50 per cent. and more of the total rock-mas between.

Thin sections of the ore studied under the micros that the ore is chiefly of secondary origin. Microsco from the relations of the sulphides to the rock m followed, principally, the lines of weakness in the s considerable replacement of them.

Uses.—The principal use made of cobalt is as a constituent in glass and earthen wares. Cobalt st high elastic limit and breaking strength, cannot steel on account of its high cost.

Probably the principal use made of nickel is in nickel and nickel-chromium steel. Some of the oth for large forgings, marine engines, wire cables, elec in alloys.

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