COMMONWEALTH OF VIRGINIA

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

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Outline of the Geology and Mineral Resources of Goochland County, Virginia

By

CARL B. BROWN

UNIVERSITY, VIRGINIA

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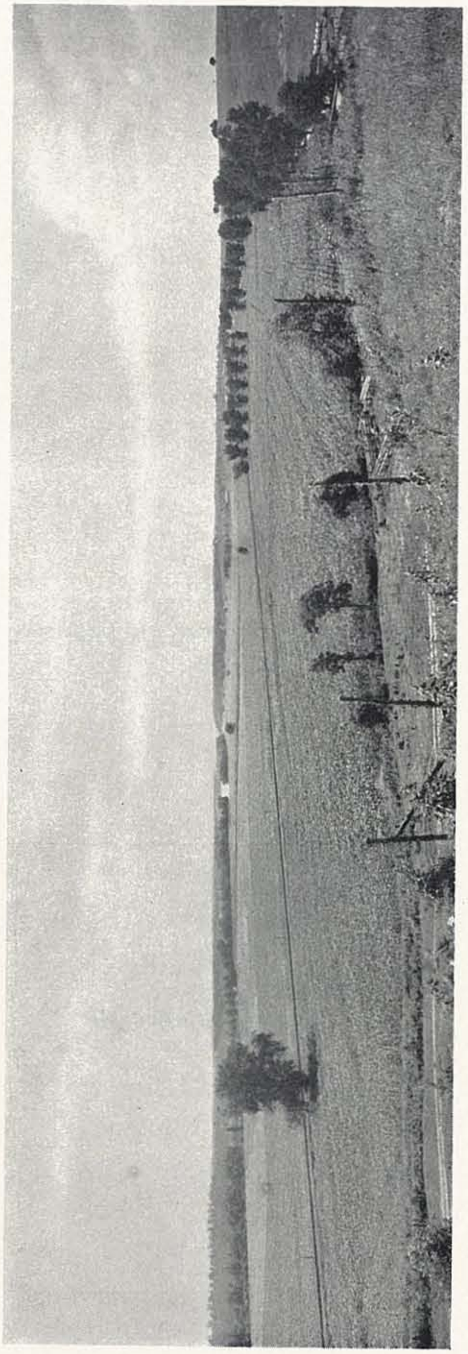

The James River flood plain, looking north from State Farm quarries.

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., September 1, 1937.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and recommend for publication as Bulletin 48 of the Virginia Geological Survey series of reports the manuscript and illustrations on an *Outline of the Geology and Mineral Resources of Goochland County, Virginia,* by Mr. Carl B. Brown.

The field work was done during the summer of 1931, when the author was employed by the Geological Survey to make a comprehensive study and detailed geologic map of Goochland County, as being rather representative of the east-central part of the Piedmont region. Since then Mr. Brown has become a member of the United States Soil Conservation Service.

This report is the first in a "County Series" of reports, in which it is planned to discuss concisely certain features of each county. The chief purpose of this report, and other similar ones, is to give the teachers and other residents of the county reliable up-to-date information, in essentially nontechnical language, about the physical features, mineral deposits, water supplies, and geologic relations and origins of these resources. Some emphasis is placed in this particular report on the effect of human occupancy upon the soil and upon conservation of the soil.

This report should be especially useful to the schools of Goochland and adjacent counties in answering inquiries about features of the physical environment. It should aid property owners to understand better the occurrence or non-occurrence of mineral resources on their lands, and should also be useful to all who are interested in the mineral resources and geology of the State.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
State Commission on Conservation and Development,
Richmond, Virginia, September 9, 1937.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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Outline of the Geology and Mineral Resources of Goochland County, Virginia

By Carl B. Brown

INTRODUCTION

General features.—Goochland County lies along the north bank of James River near the center of the Piedmont province in Virginia. (See Fig. 1.) It is 35 miles long from east to west, and 5 to 12 miles wide. On the north it is bounded by Louisa and Hanover counties, on the west by Fluvanna County, on the east by Henrico County, and on the south by Chesterfield, Powhatan, and Cumberland counties. It has an area of 287 square miles, or 183,680 acres.

Goochland County is typical of the strictly rural sections of the Virginia Piedmont. Its natural wealth is predominantly its soil resources, enhanced as they are by a favorable climate and excellent transportation routes to market centers. Former great expanses of virgin forest no longer exist, but much woodland ideally suited to scientific forestry remains. Mineral deposits are present in considerable variety but have been as yet little explored by modern methods. Gold, coal, titanium ores, common clays, and stone offer favorable possibilities for commercial exploitation and warrant systematic prospecting. Several water power sites exist and will doubtless be developed when the need arises. Excellent water for domestic use and stock is available, both from wells and streams, throughout the county.

Purpose of report.—This report is written primarily for teachers, high school students and residents in Goochland County and adjacent parts of the State. It is an attempt to present in outline form a picture of the county's natural resources upon which the livelihood of the present generation and the well-being of posterity depend. If this report succeeds in promoting a better understanding, a more appreciative conservation, and a wiser use of these resources, then its purpose will have been accomplished. Toward this end, technical expressions have been reduced to a minimum, most of the details of the geology and mineralogy have been omitted, and a glossary has been included to explain some of the terms for which nontechnical substitutes are not available.

Field work.—The field work on which this report is based was done during July, August, and September, 1931. It consisted of mapping the geology of the county on the available base maps (old recon-

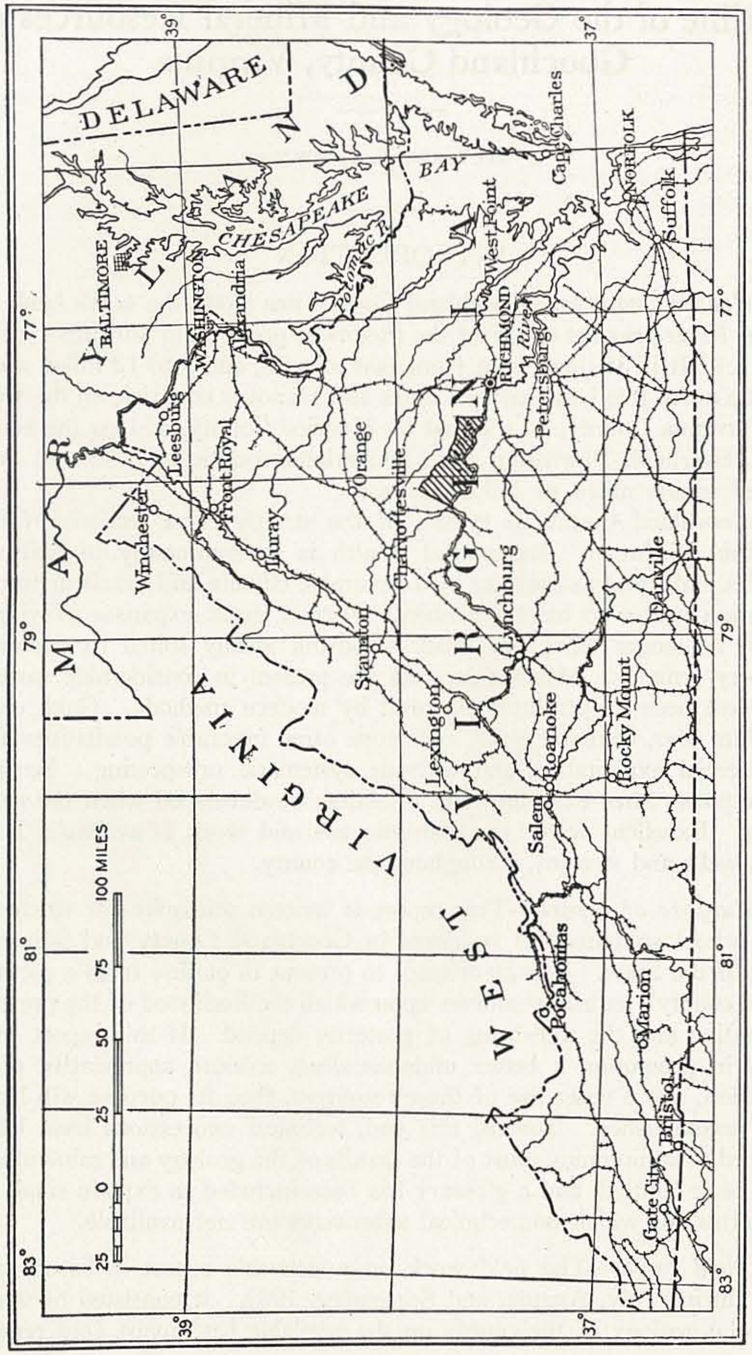


FIGURE 1.—Index map showing location of Goochland County, Virginia.

naissance topographic maps of the United States Geological Survey, on a scale of 2 miles equals 1 inch) and examining all of the mines and mineral deposits known in the county. Two subsequent visits of a few days each have served to bring information on mining activities up to date and to add a few notes on accelerated soil erosion.

Acknowledgments.—The writer is indebted to Dr. Arthur Bevan, State Geologist, for his helpful suggestions and criticism in the preparation of this report, and to Mr. C. F. Park, Jr., and Miss Anna I. Jonas of the United States Geological Survey for suggestions based on their work in the county and region.

GEOGRAPHY

TOPOGRAPHY

The landscape of Goochland County consists of gently rolling uplands interspersed with wide stream valleys, and the floodplain of James River. These surface features are typical of Piedmont Virginia, a region that is physiographically a maturely dissected plateau, which slopes from the Blue Ridge to the Fall Zone at the rate of about 6 feet in a mile. On the rolling uplands the slopes are gentle, the decayed rock and soil mantle is thick, and large woodland tracts intermingled with cultivated fields form a patchwork pattern of land use. (See Pl. 3.) Nearer James River the land is more deeply dissected, the topography is in many places rough and broken, and many slopes are too steep for farming.

The northern boundary of the county follows very closely the drainage divide between the James and South Anna rivers. From this divide the upland surface has an average southward slope of about 10 feet in a mile to James River, in addition to its regional eastward slope to the Fall Zone. James River is 150 to 200 feet below the upland surface and flows in a flat alluvial valley which averages about half a mile wide. It is bordered by a relatively even line of steep slopes and bluffs rising to the upland. (See Pl. 1.) A few rock shoals occur on the river in its course through the county, but for the most part the river flows through alluvium it has deposited in its earlier history. A few of the larger streams are bordered by bottom lands of alluvial soil, but the smaller streams are actively cutting their channel bottoms and transporting rather than depositing sediment. The area underlain by the Richmond coal basin in the eastern part of the county is noticeably flatter and at a lower elevation than the rest of the county. In this section the rocks are weaker, weather more rapidly, and consequently have suffered more erosion than the relatively resistant crystalline rocks to the west.

DRAINAGE

James River is the drainage channel for 6,242 square miles above Pemberton. It has an average flow of approximately 7,250 cubic feet per second. The largest flow ever recorded at Pemberton[1] was 149,000 second-feet at 11 a. m. on March 19, 1936.[2] This contrasts with an extreme low minimum daily discharge of 348 second-feet on October 5, 1930, during the most severe drought on record. The gradient, or fall, of James River through the county averages 1.5 feet per mile.[3]

[1] The stream gaging station is referred to as the Cartersville station.
[2] Unpublished records of the U. S. Geological Survey.
[3] James River, Va. "308" Report U. S. Corps of Engineers, War Dept.: 73d Cong., 2d sess., H. Doc. 192, p. 23, 1934.

The river has a width of 500 to 700 feet between banks which average 12 to 15 feet high and in places reach 20 feet.

The average run-off for James River above Pemberton over a 33-year period, October 1, 1899, to September 30, 1904 and October 1, 1905, to September 30, 1933, was 1.15 second-feet per square mile. The average run-off is 15.6 inches of water per year or approximately 37 per cent of the precipitation. In a dry year like 1931 the run-off was only 7.8 inches, whereas in a very wet year like 1903 the run-off was 24.7 inches.

The river overflows its banks in places during floods at a stage of 14 feet on the Cartersville gage, which is equivalent to a discharge of about 40,000 second-feet.[4] Owing to the flatness of the valley bottom which is intensively cultivated, overflow of the banks at any point is usually sufficient to cover wide areas of bottom farmland and cause extensive damage if crops are growing. During the 36-year period of record, the river has had a discharge of over 40,000 second-feet for a total of 176 days occurring in periods of 1 to 4 days duration. The most frequent month of overflow is reported to be March and the least frequent is August.

The largest tributaries of James River in Goochland County are Byrd and Lickinghole creeks. Other important tributary streams in the county, named from west to east, are Little Byrd Creek, tributary to Byrd Creek, Little Lickinghole and Big Lickinghole creeks, Court House Creek, Beaverdam Creek, Genito Creek, Dover Creek, and Tuckahoe Creek.

CLIMATE

The climate of this area is markedly uniform, and favorable both to health and agriculture. The range of temperature between February and July, the coldest and hottest months, is about 42° F. The normal monthly temperature for February is 35° F., for July 77° F., for April 54° F., and for October 56° F. The temperature rarely drops to more than a few degrees below zero and the maximum high is about 108° F., a temperature recorded once at Columbia. The ground in exceptional cases may freeze 15 inches deep, but the normal range is 2 to 7 inches. The first killing frost is usually about the third week in October, and never before the first of that month. The last killing frost generally occurs about the third week in April; never after the third week in May.

The precipitation averages about 42 inches a year, and is normally well distributed. The spring and early summer growing season is wettest, and the rainfall is generally least during the late summer and early fall, when tobacco curing is in progress. Alternate cold and warm spells in early spring are sometimes damaging to early crops, especially

[4] Op. cit., p. 24.

the fruits. The James River valley is less favorable for early crops than the adjacent uplands because of the tendency of heavier cold air to settle in the valley. On many cool mornings a dense fog settles in the valley and does not clear up until 8 a. m. or 9 a. m.

VEGETATION AND LAND USE

Statistics from the 1930 census and compilations of the Virginia State Planning Board reveal that 65.8 per cent of Goochland County, or 120,882 acres, was classified in 1929 as woodland, forest, swampy land, waste, and unused land. Of this amount 52,964 acres, or 28.8 per cent of the total area, was included in farm woodlands. The remaining 62,718 acres, or 34.2 per cent of the land in the county, was cultivated land. In 1930 there were 1,054 farms in the county, with an average size of 107.7 acres. In that year 25,297 acres of cropland, or less than one-half of the cropland available, was harvested.

The forests and woodlands of the county may be divided into two groups, one on the upland and one on bottom land. On the upland second growth hardwoods greatly predominate, though pines and scattered red cedar are plentiful. The hardwoods consist of white, post, chestnut, southern red, black, and blackjack oaks, hickory, walnut, sweet gum, black gum, beech, yellow poplar, sycamore, red maple, and holly. White oaks outnumber any other species. Shortleaf and Virginia scrub pines are the most common evergreens. Red cedar has been largely cut out in recent years and shipped to Altavista, where it is used in manufacture of cedar chests.

The bottom lands along the streams have a predominant growth of willow, birch, sycamore and gum. Formerly yellow poplar, ash, beech, water and willow oak, red maple, and loblolly pine were also plentiful but these have now been largely cut out.

The values[5] of crops and other farm produce in the county in 1930 are shown in Table 1.

TABLE 1.—*Value of farm products in Goochland County in 1930*

Product	Value
Corn and other cereals	$ 315,927
Hay and forage	141,508
Forest products	95,048
Dairy products	92,963
Chicken products	91,894
Poultry	81,527
Tobacco (518,344 lbs.)	69,920
Vegetables	61,414
	$ 950,201

[5] U. S. Bureau of the Census, Fifteenth Census of the United States, vol. 2, Agriculture, Part 2, the Southern States, pp. 171-293, 1930.

Farm woodlands of the county yielded forest products in 1929 valued at $95,048, a value of $1.79 per acre of farm woodland. The production of forest products in 1929 is shown in Table 2.

TABLE 2.—*Forest products in Goochland County in 1929*

Product	Quantity
Saw and veneer logs (board feet)	3,512,000
Pulpwood (cords)	1,097
Railroad ties	7,111
Poles and piles	3,000
Fence posts	5,781
Firewood (cords)	9,142

HISTORY AND DEVELOPMENT

Goochland County was created in 1727 by the House of Burgesses of the Virginia Colony from Henrico County, one of the original eight shires into which the colony was divided in 1634. The new county was formed for the benefit of settlers who had migrated westward along the fertile valley of James River, and was named in honor of William Gooch, governor from 1727 to 1749. Among the earliest settlers were the Huguenot refugees from France who from 1699 to 1701 established communities on both the north and south sides of James River in the vicinity of Manakin.

The section of country along James River is rich in historical lore and famous plantations. A number of old homes typifying the best in early Colonial to early nineteenth century architecture are still extant. Tuckahoe, a large H-shaped house, in the eastern part of the county, is said to have been built by William Randolph in 1690. Other old places bear names found many times in early Virginia annals. Among them are Bendover, Eastwood, Tabot built in 1855 by James A. Seddon, Confederate Secretary of War, Rock Castle, Dover, and Elk Hill, a plantation once owned by Thomas Jefferson.

From its origin more than two centuries ago Goochland has always remained a predominantly agricultural county. At first, farming was confined to the very fertile alluvial soils on the floodplain of James River. As the pressure of population became greater, primeval forests on the uplands were cleared and "new ground" was brought into cultivation. Farm produce, principally tobacco in the earlier days, moved down treacherous roads and trails from the uplands to James River and thence down the water course to markets. Old roads worn 20 feet into the residual soils still testify to countless thousands of such wagon journeys. (See Pl. 4, A.) Soil resources were rapidly exploited in the early days and fields were worn out in the course of a few years by soil washing and gullying. Land was plentiful, however, and new fields were cleared as the old ones were abandoned to second growth pine and weeds. (See Pl. 4, B.) The history of the county, in common with many other counties of the State, has been a continuous record of "mining" soil resources. Only on the better plantations along James River were steps taken to protect the soil against excessively rapid erosion, by hillside ditching and planting of winter cover crops.

The results of unscientific agriculture are evident from census statistics. An old map published about 1880 gives the population of the county as 10,313. The census of 1890 lists 9,958 people. In 1900 the population was 9,519; in 1910, 9,237; in 1920, 8,865; in 1930, 7,953. Not all of this decline can be attributed to normal migration toward urban centers. Agriculture has become less profitable both in total value of produce and relative to city or industrial occupation as a means of livelihood. Only by a well planned program of optimum land utilization, with scientific forestry and soil conservation, will the county be able to regain and maintain a status to which it is entitled by natural heritage.

The need for adequate transportation facilities in marketing farm produce from the Piedmont was early recognized. For more than a century James River was the principal artery of traffic through the State from the "back-country" to tidewater. Improvement of the river for navigation was started at Richmond in 1785, by the first James River Company, with the object of providing a water route to the Ohio Valley. It continued expanding westward, for 95 years, with vicissitudes and varying political fortunes, always dependent in large measure on the public treasury. The early work improved the river for navigation by bateaux and light draft boats from Richmond to Buchanan. In 1820 the second James River Company, and after 1835 the James River & Kanawha Company, succeeded in constructing a canal parallel to the river from Richmond to Buchanan. This canal extended along the north side of the river through Goochland County and before the War between the States was an enormous aid to agricultural expansion in the county. The traffic on the canal reached a peak in 1853 with a tonnage of more than 230,000 and a gross revenue of almost $300,000. The War between the States, the advent of railroads, and damaging floods in 1870 and 1877 combined to wreck the canal project. In 1880 the James River & Kanawha Company, approaching bankruptcy, burdened by a huge debt and suffering heavy losses from railroad competition, transferred its properties to the Richmond and Alleghany Railroad which was acquired eight years later by the present Chesapeake and Ohio Railway. In 1880 the canal was abandoned and the railroad tracks were constructed along the old towpath of the canal. This railroad line because of its low grade is one of the chief routes for coal and heavy freight between Norfolk and the Middle West.

A typical land use pattern. The lighter areas are cultivated fields; the darker areas are wooded. Aerial photograph from the Soil Conservation Service.

A. Old road worn into hillside. It is about 20 feet below the original level. North of Byrd Creek, between Columbia and Lantana.

B. Soil erosion in abandoned field now grown up in pine trees. South of Little Lickinghole Creek

In former years much local freight, particularly lumber, cattle, and farm produce, was hauled by the railroad. In recent years with the decline in output of lumber and cattle from the county, and with the advent of hard surfaced highways, much of the local shipping goes by truck to nearby cities. Two east-west highways cross the county, State Highway No. 6 in the southern part and U. S. Highway No. 250 in the northern part. The latter is now the main route from Charlottesville to Richmond. Two hard surfaced roads and several gravel roads connect these highways within the county.

POPULATION

Of the 7,953 people living in Goochland County in 1930, 3,813 were native white persons, 26 foreign born, and 4,114 negroes. The population density was 27.7 persons per square mile. The county remains, as it has always been, wholly rural and predominantly agricultural. There is no incorporated town or village in the county. The principal settlements are Goochland (population 62), the county seat, Manakin (population 300), Fife (population 125), Cardwell (population 48), and Crozier (population 50). The county seat consists of a courthouse built more than a hundred years ago (Pl. 5, A), a jail long since fallen into disuse, a testimonial to the law-abiding character of the citizenry, several small brick offices in the court yard, two stores, a church, four garages, the county bank, a frame assembly hall, and a dozen homes more or less.

There are three accredited high schools, one in each of the three magisterial districts. The State maintains a modern prison farm for men at State Farm, and one for women at Maidens.

MINERAL INDUSTRIES

No manufacturing plants of commercial size are located in the county, though at Boscobel a large crushed stone plant is in operation. In 1934 exploratory and development work was in progress at two gold mines, the Waller and Moss, near Tabscott, and one gold placer mine on Byrd Creek was being worked. In 1936 a new mill was erected at the Moss mine and a moderate production of gold was reported. The mine has not been operating since November, 1936 and no work has been in progress at the Waller mine since late in 1935. Prospecting and development were carried on at the Tellurium mine in 1936 and 1937 and a small prospecting mill for gold recovery was installed in the spring of 1936. Placer operations are still in progress at several places in the county.

GEOLOGY

GENERAL FEATURES

The geology of Goochland County is complex. The rock formations, many of them among the oldest known in Virginia, have persisted with changing character through long periods of varied history. The oldest rocks have suffered profound alteration by great heat and pressure and the injections of molten magma, or liquid rock and gases, while buried miles deep in the earth's crust. Subsequently many of the formations have been severely mashed and granulated by enormous differential pressures of the type responsible for the upheaval of mountains. There is some evidence also to indicate that the formations have been sliced into great wedges or slabs which have been shoved miles to the west along fracture surfaces, or low-angle planes of thrusting, called overthrust faults. Most of these remote events have left their records in the rocks. In some of the formations, however, they have produced changes so profound as to obscure completely the previous character of the rocks from which their origin could be traced. In other rocks new minerals and new structures were added without obliterating the old.

It is the province of geology to unravel this complex chain of events and establish an orderly sequence, not only for its scientific value, but because it sheds light directly on the occurrence, nature, and local distribution of mineral deposits. It thus enables the prospector to know where to search, the miner what to anticipate, and the property owner what to expect in regard to rock and mineral resources.

In a limited area of complex geology, such as Goochland County, it is seldom possible to learn the whole story. Many observations by other workers in adjacent areas must be used to fill in the gaps. This has been particularly true in Goochland County for two reasons: Many formations cross the county in belts because the long axis of the county is at right angles to the northeast trend of the rocks. Deep weathering has blanketed much of the county with a cover of soil and decayed rock which masks the bedrock beneath, and there are now insufficient exposures of fresh bedrock to tell all of the geologic history.

ROCKS AND MINERALS

Rocks.—The earth's crust, that outer shell of the earth beneath the atmosphere and bodies of water, is composed almost entirely of solid rock, called bedrock. This bedrock has been exposed naturally and in man-made excavations at numerous places in Goochland County, for example, along the highway just east of Columbia. Throughout much of the county, however, the bedrock is overlain by decayed rock materials, and the soil and subsoil, together called the mantle rock or regolith. In a geological sense, this mantle is considered to be rock.

All varieties of bedrock are generally classified by geologists and engineers in three groups, namely, igneous, sedimentary, and metamorphic. Igneous rocks have been formed by the cooling and solidification of masses of molten rock originating deep in the earth. Some of the molten rock cooled and crystallized while still at considerable depths below the surface, making intrusive igneous rocks, whereas other masses were forced to the surface, as lava flows and eruptions of volcanic debris forming extrusive igneous rocks. Common intrusive igneous rocks are granite and pegmatite, although other varieties, such as diabase, peridotite, and pyroxenite are found in Goochland County. The first two named are light colored and medium to very coarse grained; the others are rather dark colored and may be more or less coarse grained. These rocks have been exposed by the removal of overlying rocks through the normal processes of erosion. The aporhyolite in the eastern part of the county was probably in part erupted as lava and volcanic debris. It has since been much altered into a type of metamorphic rock.

Sedimentary rocks are commonly in beds, or layers. Most of them have been formed by the deposition of sediment—gravel, sand, mud, organic remains, and chemical precipitates—in or along bodies of water, such as seas, lakes, swamps, and rivers. Hence in many places the beds contain fossil remains of the invertebrate and vertebrate animals and the plants that lived at the times of deposition. Such organic remains are called fossils. The common varieties of sedimentary rock which are found in the southeastern part of Goochland County are conglomerate,[6] sandstone, shale, and coal. Limestone is another very common kind of sedimentary rock, but it is absent from the county.

Metamorphic rocks, the most abundant group in Goochland County, have been derived from igneous or sedimentary rocks by profound alteration. Great heat and pressure, accompanied by chemical changes, have caused the minerals in the original rocks to take on new physical forms or to combine into new minerals better adapted to the new environments. Gneiss and schist are common types of metamorphic rocks in the county. Gneiss superficially resembles granite, but close inspection shows that the minerals are arranged in more or less definite streaks or bands, the result of the enormous pressure deep in the earth's crust, to which the parent rocks were subjected. Schist is a crystalline rock in which metamorphic processes have developed cleavage. The varieties are named according to the predominant mineral, for example, mica schist.

[6] See Glossary.

Minerals.—A mineral may be defined as a substance in the earth's crust, which has a definite and uniform chemical composition and characteristic physical properties. Thus a mineral may be a chemical element or a chemical compound, either of simple or complex composition. Graphite, composed of carbon (C), and gold (Au) are examples of minerals composed of an element. Both are found locally in Goochland County. Quartz, composed of silica (SiO_2), is a common mineral having a simple chemical composition. Feldspar, on the other hand, has a complex composition. The common variety, orthoclase, contains potash, alumina, and silica.

Many of the minerals are "rock makers," that is, they occur chiefly as essential constituents of rocks. Some of the minerals in these rocks, such as feldspar and mica in pegmatites, may be of considerable economic importance. The rocks themselves, such as granite and soapstone, may have industrial uses. Other minerals may contain valuable metals, such as lead in the mineral galena and titanium in the minerals rutile and ilmenite. Still others, such as kyanite and asbestos, are nonmetals of commercial importance where they occur in large deposits of high quality.

CRYSTALLINE ROCKS

Wissahickon formation.—The Wissahickon formation is named after Wissahickon Creek in Philadelphia, Pa., where it was first described. It occurs in two belts crossing Goochland County. These belts differ greatly in their geologic history and in the rock types of which they are composed.

The eastern belt of the Wissahickon formation is much wider than the western belt. It extends through Gum Springs, Pemberton, Sandy Hook, and Goochland Court House. It is made up of several types of rocks, the oldest of which are biotite schists and gneisses of high-rank or intense metamorphism. Injected into them are a few layers of hornblende gneiss and biotite granite, probably equivalent to the Columbia granite, described below, and a great quantity of muscovite granite and pegmatite of younger age and probably equivalent to similar rocks in the pegmatite belt. The injected igneous rocks generally follow the foliation planes of the older schists, but in some places both the muscovite granite and pegmatite cut the schists at all angles. The successive injections of molten igneous material have so altered the schists that it is impossible to determine their original character. Evidence at places outside of this county, however, where injection is less abundant or absent, indicates that these schists were derived from sedimentary rocks, such as shale and sandstone. Subsequent to all of these injections the whole formation has been folded and crumpled into open folds, which in many places resemble the folded structures in rocks of the Appalachian Valley and Ridge province. (See Pl. 5, B.) Most of the mica and feldspar deposits of the county are included in this belt.

The western belt extends from South Anna River through Shannon Hill, Tabscott, and Priors Cross Roads to within a mile of Columbia. It consists of a series of foliated metamorphic rocks, chiefly chloritic, garnetiferous, and biotite schists, quartz-sericite schists, and sericitic quartzites. Other less common varieties, namely, biotite gneiss, biotite quartzite, kyanite quartzite, and hornblende schist, are found in scattered outcrops. These types are interbedded in a varying succession and a single type can rarely be traced more than a mile in one band. The foliation has a general northeast strike or trend, and a dip of 45° to the southeast.

These rocks differ from members of the same formation in the eastern belt in two major respects: They lack the lit par lit (layer-by-layer) injection of granite which is so pronounced in the eastern belt, and they have been subjected to differential stresses during mountain building which have crushed and granulated them to a more pronounced extent. New minerals have been formed, particularly sericite and chlorite which are two of the most abundant minerals. A new facies of metamorphism has resulted, which is lower in the scale of metamorphic intensity than that which previously affected the rocks.[7] In other words, because of their position in a zone of differential movement associated with thrust faulting in the upper crust of the earth, these rocks have suffered retrogression from their original more highly developed type of metamorphism. The gold mines of the county are confined to this belt and the adjoining mashed, or mylonitized, Shelton granite-gneiss on the west. The formation is of pre-Cambrian age. (See geologic time scale, p. 47.)

State Farm gneiss.—The State Farm gneiss is named herewith from typical outcrops near State Farm. (See Pl. 6, A.) It occurs in a wide belt extending from Perkinsville to Centerville, and from State Farm to Sabot. It is a relatively uniform, even-banded gneiss with well developed foliation. (See Pl. 6, B.) It is light to dark gray and medium grained. It differs from the adjacent Wissahickon formation in several respects: In general it lacks lit par lit igneous injection and it is a completely recrystallized product of thorough igneous invasion and almost complete assimilation or displacement of older schists; it shows only a limited amount of folding in any single outcrop; and it shows numerous divergences in structure from the regional trend.

This gneiss appears to be derived for the most part from an igneous

[7] For a detailed discussion of this subject see: Jonas, A. I., Geology of the kyanite belt in Virginia: Virginia Geol. Survey Bull. 38, pp. 1-38, 1932.

rock, such as granite, which has thoroughly invaded an old series of biotite schists, probably of Wissahickon age. The resulting formation has been so thoroughly recrystallized that most traces of its origin have been obliterated. The absence of fresh exposures of the State Farm gneiss along the contact with the granitized Wissahickon belt to the west precludes a definite determination of their relationship. So far as observed this boundary appears gradational. The State Farm gneiss is older than both the aporhyolite, which shows none of the intense recrystallization, and the Petersburg granite which does not have any of the foliated or gneissic structure. Inasmuch as no conclusive proof has been advanced elsewhere in the eastern Virginia Piedmont and none was found in this county for the existence of a formation older than the Wissahickon, the State Farm gneiss is tentatively considered to be derived from a younger igneous injection which took place after the original sediments of the Wissahickon were laid down but before intrusion of the magmas that formed the rocks now classed as hornblende gneiss and Columbia granite. The best exposures of the formation are at the type locality, State Farm quarries, on the Chesapeake and Ohio Railway. The formation is of pre-Cambrian age.

Columbia granite.—The Columbia granite is a light-gray, medium-grained, gneissic biotite granite (petrologically a granodiorite). It occurs in a belt lying east of the western belt of the Wissahickon formation, and extends from Columbia to beyond the northern boundary of the county. Parallelism of the biotite flakes produced by metamorphic pressures gives the rock a gneissic structure. The Columbia granite is intruded in the Wissahickon formation and is therefore younger. It is older than the Arvonia slate, of Ordovician age, which unconformably overlies it, as shown in an outcrop along the Chesapeake and Ohio Railway at Carysbrook. In most places it is separated from the Wissahickon formation by a border facies, or zone, of hornblende gneiss, which is also younger than the Wissahickon, but older than the granite. This facies is considered to be an earlier differentiation product of the magma which on cooling formed the Columbia granite. The best exposure and the type locality of the Columbia granite are in the Cowherd quarries at Columbia (Pl. 7, A), on State Highway No. 6.

Shelton granite gneiss.—The Shelton granite gneiss is poorly exposed in a small area northwest of Tabscott, in the northwest corner of the county. It is a fine-grained, gray, gneissic granite with a crushed internal structure that was produced by the same forces that so profoundly altered the western belt of the Wissahickon formation. It is a mylonitized or crushed facies of the Columbia granite and, like it, contains many bands of hornblende gneiss.

Pegmatite belt.—The "pegmatite belt" lies east of the Columbia granite, and extends through the county from Island to Hadensville, having an average width of 3 miles. It is characterized by an abundance of pegmatite and muscovite granite. The pegmatites are very coarse-grained, light-colored igneous rocks composed chiefly of feldspar, quartz and mica. They and the muscovite granite are younger than the Columbia granite. The boundary of the pegmatite belt with the Columbia granite is well defined. A few layers of hornblende gneiss and biotite granite, probably equivalent to the Columbia granite and its border facies, are also present in this belt. The several types are complexly intermixed. In general the dip of the foliation is southeast, but folding of the entire complex has produced many local variations.

Elk Hill complex.—The Elk Hill complex lies east of the pegmatite belt, and extends from East Leake to Elk Hill. It is named from good exposures in bluffs along the Chesapeake and Ohio Railway south of Elk Hill. The formation is composed of hornblende gneiss, biotite granite, muscovite granite, and pegmatite, named in the order of their age. The large amount of hornblende gneiss distinguishes this belt from others in the county. (See Pl. 7, B.) The biotite granite is probably equivalent to the Columbia granite, but the muscovite granite and pegmatite are younger. The prevailing dip of the gneissic structure is southeast.

Both this complex and the pegmatite belt are equivalent to other igneous rocks of the county, such as the Columbia granite and the muscovite granite injected into the Wissahickon formation. Some geologists have included these belts in the granitized Wissahickon. They are described separately here because they can be generally distinguished in the field.

Pyroxenite dikes.—Pyroxenite dikes occur at several places in the county. The rock is dark green, coarse grained, and is high in iron and magnesia. One of the best exposed dikes is on U. S. Highway 250, one mile west of Hadensville. In some places these dikes have been altered along their borders to soapstone. A dike of altered peridotite west of Cardwell shows seams of asbestos. These dikes cut all of the formations having pronounced gneissic structure and, therefore, are younger, but are probably older than the aporhyolite and Petersburg granite with which they are not in contact.

Aporhyolite.—Aporhyolite crops out east and northeast of Centerville, in the northeastern part of the county. It is a fine-grained to dense, greenish-gray, highly fractured volcanic rock, which accumulated originally at or near the surface of the earth and was formed from molten rock rising from the interior. The local area is an outlier of the great belt of volcanic rocks that extends from Keysville, Va., southward to Georgia. The age of the aporhyolite is not definitely known. It is younger than the State Farm gneiss, but it is older than the Petersburg granite, which is injected into it. It may be either late pre-Cambrian or early Paleozoic.

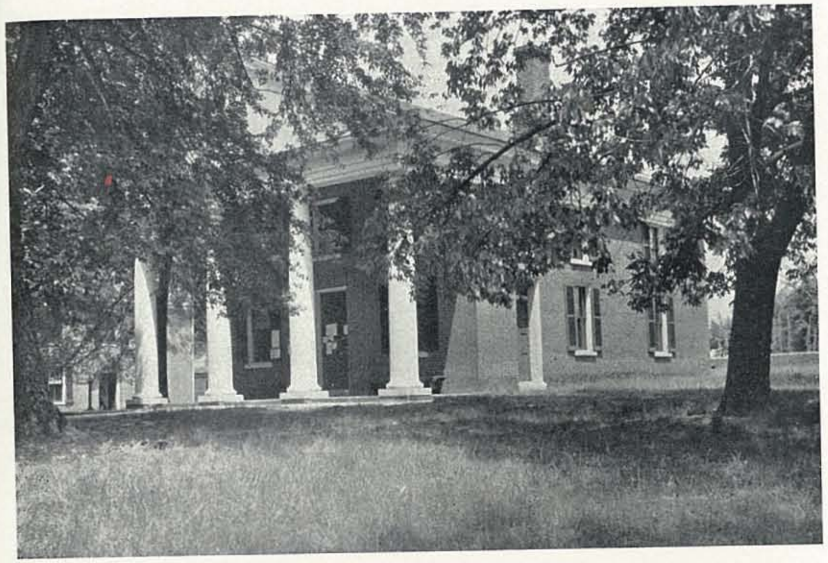
Petersburg granite.—The Petersburg granite is a coarse-grained, white and pink, muscovite granite. It is exposed in the Boscobel quarries (Pl. 8, A), and for some distance to the north. It has thoroughly invaded an older formation, which is for the most part the aporhyolite, but which is so altered in many places by the injection as to defy positive correlation. The granite in Goochland County is an outlying area of the Petersburg granite, which is exposed in many quarries in Henrico County, and in outcrops along Tuckahoe Creek, on the opposite side of the Richmond coal basin.

TRIASSIC ROCKS

Sandstone and shale.—Triassic sandstone and shale containing several seams of coal occur east of Manakin and cover the eastern part of the county.[8] This series is composed of sediments which were deposited in shallow lagoons, swamps, and on river flood plains. After consolidation these rocks sank along nearly vertical faults and for this reason have been in part preserved from erosion. Most of the sandstones and shales are gray to buff, but in places, especially near the edges of the basin, conglomerate (Pl. 8, B), red and black shale, coal seams, and red sandstones crop out. The lower part of the series, exposed in the vicinity of Manakin and again along Tuckahoe Creek, is called the "Coal Measures." The overlying thick beds of gray to buff sandstone and shale have been named the Vinita sandstone[9] from typical outcrops at Vinita Station on the Chesapeake and Ohio Railway. Large coal mines were formerly worked near Manakin.

Diabase.—Diabase dikes of late Triassic age have been intruded into the Triassic sandstones as well as the older rocks. They are the youngest igneous rocks in the county. One of the largest dikes, 250 feet wide, crosses State Highway No. 6, one mile east of Columbia. The rock in these dikes is dark green to black and medium to fine grained. It differs in one notable respect from other igneous rocks in the county. It has not been crushed or metamorphosed in any way since its formation, and thus retains all of its original structure and texture.

[8] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, 1928.
[9] Shaler, N. S., and Woodworth, J. B., Geology of the Richmond Basin, Virginia: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 435, 1899.



A. Goochland County Courthouse. Built more than 100 years ago.

B. Wissahickon gneiss one mile north of Goochland Court House. Pegmatitic muscovite granite has been injected into biotite schist.

A. State Farm gneiss at State Farm quarries.

B. Texture of the State Farm gneiss.

SOILS

Long continued weathering of the rock formations, during the last few thousand and perhaps hundred thousand years, has produced a thick zone of decomposed rock on which soils of various types have been developed. This zone of rock decay, with a maxium thickness of 50 feet or more on the upland divides, has been variously termed the "mantle rock," "regolith," and "saprolite." Soils developed on this residual decayed rock are classified according to their texture, structure, color, organic and colloid content, and drainage conditions. All soils of the county are residual soils except those on the floodplain of James River and a few of its larger tributaries, which are classed as alluvial or deposited soils.

The soils of Goochland County have not been mapped. Soil surveys of Louisa, Hanover, Henrico, and Chesterfield counties were made between 1905 and 1913 by the U. S. Bureau of Chemistry and Soils. From these reports a general outline of soil types to be expected in Goochland County may be obtained.

The predominant soils in the county belong to the Cecil and Iredell series. The Cecil soils are yellowish clays, silty loams, fine sandy loams, and sands, 6 to 15 inches deep, with subsoils to a depth of 36 inches composed of friable and greasy, heavy red clays. They have been derived from light- to dark-gray granites and gneisses.

The Durham series derived from similar rocks consists of gray to pale-yellow sandy loam with a yellow moderately friable sandy clay subsoil beginning at a depth of 10 inches. This type is developed particularly in the northeastern part of the county.

The Iredell soils consist of dark-brown clay loams, 6 to 16 inches thick, over a yellowish and reddish heavy clay subsoil as much as 36 inches deep. They have been formed from the decay of dark-green hornblende gneisses, trap dikes, and other basic rocks.

The Penn clay loam is a soil developed on the Triassic formations in the eastern part of the county. It is characterized by its peculiar Indian red color, particularly in the subsoil. The soil type consists of grayish-brown to reddish-brown, friable clay loam to silty clay loam, which passes at a depth of about 6 to 12 inches into red, moderately friable clay. The Granville silty clay loam is a related type, also derived from Triassic formations. It has a yellowish to pale-yellow silty clay loam topsoil which grades into a yellow silty clay, and at about 20 inches to mottled yellow, gray, and reddish subsoil becoming heavier and more plastic with depth.

The alluvial soil along James River is largely Congaree silt loam. This soil is a reddish-brown to chocolate-colored, mellow silt loam, which changes but little within the 3-foot section below the surface. This soil is exceedingly fertile and very productive, but is subject to frequent overflow during flood stages on the river. Other alluvial soils less common and present on benches and better drained higher portions of the flood plain include types of the Altavista and Wickham series. These are older alluvium and in part colluvium deposited from the immediate slopes.

MINERAL RESOURCES

GOLD[10]

General features.—Gold was discovered in Goochland County about 1829 in placer gravels on the Collins place. In 1832, veins were found at the site of the Waller mine, and in the next few years all the important veins known in the district were prospected. The earliest mining was confined to washing the placer gravels in crude rockers, sluice boxes, and "long toms." The first ore mined from the veins was ground in Chilean mills consisting of stone disks rolling in a stone basin. By 1836, a primitive stamp mill, believed to be the first in America, had been erected at the Tellurium mine. It consisted of square, non-rotating, wooden stamps with iron shoes, working in iron die plates. At least four other stamp mills had been erected before the War between the States stopped all mining operations. A number of attempts were made in the 1880's and 1890's and again about 1910 to revive mining in the county, but with little success. Beginning in 1930, renewed interest, and in 1933 increase in the price of gold, has led to development work and prospecting, especially at the Waller, Moss and Tellurium lode mines, and the Collins placer mine.

No adequate records of production are available, but fragmentary evidence indicates that between $500,000 and $1,000,000 worth of gold has been recovered in Goochland County. If the recovery of gold at the Tellurium mine, however, amounted to $1,000,000, as reported by Watson,[11] then the total production from the county would be about $1,500,000.

Gold-bearing veins, or lodes, and replacement deposits are largely confined to the western belt of the Wissahickon formation, but they also extend into the hornblende schist on the east and the Shelton granite gneiss on the west. The foliation of these rocks has a prevailing strike N. 50° E., and an average dip of 45° SE. The veins almost invariably follow the foliation, with rare offsets along zones of cross-fracturing. Important cross veins are rare in the district, the "West" vein at the Tellurium mine being the only important one reported.

Quartz veins and stringer lodes constitute the important ore deposits of the county. Both types are frequently accompanied by mineralization of the wall rock. In a few places the wall rock is silicified to such an extent that individual stringers are traceable with difficulty, and the ore body is termed a replacement deposit. The veins, stringer lodes and replacement deposits are gradational into one another and one ore

[10] See also Taber, Stephen, Geology of the gold belt in the James River basin, Virginia: Virginia Geol. Survey Bull. 7, 1913; and Park, C. F., Jr., Preliminary report on gold deposits of the Virginia Piedmont: Virginia Geol. Survey Bull. 44, 1936.

[11] Watson, T. L., Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, Lynchburg, Va., p. 559, 1907.

deposit may exhibit in different parts characteristics of each type. Both the veins and replacement deposits are lenticular in vertical and longitudinal sections and show a pinching and swelling characteristic of ore bodies in schist. So far as observed, well-defined faulting is negligible, but most of the deposits occur along zones of fracturing in the country rock, and post-mineral slipping along the veins has been noted in several mines. The veins range in size from a knife-edge seam to five feet or more wide. Many of the gold veins are found along the contact of mica schist and hornblende schist, but they are not confined to this position. Well-defined ore shoots are to be expected in these veins in common with veins throughout the Southern Appalachian region. Development work in this county, however, has not yet been sufficient to outline them definitely as to size and shape.

The veins are composed dominantly of quartz, but in some, feldspar is a prominent gangue mineral. At the Young American mine the vein rock strongly resembles a pegmatite of high quartz content, which suggests that it originated under similar conditions of high temperature and pressure. In most mines sericite is, next to quartz, the most abundant gangue mineral. Carbonates, principally ankerite and calcite, and chlorite are other gangue minerals locally prominent.

The most abundant ore minerals are usually pyrite and chalcopyrite. Free gold is locally present in visible grains, especially in the oxidized ores, but more commonly is disseminated through the ore in exceedingly minute particles. Galena, sphalerite, pyrrhotite, and tetradymite have been found sparingly in the primary ores. Marcasite, pyromorphite and vanadinite occur as secondary minerals.

The mineralogy, texture, and structure of the veins show that they are of deep-seated origin and that they were formed by ascending ore solutions of magmatic origin, probably given off as a final cooling product of one of the magmas from which the adjacent granites were formed.

The two problems of most practical importance to mining are: (1) To what extent the rich gold deposits near the surface are secondary chemical concentrations effected by circulating ground water and what, therefore, will be the relative value of the primary ores below; and (2) will primary ore of workable grade extend to considerable depths? Unfortunately, little evidence bearing on either of these pertinent questions could be obtained in this county. The Moss mine, at a depth of 150 feet on the dip of the vein, shows valuable ore which appears to be of primary origin, but this depth represents just about the dividing line between weathered country rock with oxidized ores, and unaltered bedrock with primary ores. In most mines of the Southern Appalachian region, gold was the last ore mineral to be deposited. Geologists who studied the primary ores from other districts concluded it was of magmatic origin, and this seems scarcely open to doubt regarding ores from depths of 300 to 800 feet. At 150 feet, however, there is some reason to question whether the gold might not be concentrated in part from above.

A number of mines in the South have yielded high-grade gold ore at depths of 300 to 800 feet, or far below the zone of possible surface enrichment. Laney[12] reports a sizeable ore shoot, at a depth of 800 feet, in the Gold Hill mine, Rowan County, N. C., that carried from $10 to $385 per ton in gold. Profitable operations have extended to depths of 650 feet at the Phoenix mine in Cabarrus County, N. C., to 600 feet at the Iola mine in Montgomery County, N. C., and well into the primary zone at numerous other mines in the South. Most of the deposits of this region were formed in the deep-seated hypothermal zone, and no evidence has yet been advanced to show that they should not extend to depths of at least several thousand feet below the present surface.

Waller mine.—The Waller mine is half a mile southeast of Tabscott. (See Pl. 2.) Taber[13] says it "was discovered in 1831, and during that year Cole and Woolfork carried on surface washings for several months. Veins were discovered by Moss in 1832, and a vein 6 feet thick is said to have been opened by the Fishers and worked until the land was purchased by Wm. K. Smith. Later it was sold to Richards, of New York, who worked the mine 12 months and then sold it to an English company for a large sum. After two years, during which it is said to have been badly managed, the property was divided and sold in two parts (about 1855). Since that time only the western part of the old estate has been known as the Waller mine. In 1865, Turner, Hughes & Co. sank a shaft and did some development work, ..." In 1876, 30 days work was done on the property. In 1910, a company sank a shaft 72 feet, and drove cross-cuts northwest at 45 and 60 foot depths. In the lower cross-cut the vein was found, but a drift started southeast soon ran into old workings. In 1911 another shaft was sunk, but at the time of Taber's visit had not cut any veins.

The Goochland Gold Mines Holding Corporation was organized in September 1930, and acquired control of a mining tract said to cover about 1,200 acres. Prospecting work was begun at once and certain old workings were cleaned out, this operation lasting until May 1931. On March 23, 1932, the new vertical Cohn shaft (Pl. 9, A) was started at a point about 300 feet southeast of the supposed outcrop of the Waller vein. The shaft was 300 feet deep in January 1933. Development work was carried on at the 300-foot level through the summer of 1933 until the present cross-cuts and drifts were completed.

[12] Laney, F. B. The Gold Hill mining district of North Carolina: North Carolina Geol. and Econ. Survey Bull. 21, pp. 98-102, 1910.

[13] Op. cit., pp. 148-151.

Details of the old English work are not known, nor of the work during 1910 and 1911 other than the brief notes given by Taber. The first work of the present company, under the direction of Mr. Leo Faust, consisted of sinking a vertical shaft in the hanging wall of a vein believed to be the "Waller." At a depth of 41 feet, a cross-cut driven 14 feet northwest entered old workings which were cleaned out and retimbered for a considerable distance in each direction. The shaft was then sunk 14 feet deeper until it intersected the vein. At this level drifts were run on the vein for 105 feet southwest and 12 feet northeast.

The Cohn shaft is located in the hanging wall side of this vein. At a depth of 300 feet a cross-cut extends 160 feet N. 37° W. At 80 feet from the shaft drifts run 60 feet northeast and 84 feet southwest.

The total production of the Waller mine is unknown. A few fragmentary records have come to light in private reports discovered among the old court records at Goochland Court House. Mr. O. MacDaniel in a report dated October 24, 1852, says: "Many thousand dollars have been washed from the surface earth in the bed of a small stream, and the ravine below the (Waller) vein . . . . ." In a report to the directors of the Waller Gold Mining Company dated February 21, 1855, a statement by Mr. Gregg, the superintendent, says that 1,500 tons of ore from the Tellurium vein, valued at £1,500 and 2,000 tons from the Waller vein valued at £10,000 had been raised and were at the mill. Since no appreciable quantity of ore remains at the mine today, this ore must have been eventually milled, and if the valuations are true, it yielded more than $55,000. Considering the extent of workings and value of the ore, the total production is estimated at $60,000 to $75,000.

The country rock penetrated by the Cohn shaft is, in large part, grayish-green hornblende schist and banded hornblende gneiss. A few bands are highly quartzose, and have been called impure quartzite. The series appears to represent a contaminated border facies of the Columbia granite, in which the early basic differentiate has injected the quartzose schists and partially assimilated them. The series has since been completely recrystallized during regional metamorphism. The gneissic banding follows the regional strike, and dips about 45° SE.

On the 300-foot level, small irregular masses, lenses, and stringers of quartz appear noticeably at 50 feet and 80 feet from the shaft, as well as less abundantly at other points. The quartz is glassy and generally barren of sulphides, but small amounts of feldspar and calcite (or ankerite) are in a few places associated with it. At 70 feet from the shaft a 2-inch stringer of chalcopyrite and bornite was cut, and at other points small irregular masses of these sulphides were found.

At 77 feet from the shaft in the cross-cut, two parallel fractures occur about four inches apart. They strike N. 50° E. and dip 65° NW. Slipping has taken place along these planes, and they show slickensides as well as a thin film of reddish, clayey gouge. They have been followed by short drifts. Stringers and lenses of quartz up to 18 inches thick, approximately parallel to these fractures, are found in the drifts. They are not continuous, but branching and lenticular, and where one stringer pinches out it is in places replaced by another at a different horizon.

Taber[14] says the Waller vein, as traced by old cuts and pits for 300 yards on the surface, strikes N. 58° E., and dips 45° SE. This vein was only 1 to 4 inches thick in the workings where Taber observed it. However, a shaft sunk in 1852 is said to have exposed a section of this vein 30 inches thick. The Goochland vein cut in the early workings is said to have been 4 feet thick near the surface. Mr. Faust believes that a mineralized quartzose band penetrated between 275 and 288 feet in the Cohn shaft is the extension of the Goochland vein. The writer had no opportunity to observe this band because the shaft was closely lagged, but it seems doubtful that any of the quartzose bands in the gneiss are a direct extension of the well defined quartz veins cut near the surface. The failure of assays to show any appreciable values in these bands lends some weight to this conclusion.

No commercial ore has been found in the Cohn workings. The only appreciable values found in numerous assays[15] were $4.20 in gold per ton (at $35 per ounce) for a 5-foot mineralized band at 145 feet in the shaft, and $7.00 per ton in gold for the 2-inch sulphide stringer cut 70 feet from the bottom of the shaft. Assays on quartz stringers, including those showing chalcopyrite, failed to give more than 0.02 oz. of gold per ton, except in one case where 0.08 oz. was reported.

The conclusion must follow from study of the Cohn workings that either the veins reputed to have yielded rich ore near the surface do not follow the same inclination in depth, and hence the Cohn workings are not sufficiently extensive to cut them, or else the veins pinch out before reaching the 300-foot level. The first hypothesis seems unlikely since the gneissic banding maintains a uniform dip, and no cross veins are known at the surface. It is possible on the other hand that the deep workings have only exposed a pinched and barren section on the dip of the vein which is represented at this level by fractures and stringers found at certain points.

Moss mine.—The Moss mine is 1½ miles southwest of Tabscott. (See Pl. 2.) It is said to have been discovered by John Moss in 1835. In

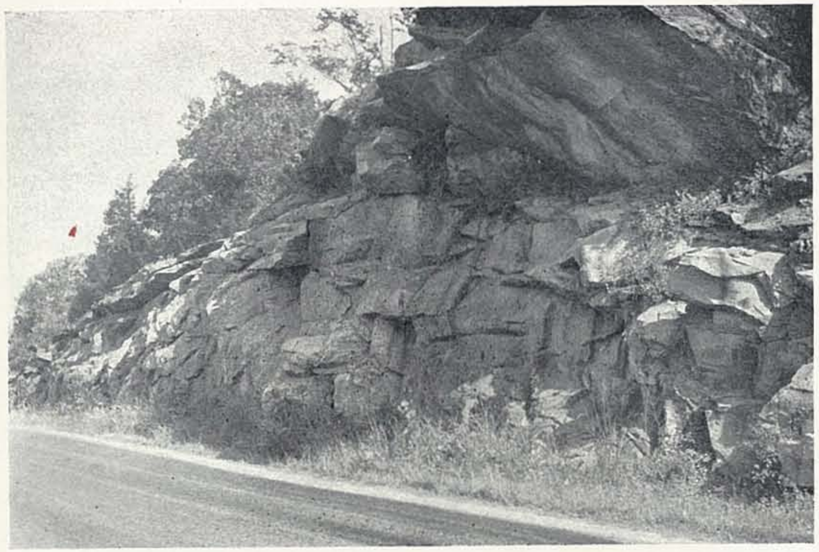
[14] Op. cit., pp. 148-151.
[15] Private report of Edmund Newton, dated August 23, 1934.

1836, according to a report by Silliman,[16] the mine was developed by two inclined shafts, 31 and 50 feet deep, connected at the 30-foot level by a drift 70 feet long which gave a continuous exposure of the vein. Silliman's measurements on the vein at this depth ranged from 16 to 30 inches in width, with an average of 24 inches. The mine was worked for two years during this period, or until 1838. It was reopened in 1891 by G. H. Manning who sank the No. 1 incline shaft, often known as the Manning shaft, to a depth of 48 feet. No drifting was done but tests of the ore from the shaft and an open cut to the southwest were made in a 3-stamp prospecting mill. In 1893 the mine was leased by a Mr. Stevens, who sank No. 1 shaft to a depth of 72 feet on the incline, sank another shaft, known as the Old Stevens shaft, about 70 feet southwest of No. 1 and connected the two by a drift on the 72-foot level.

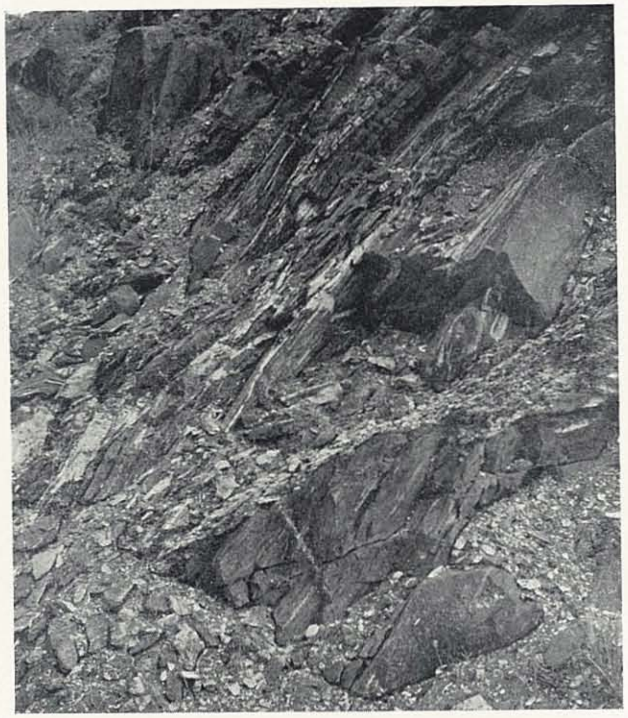
Beginning in the spring of 1902 and continuing into 1904, the property was again worked under lease by a Mr. Draper, who added another battery of three stamps to the mill. During this period No. 1 shaft was sunk to a depth of 118 feet on the slope of the vein. At 62 feet a set of three drifts, one directly over the other, in lieu of stoping, was run for a total distance of 285 feet along the vein. A second old shaft was sunk to 130 feet on the slope, and drifts were run 60 feet in each direction on the vein at a depth of 110 feet. The last 20 feet of each drift is reported to have been stoped to a height of 20 feet above the floor of the drift. The exact location of this shaft is not certain. It may have been the Old Stevens shaft. In any event it was probably between No. 1 and the present No. 2 shafts, and the old drifts passed through by the No. 2 shaft are probably the ones run by Draper. All of these older workings were inaccessible at the time of the writer's visit in 1931.

Another period of development began in December 1931 when the mine was purchased by J. C. Williams, Sr., and others. Following some unsuccessful attempts to reopen the old workings, Mr. Williams put down a drainage shaft in the footwall, 70 feet back of the vein. This shaft was sunk on a 45° incline to a depth of 132 feet solely for the purpose of draining the upper portions of the old workings to permit their retimbering. The No. 1 or Manning shaft was then reconditioned and sunk to a depth of 150 feet on the incline. (See Fig. 2.) At the 150-foot level drifts were run 105 feet northeast and 173 feet southwest. No. 2 shaft, 208 feet southwest of No. 1 at the surface along the strike of the vein, was sunk to a depth of 106 feet on the incline. During his exploration work, Williams erected a 3-stamp

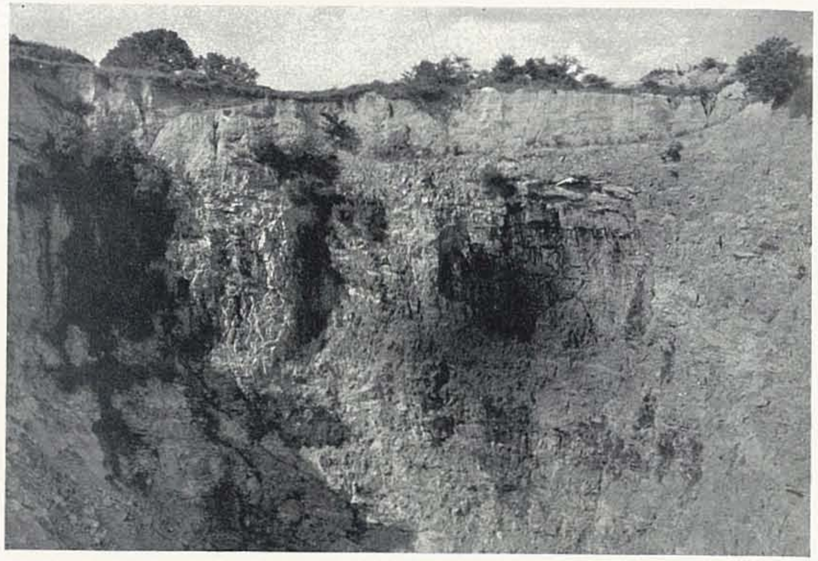
[16] Silliman, Benjamin, Remarks on some of the gold mines and on parts of the gold region of Virginia: Am. Jour. Sci., 1st ser., vol. 32, pp. 98-130, 1837.



A. Columbia granite at the type locality just east of Columbia, along State Highway No. 6.



B. Elk Hill complex. Hornblende gneiss (dark) injected by pegmatite. In road cut west of East Leake.



A. Highly fractured Petersburg granite in Boscobel quarry.

B. Boulder in Triassic conglomerate.

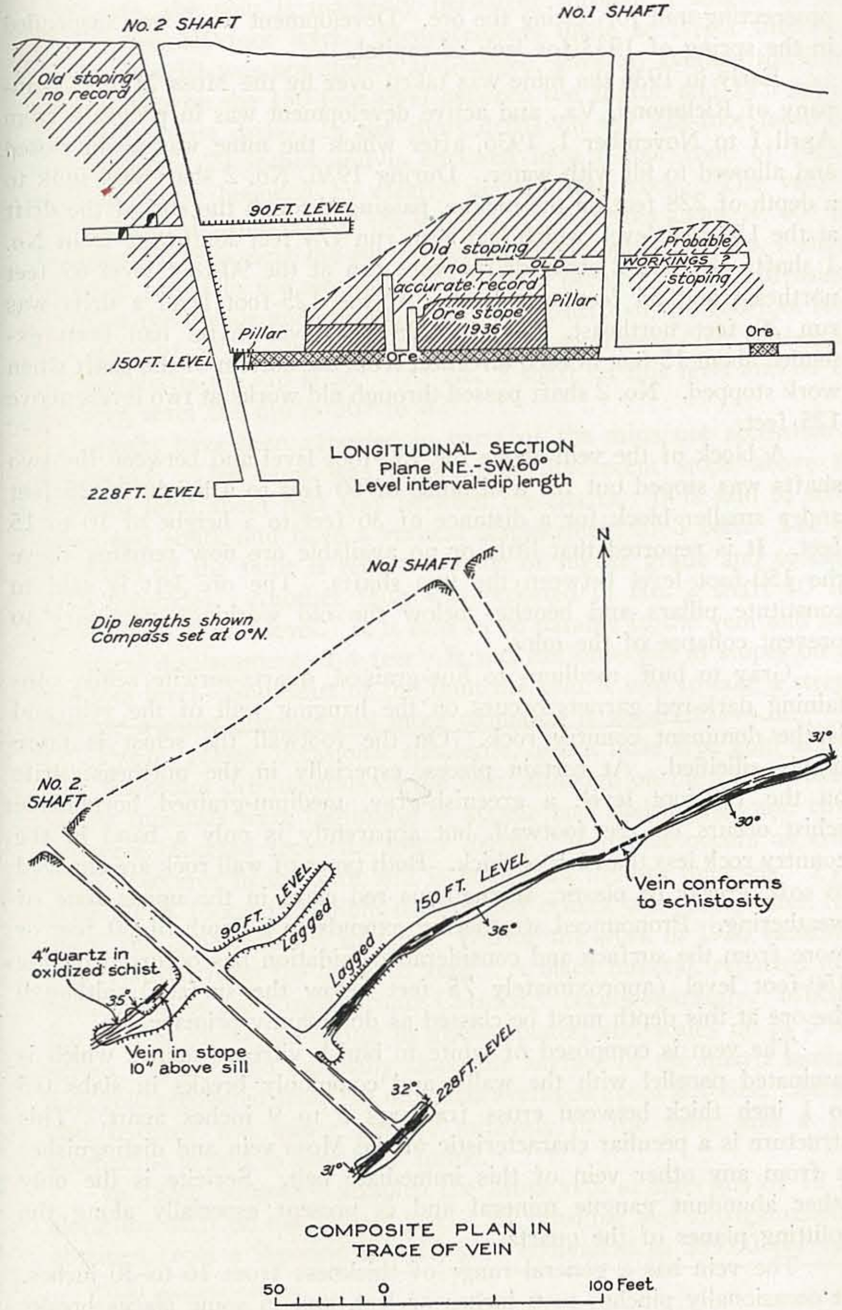


FIGURE 2.—Plan and longitudinal section of the Moss mine.

prospecting mill for testing the ore. Development work was suspended in the spring of 1933 for lack of capital.

Early in 1936 the mine was taken over by the Moss Mining Company of Richmond, Va., and active development was in progress from April 1 to November 1, 1936, after which the mine was again closed and allowed to fill with water. During 1936, No. 2 shaft was sunk to a depth of 228 feet on the incline, passing through the end of the drift at the 150-foot level, which had been run 174 feet southwest from No. 1 shaft. In No. 2 shaft drifts were run at the 90-foot level 69 feet northeast and 55 feet southwest. At the 125-foot level a drift was run 20 feet northeast. At the 228-foot level drifts had been extended about 15 feet in each direction from the bottom of the shaft when work stopped. No. 2 shaft passed through old works at two levels above 125 feet.

A block of the vein above the 150-foot level and between the two shafts was stoped out for a distance of 60 feet to a height of 25 feet and a smaller block for a distance of 36 feet to a height of 10 to 15 feet. It is reported that little or no available ore now remains above the 150-foot level between the two shafts. The ore left is said to constitute pillars and benches below the old workings necessary to prevent collapse of the mine.

Gray to buff, medium- to fine-grained, quartz-sericite schist containing dark-red garnets occurs on the hanging wall of the vein and is the dominant country rock. On the footwall the schist is more highly silicified. At certain places, especially in the northeast drift on the 150-foot level, a greenish-gray, medium-grained hornblende schist occurs on the footwall, but apparently is only a band in the country rock less than 1 foot thick. Both types of wall rock are changed to soft, greasy or plastic, ferruginous red clays in the upper zone of weathering. Pronounced weathering extends to a depth of 50 feet or more from the surface and considerable oxidation has occurred on the 150-foot level (approximately 75 feet below the surface), although the ore at this depth must be classed as dominantly primary ore.

The vein is composed of white to bluish vitreous quartz which is laminated parallel with the walls, and commonly breaks in slabs 0.5 to 1 inch thick between cross fractures 5 to 9 inches apart. This structure is a peculiar characteristic of the Moss vein and distinguishes it from any other vein of this immediate belt. Sericite is the only other abundant gangue mineral and is present especially along the splitting planes of the quartz.

The vein has a general range of thickness from 16 to 30 inches. It occasionally pinches to 6 inches or less, and in some places breaks up into several thin stringers separated by silicified wall rock. On the whole, the vein is markedly persistent through a length of 280 feet on the 150-foot level. Measurements made at 5-foot intervals, where the drift was not stulled and lagged, gave an average thickness of 20 inches on the 150-foot level between the shafts, and 11.5 inches in the northeast drift. In the short drifts on the 228-foot level the vein averages 29 inches and is enclosed in a 6-foot zone of highly silicified schist bounded by clearly defined wall rock. The vein is parallel with the foliation of the wall rock. It strikes about N. 60° E., and dips 45° SE., near the surface and near the bottom of No. 1 shaft. At other places in the workings it seems to become flatter. Measurements in the middle and end of the northeast drift of the 150-foot level give a dip of 30°. About the middle of the southwest drift connecting the two shafts the dip is 36°. At No. 2 shaft on this level and on the 228-foot level the dip is 30° to 32°.

Faults have been reported in parts of the mine not accessible to the writer. One fault was reported in the recent stope above the 150-foot level about half way between the shafts. It is said to strike north and south and have a vertical displacement of 3 feet. The ore northeast of the fault is reported to be of higher grade and to carry more sulphides. Another fault was reported in No. 2 shaft 10 feet above the 150-foot level. It is said to be parallel to the vein and have a vertical displacement of 4 feet. It was not observed in stopes on the 150-foot level. Southeast of the fault the vein is said to take a steeper dip for a short distance and more oxidation is apparent.

Pyrite, galena, occasional sphalerite, and a little free gold are the only important ore minerals of the vein, although on the 228-foot level copper minerals were beginning to appear and chalcopyrite and covellite were reported from the lower drifts. Marcasite occurs as crusts along fractures in the vein and is later than the ore minerals. Pyromorphite is found in minute needles and crusts, also along later fractures, and is a secondary mineral. During the work in 1936 vanadinite was reported from the oxidized zone. A black mineral, reported to be tetradymite by the Virginia State Chemist,[17] occurs sparingly. Much of the gold is coarse, occurring in grains, plates, and scales up to 5 mm. across. It is found especially along the surface of the quartz laminae. The gold recovered from the mine has averaged about 890 fine. Sericite and feldspar are minor gangue minerals in the vein, and a little tourmaline is said to have been found.

In 1836, Silliman[18] sampled the Moss vein at intervals of 12 feet along the drift on the 30-foot level. By crushing and amalgamation he obtained from a 9-pound sample, gold equivalent to $99.60 per ton.[19]

[17] Oral communication.
[18] Op. cit., p. 104.
[19] Old price, $20.67 per ounce.

Another sample of 3½ pounds of powdered rock, in which no gold was visible, yielded the equivalent of $139.60 per ton, and a third sample of 2 pounds yielded $204.20 per ton. During the work in 1903, the ore from drifts off of shaft No. 1 is reported to have milled $15 per ton.[20] In the west level a small pocket or shoot was encountered which assayed $150 per ton in gold and 40 ounces of silver. From drifts of the old shaft near the present No. 2 shaft, ore is reported to have milled $14.40 per ton. Regular assays of tailings averaged $2 per ton. Presumably these figures represent the value of free gold obtained on amalgamating plates. No records of concentrates are available, but, if they compare with recent concentrates, a considerable part of the value of the ore was included in them.

Systematic sampling of the mine by reliable engineers several different times during the last six years have indicated an average assay value of approximately $26 per ton for ore exposed on the 150-foot level between the shafts. Only a part of the vein in the northeast drift is reported to carry sufficient value to constitute ore. The drifts on the 228-foot level, although in a well-defined vein, have not disclosed minable ore values.

The most reliable record of the value of the ore is found in the mill production during 1936. During this period of operation, 172 tons of ore was milled after hand picking and discarding on the surface of probably not more than 25 per cent of the material hoisted, which was largely wall rock schist. This ore was obtained from slopes above the 150-foot level as indicated above, and in sinking the shaft. The mint return for gold recovered was $3,375.25 or $19.61 per ton milled.

During the work in 1936 a rich pocket was discovered in No. 2 shaft at about 175 feet. The ore is said to have showed spectacular crusts and films of free gold associated with fine-grained galena, vanadinite and pyromorphite. Exploration work has not proceeded far enough, however, to outline the dimensions or pitch of any definite ore shoots within the vein.

The mine is now equipped with a small but modern mill erected by the Moss Mining Company. (See Pl. 9, B.) It consists of a jaw crusher, 20-ton storage bin, Hardinge ball mill and counter current classifier, a Denver mineral jig, corduroy blankets, a one-cell flotation unit, a concentrate tank, amalgum drum, launder, and amalgamating plates.

Taking into account a mint return of $906.30 to J. C. Williams, Sr., for gold obtained in his prospecting mill, the mine has returned $4,281.55 since 1931. Draper's production in 1893 is reported to have been $10,000. Manning's production in 1891, as well as that during the

[20] Taber, Stephen, op. cit., p. 145.

operations of 1836-1838, is unknown. Judging, however, from the ore known to be removed from the mine and indicated values it appears that the total production has been $20,000 to $25,000.

Mining conditions are not favorable in the decomposed mica schist near the surface, because it has a tendency, when saturated with water, to "flow" under its own weight into any open space. It is difficult to timber shafts through this zone to a depth of 75 feet. In July 1937, No. 2 shaft was badly caved at the surface and needed extensive repairs. The mine required pumping 50 gallons per minute of water to maintain its level below the workings. This supply, plus a small surface reservoir covering about half an acre, furnishes ample water for all milling requirements.

Busby mine.—The Busby mine is half a mile northeast of the Moss mine. Placer gravel was worked on this tract as early as 1830 and led, shortly thereafter, to discovery of the Busby vein. In 1836 Silliman[21] reported that four prospecting shafts had been put down to depths of 20 to 26 feet, and that a vertical shaft was being sunk, which had reached 57 feet and was expected to cut the vein at 70 feet. The vein exposed in the prospecting pits was 12 to 30 inches thick, averaging 15 to 18 inches. It is described as white, coarsely granular to sugary quartz, apparently without ore minerals other than free gold.

An average sample of ore on the dump, amounting to about 6 pounds, was crushed, panned, and amalgamated, and yielded, according to Silliman, 6 grains of gold or the equivalent of $81.60 per ton (old price). A selected sample showing pin points of free gold treated in the same way yielded the equivalent of $245 per ton (old price). This ore, it should be remembered, came from within 26 feet of the surface, and was doubtless enriched by secondary concentration.

Before 1836 a small wooden stamp mill run by water power had been erected by the Fishers and D. W. K. Bowles. In that year Silliman states that a steam engine, engine house, whim, and other equipment had been built or installed, and already 12,000 to 13,000 bushels of ore had been accumulated for milling. Since the weight of one bushel of ore is approximately 100 pounds, this represented 600 to 650 tons of ore, all of which was obtained close to the surface.

According to Taber,[22] when H. Credner visited the mine in 1865 the mill was in ruins. In the interim the 600 to 650 tons of ore was milled or removed, as none is found on the old dumps today. If this ore averaged $80 per ton or more as Silliman's test showed, the value of this ore was not less than $48,000.

[21] Op. cit., p. 102.
[22] Op. cit., p. 147.

The vein referred to by Silliman has been supposed to be a continuation of the Moss vein, but continuous tracing on the surface between the two mines is not possible. In addition there are a few pits on the property located on a line with veins of the Tellurium system. Little is known of these workings. The Busby vein, however, on the basis of old reports, appears to warrant further exploration.

Payne tract.—On the Payne tract, half a mile southeast of Tabscott on the south side of the county road, several prospect pits were sunk in the early days of mining. The strike of a line connecting these is about N. 58° E. During the spring of 1933, some trenching was done on this property and one small vein was disclosed, but its value has not been determined.

Fleming mine.—The Fleming mine is three-fourths of a mile northeast of Tabscott. (See Pl. 2.) The earliest work was on placer gravel during the 1830's. In 1846, General Cook is said to have erected a 6-stamp mill and begun lode mining. His production is reported to have been at times as much as $200 per day, but the success was of short duration as the vein was soon "lost." The mine was sold in 1848 and little additional work was done except for a brief period following the War between the States, when several old shafts were cleaned out.

The workings consist of a series of old shafts and pits extending for 150 yards in a direction N. 60° E. Two old shafts are said to be 60 and 35 feet deep, respectively. The schist in one of the shafts is reported by Taber to strike N. 61° E. and dip 45° SE.

Tellurium mine.—The Tellurium mine is 2½ miles southwest of Tabscott (Pl. 2), along the Goochland-Fluvanna county line. Veins were discovered at this place by G. W. Fisher in 1832. Two years later it was leased by Fisher and Sons and D. W. K. Bowles. In 1836, they erected a primitive 6-stamp mill, believed to be the first in America, and continued working the mine until 1848 when it was purchased by Commodore Stockton. He at once erected a 40-stamp mill and operated on an expanded scale until 1857 when the mill was burned. The property was then sold, and no further mining was carried on until 1880 when a 10-stamp mill was erected. Little work was done at this time. In 1890 and 1909-1910 attempts were made to reopen the mine, but these did not meet with much success.

The deepest workings of the Fishers, confined to the Middle and Little veins, reached only 65 feet. Stockton's deepest shaft had a vertical depth of 136 feet. Nearly all of the ore mined by Stockton, however, was obtained above water level. He is said to have worked out the Big Sandstone vein above this level for 1,500 feet along the strike. During

the last operations, a shaft was sunk 90 feet in the Big Sandstone vein and short drifts were run at the bottom. Other old shafts and tunnels were cleaned out above water level.

Beginning in May 1935, prospecting and development work was started by W. S. McDonald who later operated for the Tellurium Gold Mining Company. The prospecting work to July, 1937, has consisted of cleaning out the old Harrison shaft sunk in 1910, extending the drift southwest on the vein at the bottom of this shaft from 30 feet to approximately 45 feet, and running a cross-cut 17 feet southeast from a station just northeast of the bottom of the shaft. In the southwest drift, McDonald reports he stoped out a block of ore 20 feet long and 15 feet high above the drift beginning at a point 10 feet from the shaft. In addition several prospecting shafts have been sunk on the property 15 to 30 feet deep and short drifts and crosscuts run from these.

A 3-stamp mill with amalgamating plates and blankets was set up (Pl. 10, A) and 19 tons of ore had been milled to July, 1937.

Taber states that, according to local reports, the production from 1834 to 1848 was $130,000 to $150,000, and from 1848 to 1857 it was variously reported from $75,000 to $1,000,000, but it probably was nearer the lower figure. It seems safe to estimate that the total production has been $250,000 or more, all from ore in the oxidized zone.

The country rock consists of fine-grained, quartz-sericite schist, some of it garnetiferous, and interbedded thin layers of fine-grained, even-granular, and locally ferruginous quartzites.

Taber[23] describes the Tellurium vein system in detail, from workings that were accessible at the time of his visit but are now caved. Only a brief resume of the veins is given here.

The "Big Sandstone" vein is a mineralized quartzite bed, 2 to 6 feet thick, cut in places by irregular, gold-bearing quartz stringers, which in places are as much as 1 foot thick. It exhibits some of the characteristics of a replacement deposit, but its continuity indicates it was originally a sandstone bed in the country rock. The average strike of the bed is N. 64° E., and the dip 45° SE. It is said to have been traced 3 miles, but only certain portions are mineralized, generally where quartz stringers are abundant. The portions of this vein that were worked are said to have averaged about $5.00 per ton in gold (old price).

The "Middle" vein is parallel to the Big Sandstone vein and 30 feet southeast of it. It is composed of a series of lenses of quartz containing feldspar, pyrite, and free gold. It varies from a knife-edge to 3 feet thick. The "Little" vein, also parallel and 20 feet southeast of the Middle vein, is less than 1 foot thick. It is said to have been richer than the Middle vein, but ore from both averaged $50 to $100 per ton (old price) in the oxidized zone.

[23] Op. cit., pp. 152-172.

The "West" vein is said to have been cut in a shaft 40 yards northwest of the "Big Sandstone" vein. The "West" is a cross vein, striking N. 27° E. and dipping 80° SE. Another vein known as the "Hodges" also crosses the property. Of all the veins the Big Sandstone is most persistent and uniform and, though of lower value, seems most deserving of further attention.

Benton mine.—The Benton mine is three-fourths of a mile northeast of Tabscott. Nothing is known of its history. The main working consisted of a shaft which was put down to water level or below. The mine is on the strike of the Tellurium vein system.

Young American mine.—The Young American mine[24] is on Luck Branch, 1 mile east of Priors Cross Roads. For a short time after its discovery in 1869 it was operated by a Mr. Aldrich, who erected a small stamp mill and worked the "House" vein. Placer gravel on Luck Branch was worked between 1871 and 1874. In 1880 development work was renewed and continued until 1883 by the Tagus Gold Mining Co. In 1893 a cyanide plant is reported to have been in operation. The last period of development began in 1909, when a substantial mill was erected and equipped with crusher, feeder, slow-speed Lane mill, plates and two concentrating tables. This mill was operated until 1912, but only slightly more than 1,500 tons of ore was milled.

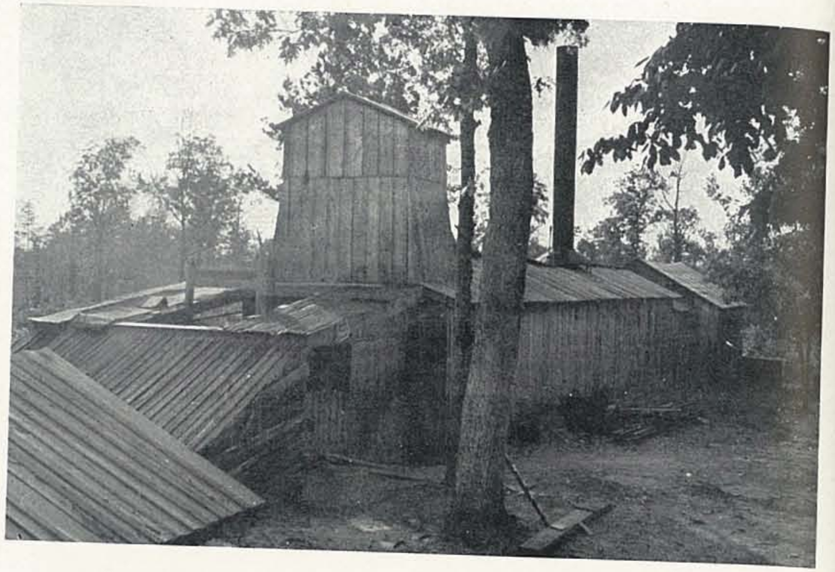
Two veins cross the property. The "Sulphur" vein has an average strike of N. 40° E., and a variable southeast dip. It ranges from a few inches to 6 feet thick and averages 2 to 3 feet. It carries irregular gold values from a few cents to $24 per ton, averaging about $5 (old price). It has been explored by the Sulphur shaft, 80 feet deep vertically and an additional 42 feet on the incline, connected by a 340-foot drift on the vein with the "H. V." shaft, which is 83 feet deep. Most of the ore above this drift has been stoped out.

The "House" vein crops out 250 yards east of the Sulphur vein. It is said to strike N. 22° E. and to average 5 to 6 feet wide. It has been stoped out above water level for 600 feet along the strike. Old reports credit the ore of this vein with an average value of $5 to $10 per ton (old price). Both veins, strictly speaking, are stringer lodes, and are made up of many quartz stringers in addition to the main vein, which is itself irregular and lenticular. Some of the parallel gold-bearing stringers are found as much as 25 feet away from the main vein. The wall rock of the vein is of two types, a dark greenish-gray, fine-grained gneiss, and a similar light-gray gneiss without hornblende.

[24] Accessible at the time of Taber's visit and described by him in detail, op. cit., pp. 118-139.

A. Shaft house at the Waller gold mine.

B. Mill and shaft house at the Moss gold mine.



A. Mill and inclined shaft at the Tellurium gold mine.

B. Collins Placer, dragline and gold-saving machine. On Little Byrd Creek about 4 miles south of Tabscott, Goochland County. From Geological Survey Bulletin 44, by Charles F. Park, Jr.

Belzoro mine.—The Belzoro mine is half a mile south of the Young American mine. (See Pl. 2.) Placer gravels were discovered on this tract in 1832, and are reported to have been very rich in spots. One short stretch known as "Dry Gulch" is said to have yielded $30,000. Several shafts and pits were sunk on the property, and a primitive 10-stamp mill was in operation before the War between the States. The vein system is the same as at the Young American mine. Two veins 300 yards apart average 2 to 3 feet, and 3 to 4 feet thick, respectively. Old reports[25] show that 2,000 to 2,500 tons of ore were milled, and that the yield of this, together with the recovery of placer gold, gave a total production of not less than $100,000. The property has not been worked since the War between the States.

Bertha and Edith mine.—The Bertha and Edith mine is located 3¼ miles northeast of Columbia. Placer gravels were worked on this property before the War between the States. In 1877, a 20-stamp mill was erected and two veins were opened. The "Oak Hill" vein averages about 3 feet thick and carries values said to average about $5 per ton (old price). It has been opened by an adit 400 feet long in the side of a low hill, 75 feet below its summit. The adit was connected by a raise with an upper level on which 300 feet of drifts was run. The "Maple Branch" vein was explored by an adit of unknown length. It is said to be narrower but richer than the Oak Hill vein. The wall rock at this mine is a light-gray, medium-grained gneiss, with interbedded layers of hornblende schist.

Collins, Morgan, Grannison and other mines.—These mines are chiefly placers. On the Collins place, the first gold in the district was found in 1829. At the Morgan mine, a 4-foot vein was worked and a 10-stamp mill was operated before the War between the States. All of these mines are located within a mile or two of the Young American.

Placer deposits.—Placer deposits in the county still yield some gold during sporadic attempts to work them. There is no indication that a sufficient quantity of these gravels remain for large scale exploitation.

Placer mining operations were under way at the old Collins placer in the valley of Little Byrd Creek about 4 miles south of Tabscott in 1934 and 1935. (See Pl. 10, B.) According to Park,[26] "The operations are controlled by the Powhatan Mining Co., and are in charge of Lewis L. Stirn. A considerable extent of the bottom land along the branch has been cleared of timber and brush. A portable machine for recovering placer gold and a steam drag line were operating; about 1,000

[25] Snell, P. A., From a report on the Belzoro mine, cited by Taber, op. cit., p. 139.

[26] Op. cit., p. 19.

cubic yards of alluvium are handled in one shift of 8 hours. The gravels are reported to run about 40 cents a cubic yard."

Placer operations are reported to have been in progress on the Bertha and Edith mine tract in the summer of 1937, but the extent of work to this time had been small.

RUTILE[27]

Rutile is found over a considerable area north of U. S. Highway No. 250, west and northwest of Centerville. It is conspicuous on the Nuckols farm, where masses weighing 2 to 3 pounds are found in abundance on the surface, and masses weighing as much as 30 pounds have been found.

Rutile is a dioxide of the metal titanium and is one of its chief sources. Titanium compounds are used in the manufacture of high-grade paints, steel-hardening alloys, and in the coloration of porcelain and enamel ware, including false teeth.

All the rutile in this area is massive and intermixed with ilmenite, an oxide of titanium and iron. The two may be readily distinguished by their color and luster. Rutile is cherry-red to deep brownish-red, and has a metallic-adamantine luster; ilmenite is black and has a sub-metallic luster.

The source of the rutile and ilmenite found in the soil has not been conclusively proved, as there are no exposures of fresh rock in the area. It is probable, however, that they are primary minerals of the pegmatite dikes that cut the State Farm gneiss. It is reported that prospect pits disclosed stringers and lenses of rutile in the pegmatite and to a small extent in the feldspathic gneiss. The stringers were granulated and elongated parallel to the walls of the pegmatite. Only one fact throws doubt on this origin, and that is the occurrence of ilmenite-bearing pyroxenite dikes in the rutile areas. Further prospecting may reveal whether these dikes bear any genetic relation to the rutile.

Prospect pits more than 100 years old are found in the area. These are supposed to have been sunk in the belief that the red ore was ruby silver, and were abandoned on discovery of the mistake. The true character of the ore was determined in 1910, and some prospecting was done during that year. In 1918 a shaft was sunk to a depth of 60 feet, but it was abandoned when no large masses of rutile were found.

The most promising commercial possibility appears to be the lumps and grains of the mineral disseminated through the residual soil and decayed mantle rock. So far no tests have been made to determine the quantity of ore minerals per cubic yard, and this should be done. Because of its specific gravity, the ore could be readily concentrated by either wet or dry gravity methods. The manner in which the two minerals are associated suggests that they could be readily separated by an electro-magnet after fine crushing. The deep residual soil could be worked by steam shovel or drag-line scraper at relatively low cost. If the quantity of ore in the soil is shown by sampling to be sufficient and market conditions are favorable, surface mining would be a feasible enterprise. On the other hand there is little indication that rutile will be found sufficiently concentrated in the underlying bedrock to warrant deep mining.

[27] See also Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3-A, pp. 248-261, 1913.

MICA AND FELDSPAR[28]

General features.—Mica and feldspar occur in pegmatite dikes in the central part of Goochland County. These dikes are lenticular, ranging in width from a few inches to 10 feet, and in length from a few feet to as much as half a mile. The larger dikes in part cut across the foliation of the country rock, but the smaller dikes generally follow the planes of foliation. The pegmatite is coarsely granular and the minerals are intimately intergrown. Feldspar makes up 50 to 80 per cent of the pegmatite, and consists of both the potash and soda-lime varieties, with the former predominating. Muscovite, the principal mica, occurs in books up to 6 inches in diameter, but a few books are larger. It is generally present to the extent of 5 to 10 per cent, and is more or less concentrated along the well-defined walls of the dikes. Garnet, tourmaline, sillimanite, and graphite are found sparingly in some dikes.

Muscovite mica is used for insulation in electrical equipment, and in other places where a transparent heat- resisting substance is needed. It is ground for certain lubricating compounds, for roofing material, and similar purposes. Feldspar is used principally in the manufacture and glazing of porcelain ware. The mines of this county have been worked exclusively for mica.

Amber Queen mine.—The Amber Queen mine is located half a mile southwest of Elpis Church. It was opened on a pegmatite dike 10 feet wide, which has been traced for half a mile in a direction N. 40° W. The dike is nearly vertical. The chief minerals are feldspar (largely orthoclase), smoky-gray quartz, and clear amber-colored mica. The mica is of high quality and occurs in books that yielded perfect square cuts 4 by 4 inches and more.

This mine was operated from 1916 to 1918. It was opened by two pits on the outcrop of the vein and a vertical shaft, located at the point

[28] See also Pegau, A. A., Pegmatite deposits of Virginia: Virginia Geol. Survey Bull. 33, pp. 15-49, 61-66, 1932.

of a triangle with reference to the pits. The shaft was 40 feet deep, and a 3 by 6 foot drift at its bottom extended 50 to 60 feet northwest along the vein. According to Mr. T. J. Slayden, the production of this mine in two years was 35,000 pounds of mica.

Irwin mine.—The Irwin mine is located on State Highway No. 6, half a mile northeast of Irwin. The lenslike dike has been almost entirely removed at the surface. It is said to have had a maximum width of 5 feet, but the portion now showing is only 22 inches wide. It strikes N. 20° E. and is nearly vertical. The mine was opened by a shaft 90 feet or more deep and 9 feet square, with a drift 6 feet long at the bottom, and also by a pit 25 feet in diameter and 20 feet deep. The best mica is said to have come from the pit. The largest marketable sheets are said to have been "about the size of the hand." The property was opened some 30 years ago and worked for 2 years. There is no record of its production.

Salter prospect.—The Salter prospect is between Goochland Court House and Sandy Hook, half a mile west of State Highway No. 49. It was opened more than 30 years ago by a pit 20 by 25 feet in diameter and about 20 feet deep. Sheets of good mica up to 4 by 4 inches were found on the dump. The dike is said to have been too small for commercial exploitation.

Bradshaw prospect.—The Bradshaw prospect is half a mile northeast of Goochland Court House, on the Glebe road. One pit 6 to 8 feet deep was sunk, and a small dike carrying mica in sheets as much as 4 inches wide was found.

Swann prospect.—The Swann prospect is half a mile west of Goochland Court House. Several narrow veins carrying small books of mica were found.

Reed prospect.—The Reed prospect is 1¾ miles northwest of Maidens. It consists of a cut 75 feet long, 25 feet wide, and 20 feet deep, trending N. 35° W. Sheets of good mica 2 inches square were found on the dump.

Turner prospect.—The Turner prospect is three-fourths of a mile south of the Amber Queen mine. It was opened more than 30 years ago by a cut 70 feet long. Sheets of mica 3 inches in diameter were found on the dump.

Owens prospect.—The Owens prospect is 200 yards south of Perkinsville. A pit 12 feet deep disclosed only small sheets of mica.

Nicholas prospect.—The Nicholas prospect is three-fourths of a mile east of Perkinsville. A cut 22 feet deep shows a dike 5 feet wide which strikes N. 30° E. and dips 60° SE. Good amber-colored mica was recovered in sheets as much as 6 inches square. The dike can be traced for nearly half a mile.

Lewis prospect.—The Lewis prospect is a few hundred yards north of Community Church and three-fourths of a mile west of Little Byrd Creek. According to Mr. H. B. Lewis, a pit 10 to 12 feet deep disclosed an 8-inch dike carrying mica in sheets as much as 8 to 9 inches across.

CLAY

Residual clay suitable for brickmaking occurs in many places throughout the county. Clays of high quality suitable for fine pottery ware, that is, residual kaolins, have not been found in sufficient quantities to warrant description.

One sample of residual clay from the Wissahickon gneiss, taken from a large cut bank a quarter of a mile north of Maidens Station, was tested by Ries and Somers,[29] with the following results:

"The material . . . . is a micaceous clay of fair plasticity, which required 46 per cent of water for tempering. The air shrinkage was 7.3 per cent, and the average tensile strength not over 20 pounds per square inch. The bricklets made from this clay burned to a good red color, with a fair ring at Cone 05, and a good ring at Cone 03. They became steel hard at Cone 1. . . . .

"This clay could be used for common brick, but its absorption is a little high."

This sample is probably fairly typical of all the residual clays of the gneissic area.

COAL

Coal seams occur near the base of the Triassic series in the eastern part of Goochland County. They crop out near Manakin on the western side of the Richmond coal basin, and along Tuckahoe Creek on the eastern side. These coal deposits have been known for more than 100 years, and in the past were extensively worked. The last important operations were at the Dover mines at Manakin about 1870, although some coal was taken out as late as 1888. That the coal is of good quality is shown by the analyses in Table 3.

[29] Ries, H., and Somers, R. E., The clays of the Piedmont province, Virginia: Virginia Geol. Survey Bull. 13, p. 48, 1917.

TABLE 3.—*Analyses of coal from eastern Goochland County*[30]

Location	Volatile Matter	Fixed Carbon	Ash	Authority
Randolph's	30.50	66.15	3.35	Rogers
Anderson's (Manakin, upper seam)	28.30	66.78	4.92	Rogers
Anderson's	26.00	64.20	9.80	Clemson
Barr's pits (first seam)	24.00	70.80	5.20	Rogers
Barr's pits (second seam)	22.83	54.97	22.20	Rogers
Barr's pits (third seam)	24.70	65.50	9.80	Rogers
Barr's pits (fourth seam)	21.33	56.07	22.60	Rogers
Crouch's (lower shaft)	30.00	64.60	5.40	Rogers
Richmond Basin (Midlothian)	25.70	62.50	9.00	Campbell
	B. t. u. 13,490			

Mines on the western side of the basin lie between Manakin and James River. A few prospect pits are located north of the village, in which direction the coal seams can be traced for 2 miles. The mines were opened prior to 1835, and one shaft was 450 feet deep before the War between the States. The mines were reopened just after the war and worked until 1870. During this period the Aspen Wall shaft was sunk 900 feet vertically and bricked up from top to bottom. It is located near the old brick smokestack still standing south of State Highway No. 6 near Manakin. It passed through one 6-foot seam of coal but was abandoned when it failed to strike the lower seam. The Company shaft close to the highway is 312 feet deep. Canal shaft on the river is 280 feet deep. The depths of the Bell and Garden Wall shafts are unknown.

Old reports differ on the number and position of the coal seams. Rogers[31] and Lyell[32] agree that there were two principal seams, the upper, 6 to 16 feet thick, separated by 30 feet of sandstone and shale from the lower seam, 4 to 8 feet thick, which rested close to the underlying crystalline rock. Several smaller seams were also found near the base of the series, and these thickened in some places to workable beds. Fontaine[33] maintained on the other hand that 100 to 600 feet of barren rock separated the lower coal seam from the crystalline rock. He stated that the lower seam is 6 to 8 feet thick and that the main seam is 40 to 50 feet higher. Wolff[34] noted three seams in the Manakin mines,

[30] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, pp. 534-535, New York, D. Appleton and Co., 1884. Clemson, T. G., Analysis of some of the coal from the Richmond mines: Geol Soc. Pennsylvania Trans., vol. 1, p. 296, 1835. Campbell, M. R., and Bownocker, J. A., The coal fields of the United States: U. S. Geol. Survey Prof. Paper 100, p. 32, 1929.

[31] Op cit., pp. 62-69.

[32] Lyell, Charles, On the structure and probable age of the coal field of the James River, near Richmond, Virginia: Geol. Soc. London Quart. Jour., vol. 3, p. 267, 1847.

[33] Fontaine, W. M., Contributions to the knowledge of the older Mesozoic flora of Virginia: U. S. Geol. Survey Mon. 6, 144 pp., 1883.

[34] Shaler, N. S., and Woodworth, J. B., Geology of the Richmond Basin, Virginia: U. S. Geol. Survey Nineteenth Ann. Rept., pt. 2, p. 430, 1899.

respectively, 6 to 8, 12, and 3 to 4 feet thick. The coal beds dip 25°-90° E.

Coal seams of comparable thickness and quality are also found along Tuckahoe Creek on the eastern margin of the basin, but none of them have been opened or explored since the War between the States, and only fragmentary and generally undependable records are available concerning them.

The mines were abandoned not so much from lack of good coal, as because of bad mining conditions due to the shattered and faulted condition of the rocks. Lack of expert geological supervision and lack of modern safety methods in mining were important factors in the failure of these mines. It appears certain from old records that there are two and possibly more workable seams of good coal at Manakin. Diamond drilling should be used as the best method of prospecting the area, and a competent geologist should be employed to supervise the operations. If this is done and favorable market conditions exist, mining may again be profitable. There is good reason to believe that ample reserves are present. Coal from this point would have the advantage of favorable freight rates to the Atlantic seaboard.

STONE

Stone suitable for building and paving blocks and for crushing is found at several places in the county. Although no high-grade building stone is present, several localities have ample reserves of stone suitable for rougher grades of work. One crushed stone plant is in operation at present.

Cowherd quarries.—The Cowherd quarries are located at Columbia on the western border of the county. (See Pl. 7, A.) The stone is a medium-grained, light-gray gneissic granite. It contains fairly abundant dark spots, or "cat-eyes," as well as stringers of quartz and lenticular veins composed of quartz, feldspar, and mica. Large blocks could be obtained, but it is doubtful if any block would be free from these defects. Horizontal joints, or so-called "bedding planes," are 6 feet or more apart in the lower part of the quarry, and vertical joints are widely spaced. The stone is suitable for curbing, paving blocks, riprap, and crushed stone. The chief difficulty in quarrying would be the proximity to the town. The effects of blasting might be injurious to foundations and windows of buildings since the whole town is underlain by the granite. These quarries have never been worked to any extent, and not at all since 1900.

State Farm quarries.—The State Farm quarries are located on the Chesapeake and Ohio Railway three-fourths of a mile south of State

Farm. The stone is a medium-grained gray gneiss. (See Pl. 6.) These quarries are the type locality of the State Farm gneiss. They were opened in 1907 and operated until 1912. Some dimensional stone was taken out, but most of the rock was crushed for ballast. At the height of operations, 5 to 25 cars a day were shipped. The quarries were opened in the side of a hill overlooking the James Valley, and were abandoned when they were worked to the point where it became unprofitable to remove the overburden. The stone is said to yield a high percentage of dust on crushing, and thus to require washing before it can be marketed for ballast.

Boscobel quarries.—The Boscobel quarries are located south of Manakin along the Chesapeake and Ohio Railway. Three openings have been made, of which the easternmost is now being worked. The floor of the quarry is 150 feet below the top of its northern face, and 50 feet below the level of the railroad. At present operations are confined to the west face of the main or eastern quarry hole. The overburden on the north face of the quarry is 40 feet thick.

The stone is a dark-colored, fine-grained injection gneiss with intermixed coarse-grained light-colored granite. It is highly brecciated and fractured and is suitable only for crushing. (See Pl. 8, A.)

Operation consists of shooting off the face of the quarry, loading the rock with a 1-yard steam shovel into large iron pans, which are hauled by truck to the south face of the quarry, where they are lifted by a 20-ton steel derrick and dumped directly into a 28- by 36-inch jaw crusher. From the bottom of the crusher, the stone is carried by a 30-inch belt conveyor up to a scalping screen, from which the coarse stone goes into a secondary 4-foot cone crusher. It then passes by bucket conveyor to a 5-compartment 300-ton bin, where it is graded by screens, washed, and stored. Part of the stone passes by belt conveyor to a second 3-compartment bin.

The stone is sold principally for railroad ballast and highway construction. The average yearly production of the quarry is 150,000 tons during 6 to 9 months operation, although the quarry had been operated almost continuously during the year which ended in July, 1937. The quarry has been in almost continuous yearly operation for the last 40 years.

Triassic sandstone.—Thick-bedded, heavy, gray Triassic sandstone crops out in the vicinity of Vinita station and along Tuckahoe Creek. Some of this stone has been quarried for local use.

MINOR MINERAL RESOURCES

A number of other mineral resources occur in the county but have not been found in sufficient quantity to justify commercial exploitation, although they have had some local use.

Graphite is found in thin seams on the property of Mr. T. J. Slayden southwest of Elpis church, and also half a mile southwest of Lantana. Kyanite occurs at several points in the gold belt, at Stage Junction in Fluvanna County, and at the Young American mine. Asbestos is found 1 mile northeast of State Farm, in small seams in impure serpentine which is an alteration product from a peridotite dike. The thickest seams are a quarter of an inch thick. Impure soapstone occurs at several localities and has been quarried for local use on the Payne Farm, 2 miles south of Tabscott. It is an alteration product occurring along the borders of pyroxenite dikes. Iron oxide is concentrated in certain beds of ferruginous quartzite in the schist belt, especially near Lantana.

WATER RESOURCES

General conditions.—Adequate water supply for domestic use may be obtained from dug wells on almost any farm in the county, at depths ranging from 10 to 50 feet. Dug wells seldom go below the zone of rock decay which is usually deeper than the water table, or surface of the saturated zone, and consequently are a relatively inexpensive source of water supply. They are ordinarily lined with rock slabs or boulders and average 3 to 5 feet in diameter after they are lined. The water supply is usually sufficient for all stock as well as human consumption on a farm of average size. In the area of crystalline rock the ground water is ordinarily free of mineral salts, though many wells have hard water, or water containing relatively large amounts of lime in solution. In the eastern part of the county, underlain by Triassic formations, the water is often less potable and some wells have been abandoned because of objectionable quantities of sulfates dissolved in the ground water.

Wells.—Where larger supplies of water have been necessary, small bore wells have been drilled with cable drilling rigs to greater depths to tap water circulating through fractures and porous beds below the water table. Usually electric, gasoline or wind-driven pumping units are installed and connected with supply tanks. Records on 15 wells drilled in the county, listed in Table 4, show depths ranging from 55 to 616 feet below the surface and water output ranging from 1 to 100 gallons per minute.

The location for drilled wells should be made by a competent geologist who will carefully consider the character, porosity, fracturing, and structure of the rock formations. Competent professional services are fully as necessary in the proper location of wells as in the development of mines or the successful exploitation of any natural resources, if the greatest return is to be obtained on the money invested. Many a drilled well in the Piedmont region has been abandoned at depths of several hundred feet for lack of water, whereas later drilling at another site on the same tract of land has developed ample supplies of water.

TABLE 4.—*Data on drilled wells of Goochland County*

Location	Owner	Date drilled	Depth (feet)	Yield*	Character of material	Remarks
Lower Byrd Creek	J. E. Riddle		105	8	Pegmatitic granite	On side of hill; 80 feet to solid rock.
Near Fife	Harvey Ransome		90	5		50 feet to solid rock.
East Leake No. 1	State Highway Camp	1931	145	2	Hornblende schist and granitized gneiss of Elk Hill complex	Solid rock at 35 feet; water "vein" at 140 feet.
East Leake No. 2	State Highway Camp	1931	55	12	Granite gneiss and hornblende schist of Elk Hill complex	400 yards from No. 1 well, toward creek; solid rock at 4 feet.
1 mile west of Pemberton	Saunders Hobson		600±	5	Gray granite in Wissahickon granitized gneiss	No water in last 200 feet.
Mount Bernard; 2 miles west of State Farm	Dr. Outen	1915-16	616	100	State Farm gneiss	Supply at 200 feet 20 gallons a minute. At 300 feet and below no increase in supply. Most of supply, therefore, between 200 feet and 300 feet.
Just east of State Farm	DeGrafton Reed Hobson		220	10	State Farm gneiss. "Black cutting" probably hornblende gneiss	60 feet to hard rock.
1 mile east of State Farm	Edwin P. Hobson		175	15	State Farm gneiss	Sand "vein" poured in sand during drilling.

TABLE 4.—*Data on drilled wells of Goochland County*—Continued

Location	Owner	Date drilled	Depth (feet)	Yield*	Character of material	Remarks
Cornwallis Hill	C. S. Luck, Jr.		125	12	Petersburg granite injected in older rocks	Solid rock at 50 feet.
Manakin	G. W. Henley		248	1—	Triassic sandstone	100 feet to hard rock; quicksand on top of hard stratum; 115 feet casing through soft rock. No "vein" of water. Supply is seepage water, not of good quality.
Manakin	Mr. Clark		135	3	Triassic sandstone	Hard rock at less than 100 feet; "vein" of water at 110 feet.
Manakin	Mrs. Gray Powell		100	2		Last 5 feet in hard rock; no quicksand.
Manakin	John Menzel		140	20		Hard rock at 100 feet. Same as other wells at Manakin except at slightly lower level.
Lower Tuckahoe	E. A. Saunders, Jr.		125	25	"Blue muck" and slate (Triassic); few lumps of coal	Water never perfectly clear.
One-half mile west of Saunders' Lower Tuckahoe	John Aiken Branch		300±	6	"Blue muck" and slate	Had to case off mud "vein."

*Approximate yield in gallons per minute.

Dam sites.—A number of dam sites suitable for development of hydroelectric power projects exist in the county. Several of these were investigated by the Corps of Engineers, U. S. Army, under the provision of the River and Harbor Act of January 21, 1927. A site at Pemberton was reported as feasible in the basic plan for 7 new hydroelectric projects in the James River basin.[35] The report, however, recommended that none of the projects be constructed at that time because of lack of adequate markets for the power output. The dam proposed for the site at Pemberton would have a mean productive head of 20 feet, and the installed power capacity would be 12,800 horsepower. The capital cost of the development was estimated to be $1,886,000.

Other dam sites investigated, but not included in the basic plan, are the Maidens site on James River, the Elk Hill dam site on Byrd Creek, and the Dogtown site on Lickinghole Creek. Numerous other sites are available for limited power production or secondary power not suitable for network distribution. Available records show only one dam in the county at present. This is the Leake's Mill dam on Lickinghole Creek, a structure 8 feet in height which develops power for grinding corn meal.

Many excellent sites for construction of impounding reservoirs exist on small streams in the county, but owing to the absence of manufacturing enterprises or urban developments in the county no surface storage of water has been necessary. A few small farm ponds and fishing ponds, impounded by low earth dams and road embankments, have been developed in different parts of the county.

[35] James River, Va. "308" Report U. S. Corps of Engineers, War Dept.: 73d Cong., 2d sess., H. Doc. 192, 1934.

GEOLOGIC HISTORY

GEOLOGIC TIME SCALE

The 1,800 million years involved in the history of the earth since the oldest known rocks were formed has been subdivided by geologists into eras, periods, and epochs. This has been done partly for convenience and clarity of discussion of geologic records and events, much the same as the relatively short span of human history has been similarly divided, and partly because definite cycles of inorganic and organic events have been recognized in the rocks of the earth's crust. Such a classification of geologic events is also of great practical importance in the search for an interpretation of the origin and environment of diverse mineral deposits—each of which has had a definite geologic ancestry.

The sequence of events and their grouping under time units are readily deciphered in a region containing a thick succession of almost horizontal beds of rock, as in the Grand Canyon of the Colorado. In such places, the oldest rocks are always at the bottom, with successively younger beds toward the top. In regions where the sedimentary rocks have been simply folded, as in parts of the Allegheny Mountains in Virginia, the same general principle applies. Where the rocks are mainly igneous and metamorphic, as in Goochland County, other criteria are used to differentiate the ages of the rock masses. The general principle of an orderly succession of events applies, however, as in all other areas, but in areas of such complex geology, it is a far more difficult task for the field geologist to decipher those remote events and to arrange them in their proper time order.

An era is the longest unit of time in the standard geologic time scale. It includes a related series of physical events, more or less marked at the beginning and at the end by profound changes in the continents, such as the upheaval of great mountain ranges. An era is indicated also by a series of changes in the development of organisms, with the beginning and end of the era indicated by very marked changes in the groups of plants and animals. Some races disappeared and new ones came upon the scene. A period is a subdivision of an era, during which similar inorganic and organic changes occurred, but on a smaller scale or in a restricted area. A period may be marked by the invasion of the continent by the sea, and its subsequent retreat. Each period is in turn subdivided into several epochs, each marked by less pronounced physical and organic changes.

The geologic time scale in general use throughout the world is given in Table 5. It lists the five principal eras, the periods into which each era is commonly divided, the characteristic life of each era as is determined from world-wide studies, and an estimate of the duration of each period. This time estimate is based upon numerous determinations of the disintegration of radioactive minerals in rocks whose positions in the standard geologic time scale are known.

TABLE 5.—*The geologic time scale*

Era	Period	Characteristic Life	Duration[a]
Cenozoic[b]	*Quaternary* Tertiary	Mammals, mollusks and flowering plants.	60
—(c)—			
Mesozoic	Cretaceous Jurassic *Triassic*	Cycads, ammonites, giant reptiles, and birds.	125
—(d)—			
Paleozoic[e]	Permian Pennsylvanian Mississipian Devonian Silurian Ordovician Cambrian	Invertebrates, fishes, amphibians, reptiles, and land plants.	368
Proterozoic		Primitive invertebrates.	900±
Archeozoic		Primitive aquatic life.	500+

a In millions of years.
b Those italicized are represented in Goochland County.
c Uplift of old Rocky Mountains in western North America.
d Uplift of ancestral Appalachian Mountains in eastern North America and disappearance of old land mass Appalachia.
e Great land mass Appalachia prominent in Piedmont and Coastal Plain regions and beyond present Atlantic coast; source of much sediment fed to streams and deposited as conglomerates, sandstones, and shales in the Appalachian Valley to the west.

PRE-CAMBRIAN EVENTS

The origin of the oldest rocks in the county and the geologic events recorded in them are obscure because profound deformation and metamorphism have almost obliterated their earlier characteristics. So far as known, the mica schists and quartzites of the Wissahickon formation are the oldest rocks in the county. Their history began with deposition of sands and muds in an ancient basin that existed in pre-Cambrian time when only the most primitive forms of life had appeared on earth. Sinking of the basin and continued deposition buried these sediments miles deep in the earth's crust. Here, under great heat and pressure, attended by movements of molten rock, they were slowly converted into mica schists and quartzites. This was probably accomplished by the slow chemical and molecular rearrangement of mineral particles and the formation of new minerals better adapted to the deep-seated environment. The igneous rock that forms the State Farm gneiss was intruded as molten rock, probably during this period, and under similar conditions converted into an even-banded gneiss.

During a later period, a succession of igneous injections was forced into the schists, all of which had a profound effect on the mineralogical and textural character of the earlier rocks. The order of injection during the second stage was: (1) A basic rock which is now the hornblende gneiss, and is in part at least, a differentiate of the magma which later formed the Columbia granite; (2) the Columbia granite which was intruded along the foliation planes of the older schists and gneisses and as large masses that completely displaced the older gneisses; and (3) an injection which was more acid molten rock that cooled and crystallized into muscovite granite and pegmatite. These successive injections completed the development of the Wissahickon, State Farm, Columbia, Pegmatite, and Elk Hill formations, except for structures developed during a later period of folding and shearing. All of these events probably took place in middle to late pre-Cambrian time, that is about 1,000 to 550 million years ago.

Pyroxenite and associated basic dikes were intruded after the main complex was formed. The volcanic aporhyolite also is younger than the schists and gneisses. It was formed by outpouring of acid molten rock on the earth's surface through volcanic action or by its solidification so close to the surface that rapid cooling prevented the formation of mineral grains that are individually distinguishable. In later times this rock was recrystallized under metamorphic pressures although still retaining its relatively fine texture. There is no definite evidence of the geologic age of the aporhyolite except that it is younger than the State Farm gneiss and older than the Petersburg granite, which is of Carboniferous age. The pegmatites which contain mica, feldspar, and rutile are believed to be associated with the pre-Cambrian granite, because, like it, they are crushed and granulated. Quartz veins, including those which are gold-bearing, appear to be genetically related to the pre-Cambrian granites, and to the final stage of their intrusion. This relation is not proved, however, and for the time their age must remain in doubt.

PALEOZOIC ERA

Sedimentary rocks of Paleozoic age (from about 550 to 185 million years ago) are not present in this county. During most of this era the Piedmont region is believed to have been a land mass undergoing long continued erosion of great mountain ranges formed in late pre-Cambrian time. Sediment derived from this area was carried into an inland sea on the west, which extended from New England at least to Alabama, until by the end of the era sediment tens of thousands of feet thick had been deposited. This major trough of Paleozoic accumulation is known as the Appalachian geosyncline. The accumulation, however, was not one continuous event but was interspersed with numerous elevations and depressions of the land which caused successive encroachments and retreats of the sea on different parts of the land.

During an epoch in the Ordovician period (from about 450 to 380 million years ago), as proved by fossil invertebrates, an embayment of the sea covered an area near Arvonia, Virginia, only a few miles west of Goochland County and many miles east of the main Paleozoic seas. Muds deposited in this part of the sea have now been transformed into the Arvonia slates, which are preserved from erosion because they were sharply downfolded into a deep, narrow syncline. The presence of these slates indicates the possibility that all of Goochland County may have been covered by the sea at one time or another during the Paleozoic era. No trace of any sediment that may have been deposited is now to be found.

The volcanic materials in the aporhyolite may have originated during igneous activity in this era. Much of the crushing and thrust faulting of the rocks occurred near the close of the Paleozoic era, during the great deformative movements that produced the ancestral Appalachian Mountains.

MESOZOIC ERA

During the succeeding Triassic period (from about 185 to 157 million years ago) streams flowing down the slopes of high mountains, formed to the west at the end of the Paleozoic era, and into shallow basins and onto floodplains, began to deposit boulders, sands, and muds. In local swampy basins vegetable matter accumulated in great abundance, slowly decayed, and eventully formed beds of coal. After the early swamp accumulations, the climate apparently became drier. The basins sank along nearly vertical faults and received only sands and some muds with local boulder deposits adjacent to the fault scarps. Many thousand feet of sediment accumulated in this way, but much of it has been since removed by denudation and carried to the sea. Certain shale beds, particularly those associated with the coal, contain many fossils, including several species of fish, molds of the small crustacean, *Estheria ovata,* Lea, and occasional vertebra of reptiles. In similar areas in northern Virginia footprints of these strange reptiles have been discovered.[36]

Molten rock was intruded in the Triassic sediments during the later part of that period. It solidified to form the diabase dikes. They are the youngest igneous rocks now found in the county.

Events in Goochland County later than the Triassic period are recorded mainly in the landscape and not in the rocks, because bedrock younger than the Triassic is either absent or represented only by gravels of uncertain age. Before Cretaceous time, which began about 125 million years ago, the region was reduced by erosion to a widespread and relatively flat plain, which covered nearly all of Piedmont Virginia. An important economic result of this deep and extensive erosion was the uncovering of the gold veins and other mineral deposits which had formed far below the surface. Subsequently, the eastern part of this plain was submerged by the sea so that it was covered with sediments far inland. It is not improbable that all of Goochland County was at one time covered with such younger sediments. On this old surface, according to some geologists, at the time it was covered by Coastal Plain sediments, the master streams of the region, including James River, were formed. In this way they account for the fact that James River has cut through such resistant formations as the quartzite at Bremo Bluff. In any case, the river must have been flowing on a surface that concealed the underlying resistant rocks. As it cut down to them, its channel being fixed, it was forced to cut also through the barriers of resistant rock.

CENOZOIC ERA

In the course of time, probably during the Tertiary period (60 to 2 million years ago), any or all the new sediments were eroded from the surface of the upper and middle Piedmont, and the land was again reduced to a relatively flat plain. At the end of this period of erosion James River was flowing in a broad flat valley at a level about even with the tops of the

[36] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 146-147, Pl. 31A, 1928.

present bluffs along its course. The sides of the old James Valley are preserved in the slopes of the interstream divides from the northern boundary of the county to the river. These slopes average about 10 feet in a mile. At a geologically recent date, probably during the Pleistocene (the last 2 million years), the old peneplain was again uplifted and the streams renewed their downcutting. James River entrenched its channel 150 to 200 feet below the old upland surface and has now closely approached temporary base level, established in many places by resistant beds of hard rock crossing the stream. It is now swinging back and forth in its alluvial flood plain and widening its valley by lateral cutting. Tributary streams are rapidly dissecting the old upland plain of which only a few flat remnants are still preserved. During the formation of this old upland surface, the deep cover of residual soil was developed by chemical decay and mechanical disintegration of the solid rock.

The humid climate during late Pleistocene time was favorable for the growth of extensive forests and forest vegetation. When white men first explored the region during the 1600's it was a vast expanse of thick forest cover over deep, mellow and exceedingly fertile soils. Birds, game, and fish were present in great profusion and variety. Streams ran clear. Quotations from the writings of Colonel William Byrd, one of the Virginia Commissioners who surveyed the boundary line between Virginia and North Carolina in 1728, probably applied fully to the primeval lower James River watershed although he was at the time describing principally the Roanoke and Dan River basins. Wrote Colonel Byrd:[37]

"The air is wholesome and the soil equal in fertility to any in the world. This charming valley will bring forth like the lands of Egypt, without being overflowed once a year. The grass in the river section grows as high as a man on horseback. The river . . . . always confined within its lofty banks and rolling down its waters as clear as crystal.

"The stream, which was perfectly clear, ran down about two knots, or two miles, an hour, when the water was at the lowest. The bottom was covered with a coarse gravel, spangled very thick with a shining substance, that almost dazzled the eye, and the sand upon either shore sparkled with the same splendid particles. At first sight, the sunbeams giving a yellow cast to these spangles made us fancy them to be gold dust, and consequently that all our

[37] Byrd, William, The Westover manuscripts containing the history of the dividing line betwixt Virginia and North Carolina, 1st ed., Petersburg, Va., Edmund and Julian C. Ruffin, 1841.

fortunes were made . . . . But we soon found ourselves mistaken and our gold dust dwindled into small flakes of isinglass. However, though this did not make the river so rich as we could wish, yet it made it exceedingly beautiful."

Throughout Byrd's "History of the Dividing Line" and "The Secret History," he continually refers to the richness of the soil and the purity of the streams in the areas drained by the James, Meherrin, Nottoway, Staunton, and Dan rivers with their tributaries. Such references as the following are numerous:

"The soil we past over this day was generally very good, being clothed with large trees, of poplar, hickory and oak. But another certain token of its fertility was, that wild angelica [Archangelica atropurpurea] grew plentifully upon it."

"In that place [the Roanoke River where the state line first crosses it on the east] the river is forty-nine poles wide, and rolls down a crystal stream of very sweet water, insomuch that when there comes to be a great monarch in this part of the world, he will cause all the water for his own table to be brought from the Roanoke . . . . "

"The high land we travelled over was very good, and the low grounds promised the greatest fertility of any I had ever seen."

"All the land we travelled over this day, and the day before, that is to say from the river Irwin to Sable creek, is exceedingly rich, both on the Virginia side of the line, and that of Carolina. Besides whole forests of canes, that adorn the banks of the river and creeks thereabouts, the fertility of the soil throws out such a quantity of winter grass, that horses and cattle might keep themselves in heart all of the cold season without the help of any fodder."

That is the portrait of the Piedmont province in its primeval state, a product of nature's generosity for a million years.

A vastly different landscape now meets the eye, even of the casual observer. So profound has been the effect of man's occupation and utilization of the land that it cannot be considered otherwise than a new event in the geologic history of the county. The clearing of forests, attendant upon man's appropriation of the land for agricultural use, has upset the equilibrium between the forces of denudation tending to reduce the land surface and the forces of protection inherent in the forest cover. Whereas under the primeval conditions denudation took place by exceedingly slow soil creep down the valley slopes to points where laterally cutting streams picked up material from their banks, today removal of vegetal cover has laid bare much of the landscape to

surface washing and direct soil removal in surface run-off. This new development has been termed "accelerated soil erosion."[38]

The streams of the county and James River no longer run clear, but are carrying greatly enlarged burdens of sediment toward the sea. Not all of the soil removed from the land, however, passes on to the ocean, for large amounts of it are deposited on the valley flood plains and on the lower slopes of fields. Upland soils are being depleted of their fertility by soil erosion, while rich bottom land and soils are often covered by sorted and less fertile erosional debris from the uplands, with consequent impairment of their productive capacity.

The result of accelerated soil erosion has been to speed up greatly the rate at which the Piedmont uplands are being reduced in mean elevation and the rate at which valleys are being filled with alluvium. Another and very important consequence of soil erosion is also apparent. The rate of run-off of surface water has on an average been greatly increased. This tends to cause floods, which have probably always occurred to some degree in the valley, to be more frequent, and more frequently higher. Run-off waters concentrate more rapidly and reach greater peaks of flow. Less water soaks into the ground and drought hazards in the drier years are correspondingly greater.

As a result of more than 200 years of cultivation in the county, most of its farm land has lost 25 to 75 per cent of the original topsoil, or A soil horizon, mainly through sheet erosion or the widespread development of small rills and bare spots from which water flows rapidly without concentration into larger channels. In addition gullies are numerous on some slopes (Pl. 4, B), particularly the more steeply sloping lands bordering James River. Although not developed to such magnitude as elsewhere in the Piedmont, in some places they are 10 feet deep, 20 feet wide and several hundred feet long. The U. S. Soil Conservation Service, on its reconnaissance erosion map of Virginia,[39] classifies almost 90 per cent of the county as area in which more than 25 per cent of the land has undergone moderate sheet erosion and occasional gullying. Almost 10 per cent of the county is shown as having undergone, in more than 25 per cent of the area outlined, severe sheet erosion and occasional gullying. Only relatively very small areas, such as the flood plain of James River and its main tributaries, have escaped widespread soil erosion.

[38] Lowdermilk, W. C., Acceleration of erosion above geologic norms: Am. Geophys. Union Trans., 15th Ann. Meeting, pt. 2, pp. 505-509, 1934.
[39] U. S. Dept. Agriculture, Soil Conservation Service: Reconnaissance erosion survey of the State of Virginia, 1934.

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GLOSSARY

Technical terms are here defined briefly in the sense in which they are used in this report. For more extended discussion the reader is referred to standard textbooks on geology.

Adamantine luster. The luster of oiled glass, exhibited by minerals of high index of refraction such as diamond.

Adit. A nearly horizontal passage from the surface by which a mine is entered. In the United States an adit is usually called a tunnel, though the latter, strictly speaking, passes entirely through a hill and is open at both ends.

Alluvium. Sand, mud, or other sediment deposited by the ordinary mechanical action of running water wherever the flow is checked, particularly on flood plains along rivers, as the rich alluvial lands of the Mississippi and the Nile, and in bars, spits, natural levees, alluvial fans and cones, and deltas.

Amalgamation. The process in which gold and silver are extracted from pulverized ores by producing an amalgam or alloy of these metals with mercury or quicksilver for which they have a great affinity. The mercury is later expelled by heating in a retort, and the precious metals are recovered.

Ankerite. A white, red, or grayish calcium-magnesium-iron carbonate.

Aporhyolite. An acid volcanic rock that has been devitrified or has had its glassy and very fine grained components recrystallized by metamorphism.

Asbestos. A white, gray or green-gray fibrous variety of chrysotile, or fibrous serpentine. Occurs in thin seams in serpentine. (Other types of asbestos occurring elsewhere are not found in Goochland County.) Used for fire-proof fabrics, wall boards, etc.

Base level. The level below which a land surface or a certain area of land can not be reduced by running water under existing conditions.

Bed rock. Solid rock. It underlies all loose surface materials. The kinds are igneous, sedimentary, and metamorphic.

Biotite. A magnesium-iron mica; the common black mica. Often compounded with many names of rocks that contain this mica; such as biotite gneiss, biotite granite, etc.

Bornite. A sulphide of copper and iron. Contains about 62 per cent copper. Called also "horseflesh ore."

Brecciated. Broken into angular fragments which have been cemented.

Calcite. A mineral composed of calcium carbonate. It is colorless to white, has perfect cleavage, and effervesces in acid.

Carbonate. A mineral consisting of a base, such as calcium or sodium, combined with carbonic acid.

Carboniferous. See Paleozoic.

Chalcopyrite. A mineral composed of copper-iron sulphide. Copper pyrites. Resembles pyrite but has a deeper yellow color and is much softer.

Chlorite. A green platy mineral with flexible but nonelastic lamellae. A silicate of aluminum, ferrous iron and magnesium.

Colloid. Solid matter consisting of particles so small that they remain suspended indefinitely in a medium such as water.

Colluvium. Deposited material, commonly containing a high percentage of unassorted erosional debris derived from steep slopes, cliffs, etc.

Covellite. A copper sulphide of indigo-blue color; very soft.

Cretaceous. See Mesozoic.

Cross-cut. A level or passageway driven at an angle to the vein or strike of the rock to connect other workings in a mine or to prospect for new veins.

Crystalline rock. A rock composed of minerals which have crystallized from the parent material. It commonly refers to igneous and metamorphic rocks.

Denudation. The washing down of surface deposits so as to lay bare underlying formations.

Diabase. A basic igneous rock commonly occurring in dikes or intrusive sheets, and composed essentially of plagioclase feldspar and augite. The plagioclase forms lath-shaped crystals lying in all directions among the dark irregular augite grains, giving rise to the peculiar diabasic or ophitic texture which is a distinctive feature.

Differentiation. The process, or processes, whereby cooling magma separates to form rocks of different types.

Dike. A long and relatively thin body of igneous rock, which, while in a molten state, has entered a fissure in older rocks and has there chilled and solidified.

Erosion. Wearing away of the lands by running water, glaciers, winds, and waves.

Facies. Variety; especially applied to an igneous rock that in some respects is a departure from the normal or typical rock of the mass to which it belongs. Thus a mass of granite may grade into porphyritic facies (containing scattered large crystals) near its borders.

Fall Zone. A zone (also referred to as the Fall Line) separating the crystalline rock formations of the Piedmont province from the less resistant sands, gravels, and marls of the Coastal Plain. In this zone falls and shoals are commonly developed on the rivers. The zone usually represents the upper limit of navigation on the rivers.

Fault. A fracture in rock along which there has been displacement.

Feldspar. A group of very common minerals in igneous and metamorphic rocks, containing alumina, silica, and potash or lime and soda. See orthoclase.

Ferruginous. Containing iron.

Flood plain. Part of a valley floor that is flooded. It is covered with alluvial deposits.

Foliation. The banding or lamination of metamorphic rocks produced by the orientation of platy or elongated minerals or the segregation of different minerals in parallel bands.

Footwall. The wall under a vein.

Formation. A unit of geologic mapping consisting of rocks of uniform character or rocks more or less uniformly varied in character.

Friable. Easy to break, or crumbling naturally.

Galena. A mineral composed of lead sulphide. It is black, heavy, and has perfect cubic cleavage. An important ore of lead.

Gangue. The nonmetalliferous or nonvaluable metalliferous minerals in the ore; veinstone or lode filling; the mineral associated with the ore in a vein.

Garnet. A reddish-brown, yellow or black vitreous to resinous mineral; a complex silicate containing iron, magnesium, and aluminum.

Gneiss. A banded crystalline metamorphic rock, having some cleavage.

Gouge. A layer of soft material along the wall of a vein or in a fault, produced by pulverizing of the rock during slippage.

Gradient. Rate of descent of a stream or a slope.

Granite. A granular crystalline igneous rock composed of quartz, feldspar, and other minerals.

Granodiorite. A rock similar to granite, in which plagioclase feldspar greatly exceeds orthoclase feldspar.

Graphite. A mineral composed of the element carbon. It is black, soft, and marks on paper.

Ground water. Underground water, which fills cavities in the rocks.

Hanging wall. The upper wall of an inclined vein.

Hornblende. A rock-forming mineral of complex silicate composition containing iron, alumina, magnesium, calcium, and alkali metals. It is dark green to black, glassy, and hard.

Hypothermal. Deep seated zone in the earth's crust, having high temperatures and pressures.

Igneous rocks. Rocks which have been formed by the cooling and hardening of molten rock materials.

Ilmenite. A mineral composed of iron and titanium oxides. It is iron-black and has a brownish-red to black streak. A source of titanium.

Intrusive. Igneous rocks which have solidified underground.

Kyanite. A gray to bluish silicate of aluminum occurring in flat blades in metamorphic rocks.

Lagged. Protection of shafts and drifts in a mine by planks, slabs, or timbers set behind the main timbers. Lagging does not carry the main weight of rock pressure on the opening, but only prevents fragments of rock from falling.

Lode. Strictly a fissure in the country-rock filled with mineral; usually applied to metalliferous lodes. In general miners' usage, a lode, vein, or ledge is a tabular deposit of valuable mineral between definite boundaries.

Magma. Molten rock materials in the earth's interior.

Mantle rock. Loose surficial material above bedrock, e. g., gravel, sand, and clay.

Marcasite. A mineral composed of iron sulphide; of paler color than pyrite; often called white iron pyrites.

Mesozoic. Next to the last great era (Cenozoic) of recorded geologic time. Follows the Paleozoic era. Includes the Triassic, Jurassic, and Cretaceous periods. The time of the development of the great reptiles and of the first hardwood forests.

Metamorphism. The processes of great alteration of rocks, as by pressure and heat, generally deep in the earth, whereby the resultant rock is unlike the parent rock.

Mica. A hydrous aluminum silicate containing potash, and often magnesium and iron, having a very fine basal cleavage that renders it capable of being split into thin, tough, transparent plates. The name of the mineral is often compounded with the name of the rock containing it, as mica schist, mica gneiss, etc. Called also isinglass.

Muscovite. Potash-bearing white mica. The most valuable type of mica.

Mylonite. Rocks which have been completely pulverized or granulated internally by extreme differential movements during metamorphism.

Ordovician. See Paleozoic.

Ore. Metallic mineral mined for its mineral content.

Orthoclase. A variety of feldspar containing potash, alumina, and silica; is white, gray, or pink; has glassy luster, and scratches glass.

Outcrop. Rock at the earth's surface not covered by any other formation, although often masked by its own residium or weathered product.

Paleozoic. The third great era of recorded geologic time. The time of great development of invertebrates, fish, and fernlike plants. The era is subdivided commonly into seven periods: Cambrian (oldest), Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian. The Mississippian and Pennsylvanian are often referred to collectively as the Carboniferous.

Pegmatite. A very coarse-grained dikelike igneous rock, similar to granite.

Peneplain. An almost flat surface of great extent which has been formed at, or near, base level by erosion by running water. The almost finished product of an erosion cycle.

Peridotite. A granular igneous rock composed essentially of olivine, generally with some form of pyroxene, and with or without hornblende, biotite, chromite, garnet, etc.

Physiography. The description and interpretation of the surface features of the earth.

Placer. A place where gold is obtained by washing; an alluvial deposit, as of sand or gravel, containing particles of gold or other valuable mineral.

Plagioclase. A variety of feldspar containing soda, lime, alumina, and silica; commonly white or gray, has glassy luster and scratches glass.

Pleistocene. The geologic time, or epoch, just before Recent time; the glacial epoch, during which ice sheets covered Canada and the northern United States.

Pliocene. The last epoch of the Tertiary period.

Pre-Cambrian. All recorded geologic time before the beginning of the Paleozoic era, i. e., before the Cambrian period.

Pyrite. A mineral composed of iron sulphide; "fool's gold;" brassy-yellow color; hard (scratches glass).

Pyromorphite. A resinous green mineral occurring in slender six-sided prisms; a chlorophosphate of lead.

Pyroxenite. A dark-green granular igneous rock, consisting essentially of pyroxene, with or without hornblende, spinel, and iron oxides, and with little or no feldspar or olivine.

Pyrrhotite. A mineral composed of iron sulphide; magnetic pyrites, brownish bronze color; black streak.

Quartz. A very common mineral composed of silica (SiO_2); colorless to white; very hard (scratches glass).

Quartzite. A metamorphosed sandstone. The grains of quartz sand have been firmly cemented by silica which has recrystallized around them.

Raise. A mine shaft driven from below upward.

Regolith. The layer or mantle of loose, incoherent rock material, of whatever origin, that nearly everywhere forms the surface of the land and rests on the "bedrock."

Relief. Difference in elevation in an area. Irregularities of the surface.

Replacement deposit. A deposit in which certain minerals have passed into solution and have been carried away, while other minerals from the solution have been deposited in the place of those removed.

Residual soil. Soil produced by decay of the underlying rock.

Resistant rocks. Rocks which disintegrate slowly under the attacks of erosive agents, such as streams. In this area they are chiefly quartzites, well-cemented sandstones, and crystalline rocks.

Retrogression. A process of change in metamorphic rocks whereby features characteristic of deep-seated metamorphism are changed to features of shallow zone metamorphism as the rocks are brought closer to the surface and subjected to near-surface stresses.

Rutile. A mineral composed of titanium dioxide; red or red-brown to black; hard (scratches glass). A source of titanium.

Sandstone. A sedimentary rock composed of cemented grains of sand, which is commonly quartz.

Schist. A foliated crystalline metamorphic rock which has distinct cleavage.

Second-foot. A flow of one cubic foot of water in one second; about 646,000 gallons per day.

Sedimentary rocks. Rocks which are in beds and are composed of (1) particles of other rocks, (2) organic remains, or (3) materials deposited from solution in water. Most fossils are found in them.

Sericite. A talclike hydrous mica (a variety of muscovite) occurring in small scales. It forms sericitic schist which is often spoken of by prospectors as talcose schist, but this latter term properly applies to schists composed largely of talc, which are much rarer.

Shale. A sedimentary rock composed of particles of clay and mud pressed and cemented together.

Silicification. Impregnation or replacement by silica (SiO_2).

Sillimanite. A vitreous brown or gray very tough mineral occurring in long slender crystals or fibrous masses; an aluminum silicate.

Slate. Metamorphosed shale. It is characterized by well-developed cleavage.

Slickensides. Smoothed and polished surfaces of fault blocks.

Soapstone. A metamorphic rock of massive schistose, or interlocking fibrous texture and soft unctuous feel, composed essentially of talc.

Sphalerite. A mineral composed of zinc sulphide; commonly yellow or brown to black; resinous luster. An ore of zinc.

Stamp mill. An apparatus (also the building containing the apparatus) in which rock is crushed by descending pestles (stamps) in a mortar box operated by water or steam power. Amalgamation is usually combined with the crushing when gold or silver is the metal sought, but copper and tin ores, etc., are stamped to prepare them for smelting.

Stope out. To excavate ore in a vein by driving horizontally upon it a series of workings, one immediately over the other, or vice versa.

Stresses. Forces exerted on rock masses in the earth.

Strike. A horizontal line on a bed of rock; the trend of a body of rock or a fold.

Stringer lode. A shattered zone containing a network of small nonpersistent veins.

Sulphide. A binary compound of sulphur and a metal.

Terrace. A benchlike flat above a stream; part of a former valley floor.

Tertiary. The first period of the Cenozoic era; just prior to Quaternary time.

Tetradymite. A pale steel-gray metallic mineral composed of bismuth, tellurium, and sulphur.

Titanium. A metallic element found in nature only in combined form, and isolated as an infusible iron-gray crystalline powder.

Topography. The surface form, or shape, of the land.

Tourmaline. A complex aluminum silicate containing iron and boron; commonly black and occurs in long striated prisms in metamorphic rocks and associated veins.

Triassic. See Mesozoic.

Unconformity. The contact of two formations which shows uplift and erosion before the upper formation was deposited.

Vanadanite. A deep-red, resinous lead vanadate, often occurring in sharp prismatic crystals.

Vein. An occurrence of ore, commonly disseminated through a gangue, or veinstone, and having a more or less regular development in length, width, and depth. A vein and a lode are, in common usage, essentially the same thing.

Wall rock. The rock forming the walls of a vein or lode; the country rock.

Water table. The upper surface of the zone saturated with ground water.

Weak rocks. Rocks which offer slight resistance to erosion, e. g., shale.

Weathering. The slow action of geologic agents at or near the surface, whereby rocks decay and disintegrate.

Whim. A large capstan or vertical drum turned by horse power or steam power, for raising coal, ore, water, etc., from a mine.

INDEX

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