MARYLAND

GEOLOGICAL SURVEY

VOLUME TWELVE

JOHNS HOPKINS PRESS
1928

MARYLAND GEOLOGICAL SURVEY

VOLUME TWELVE

CONTENTS

CONTENTS

ILLUSTRATIONS

PREFACE

The present volume is the twelfth in the series of General Reports issued by the Survey at irregular intervals which contain shorter papers and reports of more general interest. The monographic treatises on the major geological divisions are issued as a second series of Systematic Reports; while the more detailed reports, chiefly of local interest, are issued as a series of County Reports.

The papers of the present volume represent the results of studies made at different times, some of them years ago, which have been available for consultation in the office but are now presented in permanent form for more general use.

Part I. *The Molding Sands of Maryland*, by David W. Trainer, Jr., is one of a series of studies conducted in coöperation with various agencies to determine the national resources in this commodity so essential to many industries. The report gives the properties of actual or supposed molding sands from many localities in southern Maryland and shows that the State possesses deposits which may lead to the development of a molding-sand industry. The author shows that the most favorable occurrences are near the base of the Sunderland terrace and suggests a reason for their formation at this location.

Part II. *Notes on Feldspar, Quartz, Chrome, and Manganese in Maryland*, by Joseph T. Singewald, Jr., are a series of short papers on the materials named. Most of the deposits are small and situated in the crystalline rocks of northern Maryland. The author has described many of these small quarries or temporary openings and discussed the annual production during the last ten years. Although the values are not large the State has been a steady contributor of *feldspar* and *flint* for many years.

The annual production of *chrome* in Maryland at the present time seldom exceeds 100 long tons but a century ago the State was one of the chief producers in the world and the discovery of chromite by

Isaac Tyson Jr. was the cause of establishing one of the best known industries in Maryland—the Chrome Works—which is still active in refining foreign ores. The uses and demands for chrome are constantly increasing but Maryland deposits cannot compete successfully with the larger and richer deposits elsewhere.

Manganese has been found at several points in the State but attempts to develop these deposits have so far been unsuccessful. The work done, while giving no indications of large deposits, was not sufficient to demonstrate that such bodies did not exist.

Part III. *The Serpentines of Harford County, Maryland*, by Albert Johannsen represents work done by the author many years ago when he prepared the manuscript for the present publication. Terminologies and viewpoints in the subject have changed somewhat since this report was written and papers written today would lay somewhat different emphasis on the points discussed. The facts given in the report have been available for the use of the Survey for years and the field studies of the author have been used extensively in previous publications of the Survey.

Part IV. *The Gabbros and Associated Intrusive Rocks of Harford County*, by Herbert Insley is a second manuscript based on field work done some years ago during the survey of Harford County. The author presents the results of a scientific investigation of one of the more extensive rock formations of the county which is never likely to be of greater commercial importance than for road metal and railroad ballast. Large quarries have been opened along the Susquehanna and thousands of tons of these rocks are being used in the manner indicated.

PART I

THE MOLDING SANDS OF MARYLAND

BY
DAVID W. TRAINER, JR.

THE MOLDING SANDS OF MARYLAND

INTRODUCTION

Purpose of the Investigation

This investigation was undertaken by the State Geological Survey to ascertain what the possibilities were of finding molding sand deposits in the coastal plain formations in Anne Arundel, Calvert, Charles, Prince George's, and St. Mary's Counties. At the time the field work for the investigation was started, there was only one firm operating in this area. This company was not producing at that time, but was carrying on a prospecting campaign under its own auspices.

Field Work

Molding sands in general will not stand the cost of long hauls to shipping points, especially if the roads are not particularly good. In planning the field work, this point was kept in mind and special attention was given to those areas where the transportation facilities by rail, wagon, or water were good, and in addition, to those that might get good transportation in the not distant future.

Transportation Facilities

It is a well known fact that any natural resource located too remote from transportation facilities is practically worthless. This is very true of molding sand deposits. In general, no molding sand deposit will bear the cost of construction of a spur track more than 400 or 500 feet long.

There are two main types of transportation facilities in this section of Maryland, viz., the railroads, and the water ways. The former is without doubt the most important and can be a great aid in developing some of the deposits found.

Anne Arundel County has probably the best railroad facilities of any of the counties studied. The main lines of the Pennsylvania, Baltimore and Ohio, and the Washington, Baltimore and Annapolis railroads cross the northwestern part of this county. None of these lines will probably ever haul much sand for foundry purposes. The Baltimore and Annapolis Short Line Railroad traverses a section along the east side of the Severn River, which promises to produce some molding sand. The Annapolis, Washington and Baltimore Railroad also crosses a promising territory between Academy Junction and Annapolis. The Chesapeake Beach Railroad crosses this county in the southern part and may be a carrier from small spotted deposits in this section.

Prince George's County has the next best transportation facilities. The Pennsylvania, Baltimore and Ohio, and the Washington, Baltimore and Annapolis Railroads, all cross the northwestern part of the county. The Chesapeake Beach Railroad crosses this section in a southerly direction from Washington. The Pope's Creek Branch of the Pennsylvania Railroad, which leaves the main line at Bowie, serves the eastern and southern half of the county, and continues on southward through Charles County to Pope's Creek on the Potomac River. The Washington, Seaboard, and Norfolk Railroad which branches from the Pope's Creek Branch at Brandywine, continues south into Charles County, terminating at Mechanicsville in St. Mary's County. This is the only regular railroad transportation in St. Mary's County, and it is of only little importance, because it goes through the most northern tip of the county.

The northern section of Calvert County is served by the Chesapeake Beach Railroad. It traverses a section which will probably be a small molding sand producer, unless land values rise due to the demand in this section for property for summer cottages.

At present, water transportation can hardly be considered, because it consists of a weekly steamer plying between Baltimore and Washington. which is not capable of carrying any bulk freight unless shipped in barrels. This boat stops at all the wharfs on the Chesapeake Bay, the Patuxent River as far up as Lower Marlboro in Calvert County, and the Potomac as far up as Washington. The writer has been informed that it would be impossible at all times of the year to place a barge on the shores of Chesapeake Bay without proper breakwater facilities which would cost more to construct than any sand deposit could possibly warrant. This is because of the rather general heavy winds which blow on this shore with little warning. The cost of having a tug stand by for emergencies to pull a barge to sea in time of storm is also prohibitive. Thus, it seems that this type of transportation, at least on the shores of Chesapeake Bay in Calvert and St. Mary's counties, will have to be excluded. Barges or scows could be loaded with ease along the Patuxent or Potomac Rivers and hauled to Baltimore or Washington for shipment.

In conclusion it may be said that the problem of making this section of Maryland a producer of molding sand lies in the fact that the transportation facilities hinder the development of possibly good producing areas. This is true with the exception of the two northernmost counties of the group.

Laboratory Work

All the samples collected were shipped to Cornell University, where they were tested in accordance with a cooperative agreement between the State Geological Survey and the American Foundrymen's Association, as a result of which the latter organization is having studied all the samples collected by the various state surveys. The tests for permeability, fineness, and bond strength were carried out in accordance with the standard methods adopted by the American Foundrymen's Association. In addition, compression and tensile tests, as well as refractoriness tests were also made. Through the courtesy of Mr. W. M. Saunders, of Providence, R. I., dye adsorption tests have also been made on the samples.

REQUISITE PROPERTIES OF MOLDING SANDS

General Statement

The properties to be considered in sands used for foundry work are texture, permeability, bond strength, refractoriness, and life. Chemical composition is of value only in special cases, such as steel sands. The mineral composition may be considered in connection with the refractoriness of the sand.

TEXTURE

The texture of the sand is determined by the fineness test prescribed by the American Foundrymen's Association. The details of this test may be found in a publication of the Joint Committee on Molding Sand Research of the American Foundrymen's Association.[1] The test consists of determining the clay substance in the sand by decantation after the clay has been suspended by shaking with water to which 25 cubic centimeters of sodium hydroxide solution (made by adding 10 grams of sodium hydroxide to 1000 cubic centimeters of water) are added. The grains are screened dry and the quantity retained on sieves with the following number of meshes to the inch: 6, 12, 20, 40, 40, 70, 100, 140, 200, 270, and pan, is determined.

METHODS OF EXPRESSING FINENESS

Many methods for expressing the fineness of sands and screened products have been suggested and their merits discussed. Probably the most widely known of these is the Scranton method. A very complete discussion of these different methods has been made by C. M. Nevin.[2]

A figure has been recently worked out by the author for grading molding sands, and it will be found accompanying the fineness test of the different samples. This figure is determined by taking the sum of the numbers obtained by dividing the percentage weight of the material retained on each screen by the number of meshes to the inch in the screen, the figure 410 being used for the material retained in the Pan. The clay substance is not taken into account.

[1] American Foundrymen's Association, Tentatively Adopted Methods of Tests and Résumé of Activities of the Joint Committee on Molding Sand Research, June, 1924, pp. 54–57. New edition to appear in May, 1928.

[2] Nevin, C. M., Albany Molding Sands of the Hudson Valley, New York State Museum, Bull. 263, 1925. pp. 31–49.

Example:

FINENESS TEST

On	6	—				
	12	—				
	20	—				
	40	7.24	÷	40	=	.181
	70	36.46	÷	70	=	.521
	100	19.70	÷	100	=	.197
	140	4.96	÷	140	=	.035
	200	2.70	÷	200	=	.014
	270	2.94	÷	270	=	.011
Thru 270		6.10	÷	410	=	.015
Clay Sub.		20.08				
Total		100.18				.974 = Coarseness figure

The following figures are given as the limits for each grade of sand. The grade numbers used correspond to those in use in the Albany and other well known producing districts. This figure is termed a coarseness figure, because it increases as the sands increase in coarseness.

Grade 00	.325
0	.45
1	.65
1½	.825
2	1.05
3	[illegible].7
4	2.7
5	4.15

Recently the sub-committee on grading of the committee on Molding Sand Research of the American Foundrymen's Association, has tentatatively adopted a figure which is to be known as the "grain class." This figure represents the fineness of the grain of the sand minus the clay substance.

The "grain class" is obtained in the following manner: the percentage weights obtained from the fineness test, the clay substance being neglected, are multiplied by numbers which are termed "fineness factors." The sum of the numbers obtained by the multiplications is divided by the sum of the percentage weights, the clay substance being neglected. This result is known as the "grain fineness" and represents approximately the average screen size of the particles.

The fineness factors for the several different screens is listed below:

Screen No.	Fineness Factor
6	3
12	5
20	10
40	20
70	40
100	70
140	100
200	140
270	200
Pan	300

The limits for the "grain fineness" for each "grain class" is given below:

Grain Class	Grain Fineness
1	200 up
2	140–199
3	100–139
4	70–99
5	50–69
6	40–49
7	30–39
8	20–29
9	15–19
10	10–14

This method is probably best illustrated by an example:

SCREEN ANALYSIS

Percentage	Fineness Factor			
on 40	0.26	×	20	5.8
70	6.66	×	40	266.4
100	28.48	×	70	1993.6
140	19.28	×	100	1928.0
200	11.92	×	140	1668.8
270	12.08	×	200	2416.0
Pam	12.80	×	300	3840.0
	91.48			12118.6

$$\frac{12118.6}{91.48} = 132 = \text{Grain Fineness} = \text{No. 4 Grain class.}$$

It must be kept in mind that the grain class describes a sand only so far as grain fineness is concerned and carries no information regarding clay content and other characteristics. Complete grading will involve other classifications. Hence, the numbers 1, 2, 3, etc., denote the grain class and not the complete grade.

This committee has also suggested a classification of the clay content of molding sands. The grading or class letter used for this classification is known as, "Clay Class." A sand is considered in the clay class in which its percentage of clay substance falls according to the clay content zones.

CLAY CONTENT CLASSIFICATION

Clay Class	Clay Content Zones		
	Percent		*Percent*
A		Less than	.5
B	.5	to less than	2.0
C	2.0	" " "	5.0
D	5.0	" " "	10.0
E	10.0	" " "	15.0
F	15.0	" " "	20.0
G	20.0	" " "	30.0
H	30.0	" " "	45.0
I	45.0	" " "	60.0
J	60.0	" " "	100.0

FINENESS TEST

All the sands which were collected for this investigation have been subjected to the fineness test which was described briefly above. The coarseness figure for each sand has been computed in order to make a clearer comparison with sands from other states, and also to establish a grade for the sands collected. The data for the fineness test, the computed coarseness figure, and the corresponding Albany grade number; the grain fineness, grain class and clay class are included in the discussion of the deposits in Chapter IV.

The sands which have less than 5% of clay substance as determined by the fineness test, may be considered for two types of work—the finer ones for core work, and the coarser for steel casting. Sands of higher clay content, 15%–25%, which are coarse in texture, are usually used for heavy castings, while those of finer texture are used for light ferrous and non-ferrous castings.

PERMEABILITY

GENERAL STATEMENT

The terms permeability and porosity as applied to foundry sands, must in no way be confused. Permeability is the physical property of sand or any other material similarly arranged, which permits the passage of gasses; while porosity, on the other hand, is the actual percentage of the pore space present in the sand. Quite frequently a foundryman speaks of a sand as "tight" or "closed," and "open." These terms refer to the permeability of the sand—the "tight" or "closed" sands having a low permeability, while the "open" sands have a high permeability figure as determined by the American Foundrymen's Association test.

The permeability of a sand depends on several factors: (1) the coarseness of the grains and their arrangement, (2) the amount of bonding material present and its nature, (3) the water content of the sand or its temper, and (4) the density of packing.

STANDARD PERMEABILITY TEST

The Maryland sands were tested for permeability by the standard method of the American Foundrymen's Association. This test consists of measuring the flow of air through a standard specimen of sand whose water content is known and which has been rammed or tamped to a certain density. The sands are tested at several water contents in order to determine optimum (best) water content at which the maximum permeability is developed. Core sands are tested dry, because in this condition they would have a permeability as near to that at which they are used as any other. Steel sands are usually tested in the wet and dry condition. This probably is the best practice.

The permeability figures and the different water contents for which they were determined are given in the discussion of the individual sand deposits in Chapter IV.

BOND STRENGTH

GENERAL STATEMENT

Little is known at the present time of the actual chemical and physical nature of the bonding material in molding sands. It is considered to consist of two types known as (1) mobile, and (2) static, bond. The mobile bond is supposed by some investigators to be composed of actual clay substance and is probably of a colloidal or semi-colloidal nature. This type of bond is of such a nature that it can be readily washed off the grains, while static bond is not removed from the grains with ordinary washing. The clay content of the molding sands as determined by the American Foundrymen's Association fineness test is in general an indication of the amount of bonding material present.

BOND OR COHESIVENESS TEST

All samples collected for this investigation have been given the bond strength test at different water contents in order to determine the percentage of water at which the maximum bonding strength is developed. This test is made by molding a sand whose water content is known into a bar 16¾ inches long, 1 inch high, and 2 inches in width, which is pulled forward over an overhang at the rate of six inches per minute. The bar is allowed to break at the overhang and the weight of the breaks is a measure of the bonding strength of the sand. The stresses which are measured in this test are quite complex and are usually expressed in grams per break. A variation of 10% from the average weight of the breaks is allowed. These results may be expressed in pounds per square inch units by converting the results by means of the following formula: $P = .0000565 \times w^2$, in which w equals the weight of the break in grams and P the stresses in pounds per square inch. The test data will be found with the discussion of the sand deposits in Chapter IV.

COMPRESSION TEST

The strength of molding sands is sometimes tested by means of a compression test, the results being expressed in pounds per square inch.

This test as tentatively adopted by the American Foundrymen's Association measures one of the simplest stresses and one to which the green sand mold is frequently subjected. The sample used for this test is the same size and shape as the one used for the permeability determination. The machine on which these tests were made for this investigation is one designed by Mr. T. C. Adams and built at the shops of the College of Mechanical Engineering at Cornell University. The results are read directly from the machine in pounds per square inch units. This machine is not a standardized machine and others are being used. The data for this test is given with the other bond test data in Chapter IV.

TENSILE TEST

The strength of molding sands is determined by some with the aid of a tensile strength test. The tests of the samples collected for this investigation were made on a simple device developed in the laboratory. A cylinder similar in dimensions to the permeability cylinder was cut in half at the midpoint of the two inch sand sample. The two parts of the cylinder are clamped together and the sand rammed in as is done for the permeability test. The cylinder is then arranged so that it can be broken and the breaking force measured. The results are usually calculated to pounds per square inch units. This test was performed on the Maryland sands, the results calculated and the data are given with the other bond test data in Chapter IV. Since this report went to press the American Foundrymen's Association has recommended that the tensile strength be expressed in ounces instead of pounds per square inch.

DYE ADSORPTION TEST

The author is indebted to Mr. W. M. Saunders, of Providence, R. I., for running the dye adsorption test recommended by the American Foundrymen's Association on the samples of Maryland sand. There is some discussion in regard to the value of this test at the present time. The dye used for adsorption is an acid one (crystal violet). This material would be adsorbed principally by basic colloids. The exact nature of clay in the sands is not known, consequently the adsorption figure obtained does not give a clear idea of the total clay substance, as it was originally intended. The dye adsorption figures, however, will indicate the general amount of fine material, clay as well as fine silt, in the sand and may be used in selecting core sands. A core sand with a high dye adsorption figure should be avoided because it will probably give trouble by using an excess of oil in mixing. This figure for each sample will be found with the other test data.

MINERALOGICAL ANALYSIS

Mineralogical analyses were not made on the Maryland sands, but it seems wise to make a brief note in regard to the importance of the minerals in the sands in studying their refractoriness. The mineral quartz fuses at about 1700°C. and is the most refractory of the common-occurring minerals. Glauconite, an iron silicate mineral which gives the greenish tint to some of the sands collected, or a clump of easily fusible minerals in a sand might cause local fusion and consequent pitting of the casting. From this it may be inferred that the fusion temperature of sands where grains are primarily quartz will depend on the refractoriness of the clay substance present. This subject is one which is under investigation at present, and no further conclusions can be made at this time.

CHEMICAL ANALYSIS

A complete chemical analysis of molding sand has proved of little value in determining the behavior of the material in service. Accompanied by the mineralogical analysis of the grains, the chemical analysis may be of some worth in judging the refractoriness of the sand. An analysis of the clay substance in the sand will give an excellent idea of the refractoriness of the sand as a whole, when it is known how much of this material there is in the sand.

LIFE TEST

The life of molding sand, or better, the length of time it can be used without the addition of new sand or bonding medium of some kind depends on the ability of the colloids in the bonding medium to rehydrate after dehydration caused by the clay coming in contact with the hot metal.

This subject has been investigated by H. W. Dietert.[3] His method simply stated, is to heat a sample of sand in a furnace to 600 degrees Fahr. for a period of two hours and express the resulting loss in strength by the percentage of the original green strength.

Further work has been done and a tentative test for this property has been worked up by C. M. Nevin.[4]

REFRACTORINESS

The term refractoriness as applied to molding sands may refer to two distinct properties, one that of the softening temperature and the other the temperature at which the sand fuses completely. Since the grains of most sands are silicious, the refractoriness is governed largely by the amount and nature of the bond clay present. A standard method for determining refractoriness has not yet been devised, although the subject is under investigation.

GENERAL GEOLOGY OF MOLDING SAND DEPOSITS

GENERAL STATEMENT

For convenience a brief summary of the character of the material found in the Coastal Plain formations of this area will be given. The Coastal Plain sediments, which are principally unconsolidated sands, clays, and gravels, range from Cretaceous to Pleistocene in age and rest unconformably in crystalline rocks of pre-Cretaceous age. The western margin of the Coastal Plain formations runs approximately through Baltimore and Washington, and the sediments to the east and south of this line are the only possible source of molding sand in the State.

[3] Dietert, H. W., Commercial Application of Molding Sand Testing. Trans. Amer. Found. Assn., Vol. XXXII, 1925, Pt. ii, pp. 24–52.

[4] Nevin, C. M., The Life of Molding Sands; Trans. Amer. Foundrymen's Assn., 1925.

CRETACEOUS

The formations of this age rest unconformably on the pre-Cretaceous rocks. They are ordinarily divided into two groups, those of the Upper Cretaceous, which includes the following formations:

Monmouth—Glauconite sand	40 ft.
Matawan—Dark clay and glauconite sand	60 ft.
Magothy—Light sand and dark laminated clay	40 ft.
Raritan—Clay and more or less indurated sand	80 ft.

Below these are found the Lower Cretaceous formations which are generally known as the Potomac Group. This group includes the following formations:

Patapsco—Variegated clay and sand	120 ft.
Arundel—Drab clay with lignite and iron carbonate nodules	130 ft.
Patuxent—Light colored arkosic, bedded sands with clay lenses	250 ft.

The formations of Cretaceous age are exposed in parallel belts across the southern half of Anne Arundel County and the northwestern part of Prince George's County.

In general the formations of this age cannot be considered as producers of molding sands because they are composed principally of sands and white clays with horizens of iron carbonate nodules. There are, however certain exceptions. The Patapsco formation is dug in many places for building sand, while the Raritan formation, which is composed of clean white silica sand with some white clay near its base has been excavated in places in Anne Arundel County for glass sand. It was sampled in several places during this investigation as a possible source of steel and core sand.

EOCENE

The rocks of this age are divided into two formations, the Aquia, which overlies the Cretaceous beds and which is in turn overlain by the Nanjemoy formation.

These rocks are exposed in a rather wide belt south and east of the rocks of the Cretaceous age. They are well exposed in the sections northwest of Annapolis on both sides of the Severn River, in Anne Arundel County and in the northwestern part of Prince George's County.

The Aquia, which is about 100 feet thick, is composed principally of glauconitic sand. This formation is overlain by the Nanjemoy, which is about 60 feet thick and consists of glauconitic sands which are highly argillaceous and in places calcareous.

The Aquia was very carefully investigated and found to contain large deposits which might serve as possible sources of molding sand. This formation, as well as the Nanjemoy, seems to contain the exact mixture of sand and clay material to give a well-bonded sand. The clay in these deposits has possibly originated in two ways: the first, which undoubtedly is the most important, by the weathering of the glauconitic material during and since deposition, and second, the deposition of clay with the sand grains at the time the material was deposited.

MIOCENE

The rocks of this age have been divided into three formations, as follows:

St. Mary's—Sand, marl and clay	150 ft.
Choptank—Sand, marl and clay	125 ft.
Calvert—Clay, marl and diatomaceous earth	200 ft.

These beds are exposed in the southeastern part of Anne Arundel County, along Chesapeake Bay in Calvert County, along the Patuxent River in Anne Arundel, Prince George's, Calvert, St. Mary's and Charles Counties, and along the Potomac River in St. Mary's, Charles, and Prince George's Counties.

These formations are composed principally of sand, clay, marl and diatomaceous earth, and where they were studied gave little promise of producing a material which could be used in the foundry industry.

Pliocene

Unconformably above the formations just described, lies the Bryn Mawr formation, the only beds referred to this age in the State.

Very extensive areas of this material are found covering parts of Prince George's County, extending from Washington southeast into Charles County, and in the vicinity of Charlotte Hall. This formation will never be a producer of molding sand because it is too poorly sorted and is composed principally of a fine, silty clay at the surface along the principal transportation routes of Prince George's and Charles Counties, as well as in other places.

Pleistocene

The deposits of this age are usually spoken of as terraces and have been divided into three distinct formations according to their relative elevation above sea level. The highest and oldest is known as the Sunderland, the intermediate one the Wicomico, and the youngest and lowest the Talbot.

The oldest of these, the Sunderland, reaches an elevation of 200–225 feet around Baltimore and Washington, and slopes southeasterly to an elevation of between 50 and 100 feet at the southern end of St. Mary's County. The next youngest terrace, the Wicomico, reaches an elevation of 100 feet and slightly less around Baltimore and Washington and slopes southeasterly to an elevation of less than 50 feet at the southern end of St. Mary's County. The youngest, the Talbot, seems to have rather a constant elevation of about 45 feet in the areas north of Drum Point on Chesapeake Bay and Maryland Point on the Potomac River, but south of these it slopes rather rapidly to an elevation of about 10 feet at the southern tip of St. Mary's County. These deposits are very extensively distributed over the area investigated, especially in the sections along the main bodies of water, such as Chesapeake Bay, the Potomac River and Patuxent River.

The nature of the material contained in these terraces would indicate that they were deposited under rather unstable conditions, both from the point of material supplied and from the condition of the body of water in which they were laid down. These facts have a bearing on the possibilities of their being molding sand producing formations. The Sunderland, in the northern part of the area, just south of Baltimore, is principally gravel and contains an occasional boulder. This seems to indicate a very near-shore phase of deposition. As this deposit is followed south into the southern part of Anne Arundel County and the northern part of Calvert County, the unstable conditions seem to exist, but the type of material being deposited seems to be somewhat finer, and in places deposits of molding sand have been noted. Any production from this formation in this area, however, will without doubt be irregular and spotted.

The Wicomico, in general, resembles the Sunderland in origin except that the material supplied at this stage seems much finer. Of the three Pleistocene terraces, this one promises to be the most important

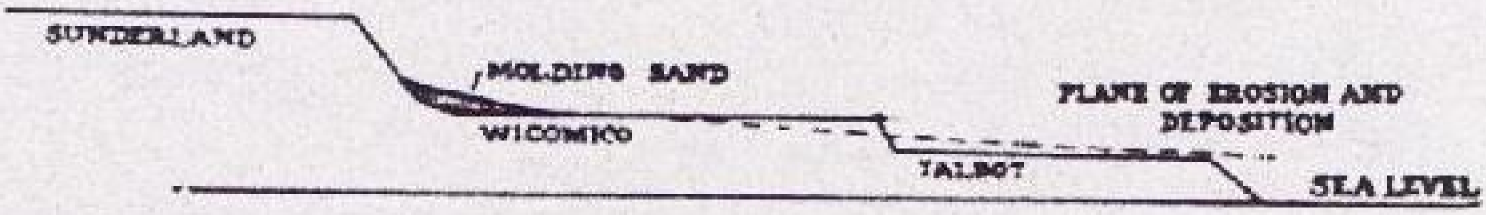


FIG. 1.—Profile of Pleistocene terraces showing deposition of molding sand at the inner margin of the Wicomico terrace

as a producer of sand. It is now being worked in one locality in Prince George County and has been prospected in many others.

An interesting relation was noted to exist between the older Sunderland terrace and the Wicomico. This relation, briefly stated, is this: molding sand seems to have formed at the junction of the two terraces, see Figure 1.

This may be accounted for in the following manner: The Sunderland terrace developed and the sea withdrew or the land rose establishing a new plane of erosion and deposition at the level of the Wicomico terrace. After this level was well established, the sea again withdrew at what appears to have been a somewhat slower rate. During the time of the withdrawal of the sea to the Talbot level, the waves and currents had an opportunity to rework the material in the Wicomico terrace and deposit the finer parts of it far back at the base of the Sunderland terrace at its junction with the Wicomico. The last part of this process is diagramatically shown in Figure 1. This explanation seems to account best for the deposits which have this geological occurrence.

The Talbot, which is the youngest and lowest of the Pleistocene terraces was examined as a source of molding sand, but with no success. This terrace is very gravelly and the sand is mostly sharp sand, poorly sorted, and worthless as a foundry material.

OCCURRENCE AND PROPERTIES OF MOLDING SAND DEPOSITS

INTRODUCTION

The accounts of the molding sand deposits of the state are arranged according to counties and geological formations. The descriptions include the following points: (a) location, geographic and situation with respect to transportation; (b) the geological formation in which the sand occurs, and the extent of the individual deposit; (c) collection of the samples; (d) owner of the property when determined; (e) use if being worked; and (f) test data.

ANNE ARUNDEL COUNTY

CRETACEOUS

MATAWAN FORMATION.—What appears to be a good deposit of molding sand was found outcropping on the Annapolis road one-quarter mile south of Boon Station. Here the road and tracks of the Baltimore and Annapolis Short Line Railroad run parallel to each other for some distance, never being more than one-eighth of a mile apart. The deposit where sampled showed the following section:

Fine sand and gravel	2 feet
Red to brown clayey sand	4 feet exposed

This same type of sand is exposed for about two miles southeast along the road from the point where it was sampled. The upper part of the section is slightly consolidated but a mixture of the whole gives a sand with an excellent feel.

MOLDING SAND, ½ MILE SOUTH OF BOON STATION

Sample No. 1505 was collected from a road side pit which was opened for road patching material.

The sand gives the following results on test:

FINENESS TEST

On	6	—
	12	—
	20	Tr.
	40	5.50
	70	19.84
	100	31.30
	140	10.84
	200	4.40
	270	4.24
Thru 270		5.84
Clay Sub.		17.86
Total		99.82

Coarseness figure .683, equivalent to 1½ Albany sand, Grain fineness 90, Grain class 4, Clay class F, Dye Adsorption figure 1976.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil. lbs. per sq. in.	Permeability
6.4	295	12.4	1.04	55
8.1	331	11.86	.84	62
10.2	307	8.3	.84	58

This sand shows excellent bond strength and permeability at 8.1% water content. This percentage of water is near the one at which many sands are worked in the foundry.

Another sample from the same formation was collected near the southern limit of the area mapped as Matawan, at a point 100 yards south of the crossing at Jones Station on the Baltimore and Annapolis Short Line. Here there are four to five feet of molding sand overlain by a foot and a half to two feet of sandy silt. The topography of the area would indicate that this deposit might have some areal extent.

MOLDING SAND, 100 YARDS SOUTH OF JONES STATION

The sample, No. 1508, was collected from the four foot face exposed at the roadside, and showed the following results on test:

FINENESS TEST

On	6	—
	12	—
	20	—
	40	2.54
	70	12.70
	100	20.14
	140	19.70
	200	12.56
	270	9.90
Thru 270		8.14
Clay Sub.		14.30
Total		99.98

Coarseness figure, .707, equivalent to 1½ Albany sand; Grain fineness, 118; Grain class, 3; Clay class E, Dye Adsorption figure 1976.

BOND AND PERMEABILITY TEST

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
4.6	242	11.06	.895	33
6.2	256	9.86	.745	36
8.3	252	8.0	.63	33

This sand was tested along with many others for refractoriness during an investigation carried on, on the refractoriness of molding sands. The sands were fired under as near oxidizing conditions as possible at intervals of four Segar cones, starting at cone 4. This sand seems to be very refractory, showing only softening at cone 19, 1510°C. The clay was separated from this sand and also tested by firing. It was classed as a Grade A natural bond clay according to its refractoriness. The grade used for the refractoriness of the bond clay has been established by the author by testing a number of clays which were separated from naturally bonded sand-clay mixture or molding sands and classifying them according to their refractoriness. The most refractory clays were put in Grade A. Four grades were established which included all the clays listed. A complete discussion of this subject cannot be taken up here.

MOLDING SAND, ½ MILE NORTHWEST OF MILLERSVILLE

Another deposit was found in this formation one-half mile northwest of Millersville Station on the Washington, Baltimore and Annapolis Railroad.

The section shows:

Clay overburden	3–4 feet
Molding sand (Matawan)	6–8 feet

This overburden might be a hindrance to development, and its exact thickness over this general area might change.

MOLDING SAND, ½ MILE NORTHWEST MILLERSVILLE STATION

The sample, No. 1507, was taken in a road cut at the corner of a newly located road and a cement road, near an underpass along the railroad. The sand seemed to be quite uniform where sampled, and gave the following results on test:

FINENESS TEST

On 6	—
12	.54
20	.76
40	4.44
70	10.04
100	10.86
140	15.50
200	12.30
270	10.70
Thru 270	10.20
Clay Sub.	24.76
Total	100.10

Coarseness figure, .683; equivalent to 1½ Albany sand; Grain fineness, 129; Grain class, 3; Clay class G; Dye Adsorption figure, 2872.

BOND AND PERMEABILITY TEST

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.5	265	12.16	.86	22.7
8.5	298	12.3	.94	27.0
10.6	303	11.0	.895	24.2
12.1	334	9.8	.86	23.2 Wet

Comparing these tests with those of sample No. 1505 taken from the same formation near Boon Station, it will be noticed that they differ principally in permeability. This is probably due to the larger amount of clay in this sample. Maximum A. F. A. bond strength was not reached in the workable range of the sand, but a maximum for compression and tensil were obtained at 8.5 per cent water.

The refractoriness of this sand was also tested. It showed softening at cone 14, 1410°C, and was completely fused at cone 19, 1510°C.

RARITAN FORMATION.—This formation was sampled in two widely separated localities which have both been worked for sand in the past, but so far as the writer knows not for sands used in any type of foundry work.

MOLDING SAND, ⅛ MILE NORTH OF ODENTON

The first deposit sampled was an old pit along the Pennsylvania railroad tracks one-eighth of a mile north of Odenton. Here the exposure in the pit showed the following section:

Sand with iron concretions	5 feet
Sand with white clay laminae	3 feet
Quartz sand with slight yellow-brown stain	12-15 feet

STEEL SAND, ¼ MILE NORTH OF ODENTON

This sample, No. 1503, was collected from the entire face of the above section. Care was taken to get the sample as uniform as possible. The material give the following results on testing:

FINENESS TEST

On	6	—
	12	1.00
	20	4.60
	40	47.24
	70	35.44
	100	5.24
	140	1.20
	200	.50
	270	.40
Thru 270		.70
Clay Sub.		3.00
Total		99.32

Coarseness figure, 2.066, equivalent to 4 Albany sand; Grain fineness, 34; Grain class, 7; Clay class C; Dye Adsorption figure, 128.

Bond tests on this sample were omitted because of the lack of clay substance to bind the grains. Permeability tests were run at the following water contents:

Per Cent Water	Permeability
3.7	550
5.6	440

This pit was sampled with the hope of suggesting this sand as a steel sand, and the tests indicated that it could undoubtedly be used for this purpose. A good exposure of this same formation was noted a half mile west of the junction of Annapolis, Baltimore and Washington Railroad, with the Pennsylvania Railroad at Odenton. In this exposure, which is a railroad cut, the same section is exposed, except that the iron concretions in the top three feet are not so numerous.

The other pit in this formation which was sampled is on Forked Creek, a small branch of the Severn River two miles west of Boon Station. Here the outcrop is twelve to fifteen feet thick and seems to be quite uniform in texture over the whole exposure. The usable sand is overlain by a thin sandy sod with a few scattered trees. Material has been shipped from this pit by boat in the past for glass sand.

STEEL SAND, 2 MILES WEST OF BOON STATION

The sample, No. 1539, was taken from the face of the bank. The screen analysis shows the sand to be of steel sand grade, showing a coarseness figure of 1.791, which corresponds to a No. 4 Albany sand. This material contained enough clay substance to allow the making of A. F. A. bond test, but not the compression and tension tests.

FINENESS TEST

On 6	—
12	—
20	.64
40	42.70
70	46.64
100	1.40
140	.74
200	.30
270	.34
Thru 270	.44
Clay Sub.	5.20
Total	98.40

Grain fineness, 34; Grain class, 7; Clay class D; Dye Adsorption figure, 128.

BOND AND PERMEABILITY TEST

Percent Water	A.F.A. Bond Strength	Permeability
2.6	74	525
3.7	79	550
6.6	68	341

Despite the fact that this sand has 5.20% clay substance, its grain size and permeability would suggest that it would make an excellent base for a steel sand mix.

The last two sands described compare very favorably with steel sands from other localities which are very widely used. This is seen from the following screen analysis:

	1	2	3	4	5	6
On 6	—	—	—	—	—	—
12	1.00	—	—	—	—	3.12
20	4.60	.64	—	3.90	1.74	12.28
40	47.24	42.70	28.94	41.79	3.60	49.82
70	35.44	46.64	54.70	45.57	61.34	24.12
100	5.24	1.40	11.46	6.70	22.06	2.56
140	1.20	.74	3.82	1.70	7.28	.54
200	.50	.30	.70	.29	1.84	.26
270	.40	.34	.06	.04	1.00	.24
−270	.70	.40	.16	.05	.86	.40
Clay Sub.	3.00	5.20	—	—	—	6.90
Total	99.32	98.40	99.84	100.04	99.70	100.26

1. 1503, Maryland.
2. 1539, Maryland.
3. Ottawa, Illinois, Silica.
4. O. W. D., New Jersey.
5. Geanga, Ohio.
6. 502, Milleville, New Jersey.

PATAPSCO FORMATION.—About a mile east of Glenburnie, on the Annapolis road, a six foot exposure of what appears to be fair core or steel sand was noted. The sand is overlain by 2½ to 3 feet of gravelly material. The deposit is laminated and some of the liminae are darker in color due to iron staining while others are fairly well indurated. This outcrop was not sampled.

ARUNDEL FORMATION.—There is a very exceptional occurrence of molding sand occurring in this formation. This deposit is unusual because at most of the outcrops in this area the Arundel material is principally clay. This exposure was found on a hilltop one mile southwest of Savage Station on the Baltimore and Ohio Railroad. There are three and possibly five feet of molding sand available here in an area of forty to sixty acres. The overburden consists of a gravelly sod about two feet thick. The material would have to be hauled at most three-quarters of a mile to the Baltimore and Ohio tracks. The sand seems to be fairly uniform at the outcrop and does not contain any clayey impurities.

MOLDING SAND, 1 MILE SOUTHWEST SAVAGE STATION

The sample, No. 1519, was collected at a roadside cut on property owned by E. Fisher. The results of the tests made on this sample follow:

FINENESS TEST

On	6	—
	12	—
	20	.20
	40	12.18
	70	36.08
	100	15.14
	140	8.76
	200	4.80
	270	4.60
Thru 270		6.64
Clay Sub.		11.20
Total		99.60

Coarseness figure, 1.088; equivalent to 3 Albany sand; Grain fineness, 113; Grain class, 3; Clay class E; Dye Adsorption figure, 560.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
3.8	113	3.0	.18	38
5.8	119	3.4	.256	62
8.2	104	2.36	.19	79
10.2				67

It will be noticed from these tests that the maximum bond strength for all the bond tests is developed when the sand has a moisture content of 5.8%. This is a slightly lower water content for maximum bond strength than was found in the sands described above. It will be noticed, however, that this sand has a considerably lower clay content than the others, which may account for this.

EOCENE

AQUIA FORMATION.—The Aquia formation, which is the lower of the Eocene formations, promises to be the most potent continuous source of good molding sand of any of the formations of the Coastal Plain in Maryland. This formation is most accesible in the areas east and west of the Severn River, because here it is crossed by the Baltimore and Annapolis Short Line Railroad and the Annapolis, Washington and Baltimore Railroad.

This formation was sampled first on a side road to Bestgate Station on the Annapolis, Washington and Baltimore Railroad about a quarter of a mile southwest of the station. Here the outcrop showed four feet of molding sand whose grains were principally quartz with some glauconite, overlain by about two and one-half feet of sandy material, with some sod.

MOLDING SAND, ¼ MILE SOUTHWEST OF BESTGATE STATION

The sample, No. 1506, which was collected from the roadside cut, gave the following results on test:

FINENESS TEST

On	6	—
	12	—
	20	—
	40	7.24
	70	36.46
	100	19.70
	140	4.96
	200	2.70
	270	2.94
Thru 270		6.10
Clay Sub.		20.08
Total		100.18

Coarseness figure, .973, equivalent to 2 Albany sand; Grain fineness, 82; Grain class, 4; Clay class G; Dye Adsorption figure, 2480.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression lbs. per sq. in.	Tensil. lbs. per sq. in.	Permeability
7.5				115
9.6	329	11.8	1.37	146
11.0	320	11.3	1.19	110

This sand seems to require more water to obtain its maximum strength and permeability than might be expected. These figures could be reduced in actual service, because the sand is very strong and open.

Cones of this sample were made up and heated in the manner already described, and the following facts were noted. Softening commenced at cone 9, 1310°C. and complete fusion was reached at cone 14, 1410°C.

MOLDING SAND, 1½ MILES SOUTH OF WOYTYCH

Sand similar to this just described and from the same formation outcrops along the main road a mile and a half south of Woytych Station where the road parallels the tracks. A good exposure is found at this place which shows the following section:

Iron oxide cemented sand (with an occasional one foot glauconite bed)	15 feet
Molding sand	10 feet

Six feet of good molding sand overlain by a two and a half foot overburden was located in this formation at the first railroad crossing on the Washington, Baltimore and Annapolis Railroad north of Iglehart.

From the sections of this formation studied in this vicinity, it is very evident that the molding sand in the upper part of the formation is divided by a distinct bed of sand cemented by iron oxide. By a careful study in this area it would be possible to indicate the best places to prospect from the elevation of this cemented bed, because it is known that good molding sand may be found above and below it.

This formation was sampled at another locality east of the Severn River on the New Annapolis road, one and one-half miles southeast of Revell Station on the Baltimore and Annapolis Short Line Railroad.

The outcrop which was sampled is approximately fifty yards east of the railroad tracks. The same material shows along the roadside for about 200 yards. The general section exposed is as follows:

Soil and fine sand	2½ feet
Molding sand	6 feet

This deposit is probably fairly extensive, as is indicated by the topography and seems to be quite uniform in texture with the exception of a few iron lumps not over a quarter inch in diameter.

MOLDING SAND, 1¼ MILES SOUTHEAST REVELL STATION

The sample, No. 1509, was subjected to the usual tests with the following results:

FINENESS TEST

On 6	—
12	.40
20	.32
40	4.80
70	52.64
100	14.80
140	3.74
200	1.48
270	1.68
Thru 270	3.08
Clay Sub.	15.76
Total	98.70

Coarseness figure, 1.116, equivalent to 3 Albany sand; Grain fineness, 62; Grain class, 5; Clay class F; Dye Adsorption figure, 2080.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.5	—	—	—	99
9.1	284	12.2	1.18	128
11.2	309	10.6	.905	119
13.2	299	9.16	.786	87

This test indicates that this sand has excellent strength but not as much permeability as might be expected from such a coarse sand. The reason for this may be that the clay has a tendency to close the pores, giving the low permeability. This sand, on firing, showed a behavior similar to No. 1506 from the same formation, softening at cone 9, 1310°C., and completely fusing at cone 14, 1410°C.

PLEISTOCENE

Two samples were taken from the oldest terrace, the Sunderland, one coming from the northern section and the other from the southernmost part of the County. As has already been said, these deposits cannot be expected to yield any great amount of sand because of the unfavorable conditions which existed during their deposition.

The deposit sampled in the northern part of the county outcrops along the old Annapolis road from Shipley a mile south to an underpass on the Washington, Baltimore and Annapolis Railroad where it was sampled. The railroad tracks parallel the road here for over a mile, which would facilitate shipping. The complete outcrop shows the following section:

Pleistocene		
Sunderland—Clay and Gravel		3 feet
	Laminated red clay and yellow sand (molding sand)	6 feet
	Clay and gravel	6 feet
Cretaceous		
Potapsco—White Clay		3 feet to road

MOLDING SAND, 1 MILE SOUTH SHIPLEY STATION

The sample, No. 1520, was collected from the laminated red clay and yellow sand shown in the above section. The tests of this sample showed the following results:

FINENESS TEST

On	6	—
	12	—
	20	—
	40	1.36
	70	7.90
	100	11.80
	140	12.24
	200	10.90
	270	11.76
Thru 270		17.90
Clay Sub.		25.82
Total		99.68

Coarseness figure, .495, equivalent to 1 Albany sand; Grain fineness, 158; Grain class, 2; Clay class G; Dye Adsorption figure, 1440.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.4	—	14.6	1.32	40
8.4	360	14.7	1.27	49
10.4	353	11.6	.88	55
12.5	—	—	—	29

These tests show that the sand is very strong but not very "open."

On firing, this sand proved to be rather refractory, showing only a slight indication of softening at cone 19, 1510°C. The clay, which was separated from the sand, was classed as grade B, according to the refractoriness, and was analyzed chemically as a clay representing this grade. The chemical analysis of this clay follows:[3]

SiO_2	54.80
Al_2O_3	22.60
Fe_2O_3	8.57
CaO	.75
MgO	.30
Loss on ignition	10.14
Total	97.17
Total Flux	3.88

[3] Analysis by Prof. G. W. Cavanaugh.

The total flux was determined by taking the difference between the total determined constituents and 100 percent and adding to it the amount of CaO and MgO. It was found that the fusing point of the clays was indicated best by determining the flux in this manner.

This formation was sampled in the very southernmost part of the county in a pit which has been operated in the past by the Plum Point Molding Sand Company. This property is located near the tracks of the Chesapeake Beach Railroad about 2½ miles west of the village of Friendship on land owned by Lial Wilson. The face of the pit is about twenty feet high and the same material was found outcropping at the railroad crossing and in the railroad cut a quarter of a mile southeast of the crossing. The material seems to be quite uniform where it outcrops and is usually overlain by a sod soil eight to ten inches thick. On further testing it might be found, however, to run rather irregular in texture and clay content, from the nature of the deposits of this age and from a study of the Sunderland terrace in general.

MOLDING SAND, 2½ MILES WEST OF FRIENDSHIP

The sample, No. 1527, was collected from a face that had been worked in the pit and subjected to the usual tests, which are given below.

FINENESS TEST

On 6	—
12	—
20	Tr.
40	1.58
70	20.70
100	16.58
140	22.04
200	8.80
270	5.70
Thru 270	8.80
Clay Sub.	15.56
Total	99.76

Coarseness figure, .745, equivalent to 1½ Albany sand; Grain fineness. 110; Grain class, 3; Dye Adsorption figure, 1640.

A peculiar thing may be noted from the above analysis, which is not usually found to be true of the sands which have been blended by nature. The amount retained on the 70 and 140 mesh screens is higher than that retained on the 100 mesh. The usual fact is that the sands found in nature are well graded and an analysis shows a peak on one screen, grading to finer and coarser from this. There are only two ways to account for this discrepancy: the first is that the sample represents two distinct layers which were not noted when the sand was collected, and the second is that the 100 mesh screen had a hole which allowed material to pass to the 140 mesh screen which it should have retained. The latter is not probable, because it does not show in the other analysis made during this investigation.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
4.6	250	11.3	1.05	29
6.3	257	9.3	.735	40
8.2	252	8.0	.67	47
10.5	—	—	—	31

This sand also showed excellent refractory qualities, showing only a slight indication of softening at cone 19, 1510°C. It is interesting to note that the two sands collected from the Sunderland terrace in this county both showed excellent refractory properties, which probably indicates that the clay deposited during the Sunderland time was of rather a refractory nature.

CALVERT COUNTY

The only deposits of sand which were sampled in this county were found in a terrace of Pleistocene or more recent age.

The first sample was collected near the end of the main road to Cove Point Wharf, about six miles northeast of Drum Point, which is the southernmost extension of this county. Here the prevailing winds have built up a recent beach over a quarter of a mile wide in places, which juts out into Chesapeake Bay in the form of a spit. The exact depth of material was not determined.

STEEL SAND, FROM BEACH NEAR COVE POINT

The sample, No. 1 528, was obtained from a pit dug over three feet deep into the surface of the beach.

The sand is very well sorted and contains little or no clay, as the following tests indicate.

FINENESS TEST

On	6	—
	12	—
	20	Tr.
	40	64.64
	70	33.58
	100	.28
	140	.20
	200	.06
	270	.10
Thru 270		.18
Clay Sub.		.40
	Total	99.44

Coarseness figure, 1.103, equivalent to 3 Albany sand; Grain fineness, 29; Grain class, 8; Clay class A; Dye Adsorption figure, 120.

A bond test of this sand would mean nothing if it could be made, but the following permeability tests and the above screen analysis show that this sand would make an excellent material for steel casting mixtures.

Per Cent Water	Permeability
Dry	417

What appears to be a rather extensive deposit of good molding sand was sampled at Leitch Wharf on the Patuxent River, directly west of the town of Prince Frederick. There are about three feet of sand exposed here, overlain by about a foot of sand and oyster shells, which have been ploughed in. This material should cover a wide area in this vacinity, but irregularities in texture should be expected because of the mode of origin of the material.

MOLDING SAND, LEITCH WHARF

The sample, No. 1529, was collected from the face of the cliff along the river, and gave the following results on test:

FINENESS TEST

On	6	—
	12	—
	20	.34
	40	8.80
	70	30.00
	100	19.54
	140	10.64
	200	5.24
	270	4.60
Thru 270		6.50
Clay Sub.		13.94
Total		99.60

Coarseness figure, .995, equivalent to 2 Albany sand; Grain fineness, 87; Grain class, 4; Clay class E: Dye Adsorption figure, 1420.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
4.6	225	10.2	.62	67
6.4	256	7.4	.64	87
8.5	201	6.6	.555	72

These tests show that this material has an excellent bond and permeability for a sand of this grade.

The Plum Point Molding Sand Company has prospected the Sunderland terrace on the hill just northwest of the Pushaw Crossing on the Chesapeake Beach Railroad in the northern part of the County. The railroad cuts through a small hill here which is composed almost entirely of Sunderland terrace material. The section is not well exposed in the cut, but three feet of molding sand was found, overlain by a sandy sod, one and one-half feet thick, in the test pit. This deposit is similar in origin to those in Anne Arundel County west of Friendship, and might be expected to show changes in texture. The sand in the test pit was quite uniform where the sample, No. 1538, was taken. All the regular tests were run on this sand, with the following results:

MOLDING SAND, PUSHAW CROSSING

FINENESS TEST

On	6	—
	12	—
	20	—
	40	.30
	70	1.30
	100	9.10
	140	33.68
	200	24.80
	270	12.84
Thru 270		9.30
Clay Sub.		8.50
Total		99.82

Coarseness figure, .554, equivalent to 1 Albany sand; Grain fineness, 141; Grain class, 2; Clay class D; Dye Adsorption figure, 1920.

BOND AND PERMEABILITY TESTS

Percent Water	A. F. A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
2.3	—	—	—	20
4.4	179	6.1	.61	30
6.3	184	6.3	.98	27
8.5	169	4.4	.45	24.2

This sand seems to have a relatively low A. F. A. bond and compression strength as well as tensile strength. The permeability seems to be low for a sand of this grade.

The following notes may be of interest to anyone wishing to prospect for molding sands in this county:

The only proven deposit of molding sand along the Chesapeake Bay shore occurs in the Wicomico terrace at Plum Point. The deposit is at best a quarter of a mile back from the Bay shore and 40–60 feet above it. This material has been proven by the Plum Point Molding Sand Company, but there is no good means of transporting it at present.

The materials in the area about Drum Point and Solomon's Island show nothing of importance to the foundry sand industry.

At Parker's Wharf on the Patuxent River, the following section was noted:

Red clay and gravel	3 feet
Black clay	2 feet to water

This material of course would be of no value.

A poor grade of molding sand of only slight depth was noted at Deep Landing.

Three-quarters of a mile east of the Wharf at Lower Marlboro, a four foot section of good molding sand was noted near the junction of the Wicomico and Talbot terraces. This material might be found to run rather irregularly. A mile north of Lower Marlboro the Talbot terrace is composed of gravel, which is worthless for the foundry industry.

At Ferry Landing the section exposed shows gravel underlain by clay.

The section exposed at Lyon's Creek Wharf shows diatomaceous earth overlain by gravel.

CHARLES COUNTY

A geological map of this county was not available for this investigation, and consequently the interpretation of the geology of the occurrences may not meet with the exact agreement of all.

On the main road from the Patuxent River, about a mile and a half west of the landing at Benedict, a deposit of molding sand ten to twelve feet thick was located. This material is overlain by a sand and silt sod a foot and a half thick. This deposit has an elevation of sixty to eighty feet above sea-level, which would indicate that it is part of a Wicomico terrace. The best molding sand is in the top four feet of the section, below the overburden.

MOLDING SAND, 1½ MILES WEST OF BENEDICT

The sample, No. 1533, was collected from this part and gave the following results on testing:

FINENESS TEST

On	6	—
	12	—
	20	Tr.
	40	.78
	70	13.56
	100	29.00
	140	19.60
	200	10.50
	270	7.24
Thru 270		8.00
Clay Sub.		11.52
Total		100.20

Coarseness figure, .749, equivalent to 1½ Albany sand; Grain fineness. 111; Grain class, 3; Clay class E; Dye Adsorption figure, 1560.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
4.5	248	11.1	1.0	42
6.3	255	10.0	.81	49
8.5	234	8.6	.67	55
10.2	—	—	—	33

These tests indicate that the sand, according to its grade has excellent bond strength and fair permeability.

On the property adjoining the amusement park at Marshall Hall on the southeast, a deposit of fair molding sand was found. This sand occurs in a flat-topped terrace at an elevation of about forty feet above sea level, which would indicate that it was of Talbot age or a terrace above the Potomac River of more recent age.

The material was found to have a depth of two and a half to three feet and is overlain by a sod about 8 inches thick. It could be easily shipped by barge on the Potomac River. This property is owned by the Mt. Vernon Steamboat Company, but no sand has ever been excavated here for any purpose.

MOLDING SAND, NEAR MARSHALL HALL

The following results were obtained from the usual tests which were made on this sample, No. 1537:

FINENESS TEST

On	6	—
	12	—
	20	.50
	40	29.44
	70	24.54
	100	2.76
	140	6.94
	200	1.94
	270	2.64
Thru 270		8.00
Clay Sub.		22.00
Total		98.76

Coarseness figure, 1.220, equivalent to 2 Albany sand; Grain fineness, 74; Grain class, 4; Clay class G; Dye Adsorption figure, 520.

BOND AND PERMEABILITY TEST

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.1	179	6.8	1.5	25.8
7.8	181	6.1	1.5	34.0
10.0	165	5.4	.55	88.0

The best working temper of this sand would be around 6% moisture, which would give approximately maximum bond strength and a fair permeability.

The following notes on specific locations along the railroad and river will give some idea of the poor possibilities of finding molding sand in these areas, and thus save some time for prospecting those areas which show occurrences near possible transportation.

Light brown to gray clay or loam was found exposed in a road cut in front of a school a half mile east of Wardsville station, on the Washington Seaboard, and Norfolk Railroad.

Just east of Gallant Green station a similar clay to that just mentioned was found. Gravel was also found exposed in a small pit a half mile south of Gallant Green.

Clay is exposed along the State Road one mile south of Hughesville at the railroad crossing.

Molding sand is exposed in a twelve to fifteen foot cut along the State Road, just west of the bridge over Budd Creek. There is no means of transportation here.

At a long curve in the State Road, which overlooks the head of the Wicomico River, a mile and a half southwest of Newport, the following section is exposed on the northwest side of the road:

Overburden, sand and gravel......................	1 foot
Molding sand (dark brown)........................	4 feet
Light yellow sharp sand...........................	6-8 feet
Light yellow molding sand, fine texture..........	4 feet to the road

There is no possible means of transporting this material.

Molding sand occurs in a cut along the State Road just north of Wayside. This occurrence seems to be at the junction of two terraces.

About a mile southeast along the road from the terminal of the Pope's Creek Branch of the Pennsylvania Railroad, fifteen feet of sharp sand covered by gravel is exposed. This section shows no molding sand, but some of the material might be used for cores.

The possibility of finding sand along the Potomac River was carefully investigated at Clifton Beach; Liverpool Wharf, where a small deposit was noted about a mile east of the wharf; Indian Head, Glymont, and McGhiesport. Most of the material was worthless as far as this investigation was concerned.

PRINCE GEORGE'S COUNTY

CRETACEOUS

MATAWAN FORMATION.—In a railroad cut where Central Avenue crosses the Chesapeake Beach Railroad, about a mile and a half east of the District of Columbia line, twelve feet of molding sand are exposed. The top four feet of the section show the best molding sand, while the bottom is a laminated sand with gray clay laminae. The material is overlain by a light sandy overburden about a foot and a half thick. The topography would indicate that this material might well be expected to occur in the area mapped as underlain by the Matawan formation in this area.

MOLDING SANDS, 1½ MILES EAST OF DISTRICT LINE

The exposure was sampled in two parts. Sample No. 1511 represents the top four feet, and sample No. 1512 the bottom eight feet.

The complete tests of these two samples follow:

FINENESS TEST

	No. 1511	No. 1512
On 6	—	—
12	.90	.96
20	1.26	.84
40	10.60	4.04
70	15.00	6.60
100	9.18	8.20
140	16.90	25.74
200	14.70	19.40
270	10.68	10.00
Thru 270	8.20	9.90
Clay Sub.	11.96	14.32
Totals	99.38	100.00

Coarseness figures, .964 and .741, equivalent to 2 and 1½ Albany sands; Grain fineness, 112 and 131; Grain class, 3 and 3; Clay classes E and E; Dye Adsorption figures, 3104 and 4600.

These tests indicate that No. 1512 is slightly finer in texture than No. 1511. The fineness test of No. 1511 shows the poorly graded character of this sample, as was already shown above for sample No.

1527. In this case, however, the explanation seems evident. What seemed to be clear boundaries between the upper and lower parts of the section were evidently not well defined and the sample which was taken from the top four feet of the section probably contains some of the material of the bottom eight feet, thus making No. 1511 seem to be poorly graded.

BOND AND PERMEABILITY TESTS

Sample No. 1511

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.8	260	10.8	.96	31
8.9	268	9.4	.725	38
10.6	264	8.3	.700	28

Sample No. 1512

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
5.3	—	—	—	15.7
7.4	279	10.7	.81	15.7
9.4	264	11.6	.84	16.7
10.0	—	—	—	13.8

Both of these samples seem to have equally good bond strength, developed at about 5% water content. The permeability of sample No. 1512, however, is exceptionally low, which might make it undesirable for some types of work.

Magothy Formation.—A good exposure of molding sand was found and sampled in a railroad cut one-eighth of a mile northeast of Hillmead station on the Washington, Baltimore and Annapolis Electric Railroad. The section exposed here in the Magothy formation is as follows:

Sand with iron concretions	1½–2 feet
Fine yellowish-brown molding sand	3 feet
Mottled sand and clay (gray to brown), containing mica	3 feet

This material is exposed for about 100 yards in the cut and should be found on the adjoining property owned by a Mr. Boyd.

MOLDING SANDS, ¾ MILE NORTHEAST OF HILLMEAD

Sample No. 1523 represents the material in the first three feet below the overburden, while sample No. 1524 was taken from the next three feet below.

The regular tests were made on these samples and the following results obtained:

FINENESS TEST

	No. 1523	No. 1524
On 6	—	—
12	Tr.	.24
20	.90	.70
40	3.60	7.08
70	5.54	16.14
100	4.60	16.40
140	30.56	12.50
200	22.34	20.74
270	10.14	10.90
Thru 270	7.90	6.44
Clay Sub.	13.46	9.06
Totals	99.04	100.25

Coarseness figures, .647 and .875, equivalent to 1 and 2 Albany sands; Grain fineness, 130 and 112; Grain classes, 3 and 3; Clay classes E and D; Dye Adsorption figures, 2320 and 3200.

BOND AND PERMEABILITY TESTS

No. 1523

Percent Water	A.F.A. Bond Strength	Compression, lb. per sq. in.	Tensil. lbs. per sq. in.	Permeability
5.2	225	9.26	.62	19.5
6.7	248	9.3	.595	20.0
8.9	240	8.8	.585	23.4
10.2	—	—	—	20.0

Sample No. 1524

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil. lbs. per sq. in.	Permeability
5.2	215	9.0	.70	12.6
7.1	240	7.6	.53	13.0
9.2	231	7.7	.54	13.8
10.3	—	—	—	13.4

Both of these samples show equally good bond strength at about 7% moisture, but sample No. 1524 is considerably less permeable than No. 1523. This may be accounted for by the large amount of material retained on the small screens in this sample, which is not shown in the coarseness figure, but is only shown by the permeability test.

Sample No. 1524 was tested for its refractory properties, with the following results: At cone 14, 1410°C., it showed slight softening, but fused completely at cone 19, 1510°C.

PATAPSCO FORMATION.—This formation was sampled at two different localities in Prince George's County. The first locality sampled is just southeast of a crossover on the Washington, Baltimore and Annapolis Railroad, on the road from Landover to Brightseat. The outcrop extends along the road for about 75 yards and is about three feet thick. The overburden is a light sand one foot thick. This material is situated so near to the railroad tracks that it could be shot into cars with only one handling by means of an inclined chute.

MOLDING SAND, BETWEEN LANDOVER AND BRIGHTSEAT

A complete series of tests was run on the sample, No. 1521, collected at the roadside outcrop.

FINENESS TEST

On 6	—
12	—
20	Tr.
40	13.20
70	30.04
100	4.96
140	4.86
200	2.34
270	3.10
Thru 270	11.04
Clay Sub.	30.06
Total	99.60

Coarseness figure, .894, equivalent to 2 Albany sand; Grain fineness, 94; Grain class, 4; Clay class H; Dye Adsorption figure, 640.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil. lbs. per sq. in.	Permeability
6.2	—	9.3	.53	16.2
8.2	217	8.5	.51	49.0
10.3	228	8.0	.61	72.0

This sand has good bond strength and permeability at about 8% moisture.

Just southwest of where the concrete road crosses the Washington, Baltimore and Annapolis Railroad at Vista Station, about three feet of good molding sand is exposed for a hundred yards along the tracks. This deposit is overlain by an overburden of fine sand not over a foot thick. The sand varies slightly in texture from the top to the bottom of the section, the lower portion being a little coarser. There is not a great enough difference in texture, however, to hinder recognizing the total section as one grade of sand, as the screen analysis will show.

MOLDING SAND, SOUTH OF VISTA STATION

A complete set of tests was run on this sample, No. 1522, and the following results were obtained:

FINENESS TEST

On 6	—
12	.74
20	1.06
40	11.94
70	20.60
100	11.12
140	7.30
200	4.90
270	7.04
Thru 270	13.24
Clay Sub.	21.30
Total	99.24

Coarseness figure, .954, equivalent to 2 Albany sand; Grain fineness, 111; Grain class, 3; Clay class G; Dye Adsorption figure, 1400.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.3	—	12.0	.81	7.7
8.3	275	13.0	.87	9.4
10.3	262	11.7	.71	14.7
11.3	—	—	—	18.4

This sample shows exceptional bond strength but rather poor permeability, which might indicate that it would need to be "opened" for certain types of work.

The same type of sand outcrops about a half a mile farther southeast along the same road. At this point a three foot section is exposed. About three quarters of a mile from the railroad on the east side of the Folly Branch a six foot section of the same material is exposed along the road.

EOCENE

AQUIA FORMATION.—This formation in Prince George's County will probably be found to be the best source of molding sand of any in the county.

Outcrops were first noted a quarter of a mile north of the crossing at Leeland Station on the Pope's Creek Branch of the Pennsylvania Railroad. Here, however, the good molding sand is overlain by 1 to 1½ feet overburden of Bryn Mawr material. Along the road, one-eighth of a mile northeast of the crossing, four to five feet of molding sand is exposed, overlain by a light sod a foot to a foot and a half thick. The sand seems to be very uniform at the exposure, except that the lower part is slightly more clayey. This part was not sampled.

The topography indicates that this deposit would have a good lateral extent. The property from which the sample was taken, is owned by a Mr. L. B. Belt.

MOLDING SAND, ½ MILE NORTHEAST LEELAND STATION

The sample, No. 1517, was tested in the usual manner with the following results:

FINENESS TEST

On	6	—
	12	—
	20	—
	40	.94
	70	9.40
	100	15.04
	140	24.76
	200	15.50
	270	10.08
Thru 270		8.60
Clay Sub.		14.10
Total		98.42

Coarseness figure, .619, equivalent to 1 Albany sand; Grain fineness, 120; Grain class, 3; Clay class E; Dye Adsorption figure, 2800.

BOND AND PERMEABILITY TEST

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
5.0	—	11.3	—	46
7.3	268	11.3	1.12	52
9.1	308	11.6	1.01	44
11.3	254	10.8	.90	26

This sand shows excellent bond strength and good permeability for a sand of this grade. These properties are best developed at about 8% moisture, which is a good working temper.

This sand was subjected to a firing test and it was found that it fused completely at cone 14, 1410°C. The clay separated from this sand was also tested for refractoriness and was classed as grade C. This clay was chosen to represent the natural bond clays of this grade and a chemical analysis was made of it.[6]

[6] Analysis by Prof. G. W. Cavanaugh.

SiO_2	55.33
Al_2O_3	21.50
Fe_2O_3	8.00
CaO	.90
MgO	1.72
Loss on Ignition	8.20
Total	95.65

Another exposure of molding sand in this formation was found along the main road a quarter of a mile northwest of Hall Station on the Pope's Creek Branch of the Pennsylvania Railroad. Here the sand is exposed on the edge of a flat field to a depth of three and one-half to four feet, overlain by a light sod one to one and one-half feet thick. This material should underlie an area of approximately one hundred acres, but this could only be determined definitely by testing the field. A mile and a half west of the station and on the same road an eight foot section of the same material was found exposed. This gives some idea of the general extent of the sand in this locality.

The first roadside exposure, one-quarter of a mile northwest of the station, was sampled.

MOLDING SAND, ¼ MILE NORTHWEST HALL STATION

The sample, No. 1518, was subjected to the usual tests.

FINENESS TEST

On 6	—
12	—
20	Tr.
40	1.94
70	9.90
100	15.40
140	30.50
200	13.04
270	6.70
Thru 270	5.64
Clay Sub.	17.1[illegible]
Total	100.2[illegible]

Coarseness figure, .638, equivalent to 1 Albany sand; Grain fineness, 113; Grain class, 3; Clay class F; Dye Adsorption figure, 4200.

BOND AND PERMEABILITY TEST

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
7.7	273	10.4	1.27	42
9.4	321	14.7	1.33	47
11.5	319	11.96	1.12	44

These tests show that the sand has excellent bond strength and permeability for its grade, and that the maximum figures for these properties are all reached at approximately the same water content.

Two samples were collected from one exposure of the Aquia formation at the first crossroad east of Vista Station on the Washington, Baltimore and Annapolis Railroad. The section exposed here shows nine feet of molding sand and should have a good lateral extent to the north and northeast to the railroad.

The exposed section which was sampled follows:

Heavy sandy clay	2¼ feet
Well-bonded molding sand	3 feet
Very light molding sand	6 feet

The property where the samples were taken is owned by Daniel B. Loyd, Buena Vista Farm, and up to the present, no sand of any kind has been removed from the property.

The main road east from the point where the two samples of this material were collected has been recently relocated, and many of the cuts show excellent molding sand, and in places patches of gravel and iron formation similar to that found in the Aquia in Anne Arundel County. This seems to indicate that any of the area mapped as Aquia in this general area might be expected to produce some molding sand of a fair grade.

MOLDING SANDS, EAST OF VISTA STATION

Sample No. 1525 was taken from the top three feet, beneath the overburden in the section noted above, while sample No. 1526 represents the lower part.

The regular tests were run on both of these samples, with the following results:

FINENESS TESTS

	No. 1525	No. 1526
On 6	—	—
12	—	—
20	—	Tr.
40	.64	3.24
70	2.70	13.30
100	8.88	19.30
140	25.00	26.34
200	26.74	18.40
270	15.04	7.14
Thru 270	11.00	5.24
Clay Sub.	9.70	7.40
Totals	99.70	100.36

Coarseness figures, .538 and .785, equivalent to 1 and ½ Albany sands; Grain fineness, 148 and 110; Grain classes, 2 and 3; Clay classes D and D; Dye Adsorption figures, 5600 and 1920.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
No. 1525				
3.1	—	—	—	16.2
5.3	—	—	—	19
7.5	319	14.2	1.32	18.4
9.3	328	11.8	1.09	16.2
11.4	320	10.7	.97	15.7
No. 1526				
4.5	187	7.4	.55	34
6.5	190	5.8	.39	36
8.3	170	4.5	.35	33

Comparison of these tests brings out a rather interesting point. Sample No. 1525 has only a small amount more clay substance than No. 1526, but it nevertheless shows a greater bond strength and lower permeability than No. 1526, of which the reverse is true, greater permeability and lower bond strength.

On firing sample No. 1525 showed almost complete fusion at cone 14, 1410°C., and at cone 19, 1510°C. it was completely fused.

PLIOCENE (?)

Two samples were collected from the Bryn Mawr formation in this County and they both seem to be sands of rather good quality.

The first sample was collected in a road cut a half mile southeast of Seat Pleasant where the main road curves towards the tracks of the Chesapeake Beach Railroad. The sand is exposed in an eight to ten foot section which has a light sod overburden about a foot thick. The sample was taken from the top four feet of the section below the overburden, this being the best molding sand. It would be rather difficult to predict the lateral extent of this deposit because it is known that this formation has many phases which vary very rapidly.

MOLDING SAND, ½ MILE SOUTHEAST SEAT PLEASANT

The sample, No. 1513, was tested in the usual manner, with the following results:

FINENESS TEST

On 6	—
12	Tr.
20	.36
40	1.50
70	6.38
100	16.84
140	14.60
200	14.04
270	17.00
Thru 270	10.10
Clay Sub.	19.10
Total	99.92

Coarseness figure, .576, equivalent to 1 Albany sand; Grain fineness, 140; Grain class, 2; Clay class F; Dye Adsorption figure, 3088.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.9	281	13.0	1.04	30
8.9	304	11.3	.99	38
10.9	293	10.0	.85	27

The strength and permeability of this sand seems to be excellent for a sand of this grade.

This sample was also subjected to a firing test and showed that it would soften at cone 19, 1510°C., but not fuse completely.

The second sample taken from the Bryn Mawr formation was collected in a road cut three quarters of a mile southeast of Duley Station on the Pope's Creek Branch of the Pennsylvania Railroad. Twelve feet of sand are exposed here, and this material might be expected to cover three or four acres. The molding sand is overlain by a light sand sod about 1½ feet thick. The sand seems to be quite uniform in texture, but varies some in bonding strength. It would be necessary to haul this sand three-quarters of a mile to Duley Station for shipment.

MOLDING SAND, ¾ MILES SOUTHEAST DULEY STATION

The sample, No. 1530, was collected from the top part of the twelve foot section and gave the following results on test:

FINENESS TEST

On 6	—
12	—
20	Tr.
40	1.26
70	1.50
100	3.74
140	30.50
200	29.20
270	14.64
Thru 270	7.64
Clay Sub.	10.96
Total	99.44

Coarseness figure, .527, equivalent to 1 Albany sand; Grain fineness, 142; Grain class, 2; Clay class E; Dye Adsorption figure, 1600.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
4.4	247	10.16	.83	28
6.4	263	8.8	.63	33
8.2	213	7.4	.55	30

For a sand of such fine grade as this one, it shows excellent bond strength and good permeability.

PLEISTOCENE

WICOMICO FORMATION.—The deposit most recently worked by the Plum Point Molding Sand Co. is located on a farm owned by George Wilson along the tracks of the Chesapeake Beach Railroad, a half mile southeast of Marlboro Station. The material excavated is from a terrace of Wicomico age which underlies the tops of two ridges that extend northwest to the railroad. The main deposit is broken by small gullies which have cut down through the material. The overburden in the pit which has been worked is a problem because it reaches a thickness of about three feet in places. From the manner in which the pit has been worked it may be judged that the deposit was not any too uniform. Sand has been taken from different places in the pit, leaving some of the material untouched. As has been mentioned before, this might very well be expected from deposits of terrace origin in this area. This sand has been used for making light castings.

MOLDING SAND, ½ MILE SOUTHEAST MARLBORO STATION

Two samples were taken on this property, No. 1515 from a pie of sand in the pit which had been made ready to ship, and a sample, No. 1516 from a test pit on the ridge south of the workings.

These samples were tested and showed the following results.

FINENESS TESTS

	No. 1515	No. 1516
On 6	—	—
12	—	—
20	—	—
40	—	.14
70	.18	.36
100	1.20	2.64
140	16.24	21.34
200	36.60	32.68
270	24.90	24.74
Thru 270	10.28	9.92
Clay Sub.	9.96	8.46
Totals	99.36	100.28

Coarseness figures, .431 and .466, equivalent to 0 and 1 Albany sands: Grain fineness, 145 and 162; Grain classes, 2 and 2; Dye Adsorption figures, 2280 and 2400.

These tests show the exceptional fineness of the sand and suggest that it could be used for casting some of the nonferrous metals with probably better results than the ferrous. The clay substance of both samples is exceptionally low.

BOND AND PERMEABILITY TESTS

No. 1515

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
2.4	—	—	—	17.8
4.5	188	7.8	.51	19.0
6.5	174	6.16	.425	18.4
8.6	167	4.6	.38	17.3

No. 1516

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.5	219	6.8	.585	21.0
8.4	225	7.0	.50	22.7
10.6	184	5.3	.50	19.5

The slightly greater coarseness of sample No. 1516 may account for higher permeability, but the lower clay content would not account for the greater bond strength. Of the two samples, No. 1516 would seem to be the better for any purpose for which it might be used. The similarity of the two samples taken from this deposit, as is shown by the tests, would indicate that the deposit was fairly uniform.

The Wicomico terrace was sampled in the southern part of the County also. The exposure sampled is three-quarters of a mile from Truman's Point Wharf on the Patuxent River and about a half mile directly west of the river at this point. The sand is exposed in a section eight to ten feet thick. The topography indicates that the material would underlie about thirty to forty acres. There is an overburden of one to one and one-half feet of sand which could be easily removed. The property from which the sample was taken is owned by the Eagle Harbor Development Company.

MOLDING SANDS, ¾ OF A MILE WEST TRUMAN'S POINT WHARF

Two samples were taken of this deposit, the first, No. 1531, from the top four feet of the section near the top of the hill, and the second, No. 1532, from the four feet of sand exposed below. These samples were tested in the usual manner with the following results:

FINENESS TESTS

	No. 1531	No. 1532
On 6	—	—
12	—	Tr.
20	—	Tr.
40	1.3	1.28
70	11.64	12.34
100	32.00	31.30
140	23.84	23.00
200	9.70	7.78
270	5.14	5.44
Thru 270	6.90	6.64
Clay Sub.	9.70	11.60
Totals	100.22	99.38

Coarseness figures, .733 and .760, equivalent to 1½ Albany sands; Grain fineness, 106 and 104; Grain class, 3; Clay classes D and E; Dye Adsorption figures, 1800 and 2000.

It is very evident from these analyses that the two samples do not vary in texture. Sample No. 1532 shows a slightly higher percentage of clay substance than No. 1531.

BOND AND PERMEABILITY TESTS

No. 1531

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
4.4	248	9.4	.78	40
6.2	235	7.6	.59	40
8.4	189	5.5	.53	47
10.2	—	—	—	30

No. 1532

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
2.0	—	—	—	49
3.7	255	8.7	.77	67
6.3	257	8.1	.68	49
8.6	208	6.5	.58	42

These tests show that the excess of clay substance in sample No. 1532 helps to increase its bond strength, but the permeability of the two sands remains practically the same.

SUNDERLAND FORMATION.—This terrace was sampled two and one-half miles southeast of Seat Pleasant about an eighth of a mile from a double crossing of the Chesapeake Beach Railroad. The Aquia is present here, and may show in this section with only a slight cover of Sunderland material. The section exposed shows six to eight feet of molding sand overlain by two feet of gravelly sod.

MOLDING SAND, 2½ MILES SOUTHEAST OF SEAT PLEASANT

The sample, No. 1514, was collected from the six foot face exposed in the road cut and gave the following results on test:

FINENESS TEST

On	6	—
	12	.84
	20	.74
	40	2.94
	70	10.40
	100	15.96
	140	31.28
	200	9.10
	270	6.80
Thru 270		7.64
Clay Sub.		13.60
Total		99.30

Coarseness figure, 1.099, equivalent to 3 Albany sand; Grain fineness, 82; Grain class, 4; Clay class E; Dye Adsorption figure, 5280.

BOND AND PERMEABILITY TEST

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
3.4	—	—	—	34
4.6	—	—	—	63
6.7	—	—	—	44
9.3	315	14.24	1.27	40
11.4	338	12.8	1.12	36
13.6	331	12.06	.96	28

These tests indicate that this sand has good bond strength and permeability for its grade, developed at widely different water contents. This fact would not cause this sand to be taken out of the class of usable sands, because its properties are well enough defined for all practical purposes at the usual service temper.

ST. MARY'S COUNTY

The samples collected in this county were taken from Pleistocene terraces of Wicomico and Sunderland age.

HEAVY CASTINGS SAND NEAR QUEEN TREE LANDING

A small outcrop was sampled a half mile southwest of Queen Tree Landing on the road from the landing. The poor exposure would not allow any conclusion to be made in regard to the uniformity or vertical extent of the material. There are about three feet of molding sand exposed here, overlain by sod of about one foot. The property adjoining the road is owned by the Queen Tree Farm, Laurel Grove, Maryland. This sample, No. 1535, was tested in the usual manner with the following results:

FINENESS TEST

On	6	2.04
	12	3.34
	20	3.80
	40	19.94
	70	28.14
	100	10.90
	140	4.84
	200	1.84
	270	1.74
Thru 270		3.30
Clay Sub.		20.26
Total		100.14

Coarseness figure, 1.875, equivalent to 4 Albany sand; Grain fineness, 55; Grain class, 5; Clay class G; Dye Adsorption figure, 1504.

This sand is exceptionally coarse and could be readily used for making heavy castings.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
4.8	—	—	—	156
6.4	343	14.0	1.58	253
8.6	331	12.7	1.55	300
9.6	—	—	—	187

These tests show that this sand has a very good strength and high permeability which would also add to its value as a sand for making heavy castings.

A half mile north of Charlotte Hall the following section was exposed where the main road cuts the east edge of a small hill:

Brown Clay	12 feet
Molding Sand (in terrace around hill)	4 feet to road

This material is mapped as Sunderland, and the terrace which extends around the hill may contain molding sand similar to that which was sampled. This sand could be shipped very readily on the Washington, Seaboard and Norfolk Railroad. The deposit in general is not very promising, but it was sampled because of its proximity to the railroad and because of the scarcity of good sand in this section.

MOLDING SANDS, ½ MILE NORTH CHARLOTTE HALL

The usual tests were made of this sample, No. 1534, and the results are stated below:

FINENESS TEST

On 6	—
12	—
20	Tr.
40	.60
70	26.54
100	39.54
140	8.60
200	1.80
270	1.18
Thru 270	1.70
Clay Sub.	19.80
Total	99.76

Coarseness figure, .952, equivalent to 2 Albany sand; Grain fineness, 71; Grain class, 4; Clay class F; Dye Adsorption figures, 1520.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.4	326	14.6	1.23	122
8.2	342	12.2	1.29	134
10.4	304	10.0	1.09	93

This sample shows good strength and permeability at the usual working temper and should make an excellent sand for foundries making a casting of medium weight.

This sand seemed to be refractory when subject to the firing test and showed only partial softening at cone 19, 1510°C.

One half mile northeast of Stone Wharf on St. Clement Bay a ten foot exposure of molding sand was noted which appears to be very near the mapped junction of the Sunderland and Wicomico terraces. An attempt has been made above to explain the occurrence of molding sand at the junction of these terraces, and the explanation seems to hold very well, especially in the deposits noted in this area. The same material occurs a half mile east of the bridge at Clement and also at the top of the hill an eighth of a mile north of Dynard Post Office. The first deposit mentioned has an overburden of about two feet of sharp sand and gravel. This material could be shipped by barge on the river.

MOLDING SAND, NEAR STONE WHARF

The sample, No. 1536, was collected at the exposure in the road cut northeast of Stone Wharf and the usual tests were made on it.

FINENESS TEST

On 6	—
12	—
20	—
40	1.50
70	24.24
100	30.64
140	11.70
200	4.74
270	3.50
Thru 270	7.38
Clay Sub.	16.00
Total	99.70

Coarseness figure, .829, equivalent to 2 Albany sand; Grain fineness, 94; Grain class, 4; Clay class F; Dye Adsorption figure, 2000.

BOND AND PERMEABILITY TESTS

Percent Water	A.F.A. Bond Strength	Compression, lbs. per sq. in.	Tensil, lbs. per sq. in.	Permeability
6.5	292	15.0	1.65	55
8.4	350	13.0	1.35	72
10.7	357	10.2	1.09	62
12.0	324	9.5	.90	52

These tests show a fair bond strength and permeability developed best at about 8% of water.

SUMMARY AND CONCLUSIONS

Anne Arundel and Prince George's counties will undoubtedly become the foremost producers of molding sand of the five counties studied, for two reasons, i.e., they are fortunate enough to have good railroad transportation facilities, and the older formations of the coastal plain are exposed within their boundaries. The number of samples collected from the Aquia formation of Eocene age, in no way indicates its possible importance as a source of a medium grade molding sand with good bond strength, fair permeability, and medium refractory properties.

The samples taken in Calvert, Charles and St. Mary's counties are indicative of the type of sand which may be expected to occur in the Pleistocene terraces on that region. It is the writers opinion that many of these deposits may be found in the future, but only a few will prove to be big producers, because there does not seem to have been the necessary stability of conditions during their deposition, a conclusion inferred from the extensive variability in texture and other properties.

If core and steel sands are ever produced from this area they will probably be taken from the Raritan formation, which contains a good thickness of clean silica sand with a texture suitable for this type of work. The only exception to this is the deposit of recent beach material found at Cove Point Wharf on Chesapeake Bay in Calvert County.

The geological map of this area will be a great aid in prospecting for molding sands. It is suggested that the Aquia formations east and west of the Severn River and in the northeastern part of Prince George's County be more carefully prospected, because these places seem to be very good localities for molding sand.

This report has blocked out in a general way the localities where future production may be expected. With these points as centers, more prospecting may lead to the development of a thriving molding sand industry in this section of the State.

PART II

NOTES ON FELDSPAR, QUARTZ, CHROME, AND MANGANESE IN MARYLAND

BY

JOSEPH T. SINGEWALD, Jr.

NOTES ON FELDSPAR, QUARTZ, CHROME, AND MANGANESE IN MARYLAND

THE FELDSPAR INDUSTRY IN MARYLAND

Introductory

Feldspar is a compound of silica, alumina, and one or more of the bases potash, soda, and lime. The commercial varieties are the potash and soda feldspars, the calcium feldspars not being adapted for the uses to which the former are put. There are two mineralogic varieties of potash feldspar—orthoclase and microcline—which are chemically identical and so nearly alike physically that no distinction is made between them commercially. The theoretical chemical composition of the potash feldspar is 64.7 per cent SiO_2, 18.4 per cent Al_2O_3, and 16.8 per cent K_2O, corresponding to a formula $KAlSi_3O_8$. The formula of the soda feldspar, albite, is $NaAlSi_3O_8$, and the theoretical chemical composition is 68.7 per cent SiO_2, 19.5 per cent Al_2O_3, and 11.8 per cent Na_2O. In Maryland both soda feldspars and potash feldspars are worked. The potash feldspars, however, always contain more or less soda and the percentage of soda in some cases exceeds that of potash.

The potash feldspars of Maryland range in color from nearly white through light shades of buff and flesh to pink. Their hardness is slightly greater than that of steel, and they have two well defined cleavages approximately at right angles. The great bulk of the feldspar production of Maryland is of the potash or, as it might more properly be called, of the potash-soda variety.

The commercial soda feldspar of Maryland is white in color. Hardness and cleavage are essentially the same as in the potash-soda feldspars. The soda feldspar is most easily distinguished from the latter by the presence of faint parallel striations on one of the cleavage faces which result from repeated twinning.

PRODUCTION

In the following table the production of feldspar in Maryland and for comparison the total production of the United States are given for the years 1916 to 1926 inclusive. There is also given the rank of the state as a feldspar producer.

FELDSPAR PRODUCTION IN MARYLAND AND UNITED STATES FROM 1916 TO 1926

Year	Maryland			United States	
	Tons	Dollars	Rank	Tons	Dollars[1]
1926	2,868	16,320	8	209,989	1,607,401
1925	4,554	26,438	7	185,706	1,315,654
1924	4,854	25,020	7	204,772	1,509,339
1923	2,750	17,010	7	145,004	1,057,595
1922	2,899	18,099	6	117,127	844,568
1921	5,155	33,798	5	91,865	617,652
1920	17,999	100,822	4	135,551	851,123
1919	6,982	39,610	5	63,441	347,992
1918	8,784	40,299	4	99,129	674,346
1917	14,088	56,958	3	126,715	474,767
1916	21,364	83,957	3	118,465	404,689

The figures show a considerable decline in the Maryland production despite an increase in feldspar production in the United States. The average annual production in Maryland is now only one-fourth that of a decade ago, whereas the United States production has increased more than one and a half times during that period.

USES

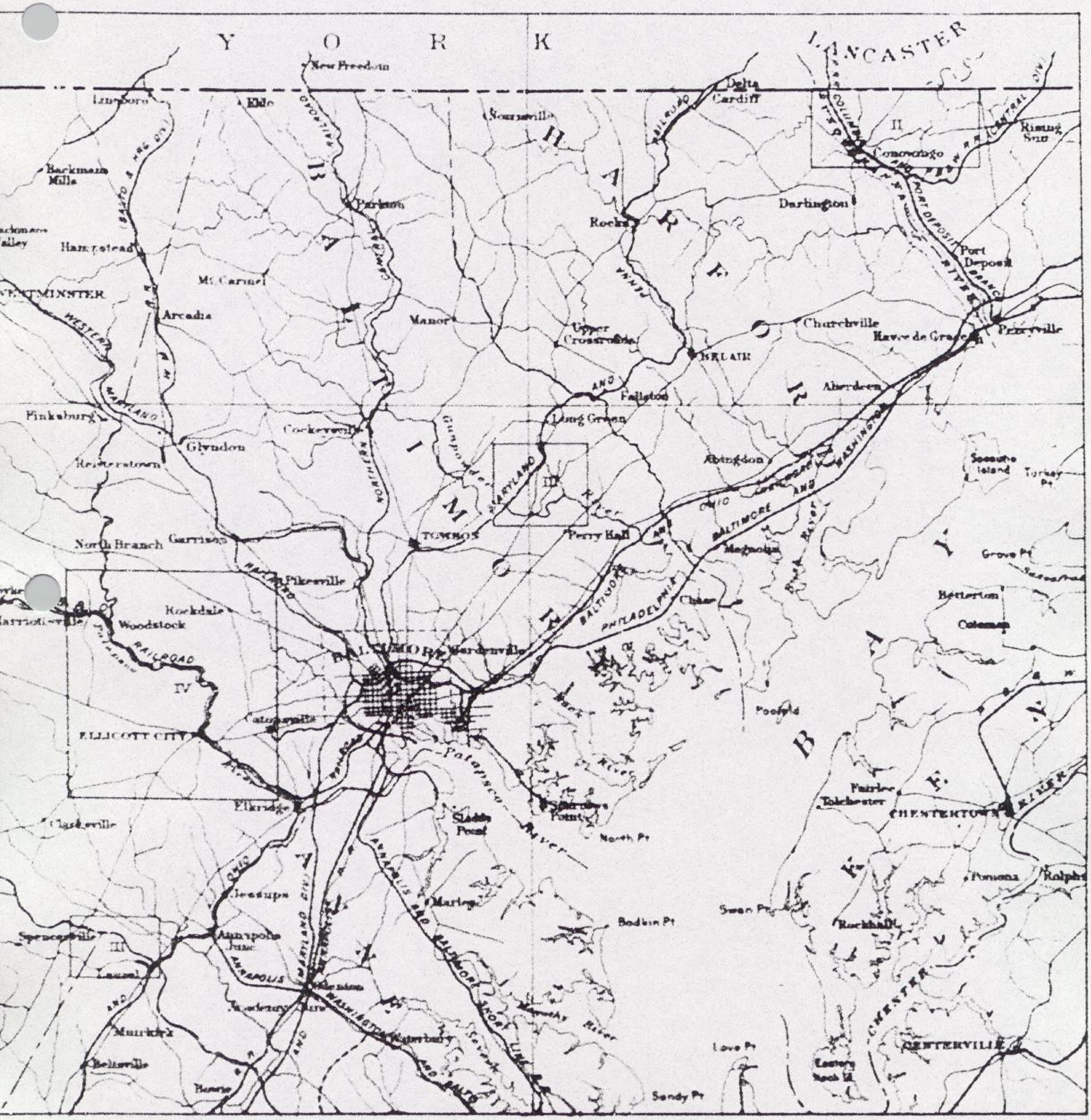
The principal use of feldspar is in the ceramic industries, particularly in the manufacture of white pottery ware. It is used both in the body and in the glaze of pottery and vitrified sanitary ware, in which on account of having a lower melting point than the other ingredients, it serves as a flux to bind the clay and quartz together. In the body of the ware 10 to 35 per cent of feldspar is used, and in the glazes from 30 to 50 per cent. Large quantities are also used in the manufacture of glass and enameled wares. Most of the Maryland product is put to the aforementioned uses. Special uses for limited quantities are in scouring soaps; in artificial teeth, for which purpose the very highest grade is demanded; as a binder in emery and corundum wheels; and in the manufacture of opalescent glass. Large quantities of feldspar are used for roofing, stucco finish, and poultry grit though there has been little production for these purposes in Maryland. These products do not demand as high-grade feldspar as that used for pottery purposes, and it is surprising that Maryland feldspar containing too many impurities for the latter use has not been more extensively marketed in those forms. The first attempt made a few years ago was doomed to failure on account of the distance from the railroad at which the plant was located. A recent venture is meeting with greater success.

A future demand of promise for feldspar is in the utilization of its potash content, and possibly at the same time the extraction of the alumina. About fifteen years ago a plant was erected at Curtis Bay to extract potash from feldspar but did not pass beyond the experimental stage. The erection of a plant in the vicinity of Baltimore for the extraction of both potash and alumina was considered ten years ago. During 1915 and 1916 a large part of the Maryland feldspar production was used by the fertilizer factories about Baltimore. The ground feldspar was given a preliminary acid treatment to make part of the potash immediately available, but the process was not successful and the use of feldspar for this purpose was soon abandoned. The direct use of finely ground feldspar as a potash fertilizer is also of doubtful value since the mineral is affected so slowly by normal processes of rock weathering that the potash does not become available in soluble form in a reasonable time. A large amount of potash is being recovered by some of the cement plants as a byproduct in their flue dust, particularly where the raw materials carry more than the average percentage of potash. Since the ingredients of feldspar other than potash, namely alumina and silica, are important constituents of cement it has been suggested to add feldspar to the cement mixture in place of some of the shale that supplies these ingredients and thereby greatly augment the potash production. So far as known to the writer no definite steps have been taken to this end, one great objection being the much higher cost of feldspar than shale obtained from a company's own quarries. A proposition to use feldspar and limestone instead of shale and limestone in the manufacture of a cement that would command a higher price than ordinary cement and thereby at the same time make a large recovery of by-product potash appears more feasible.

OCCURRENCE

Feldspar is one of the most widely distributed minerals in nature, and is found in nearly all rocks; but in most rocks it occurs in too small grains and too intimately mixed with other minerals to be of commercial importance. The potash-soda feldspar of the trade is not the pure mineral but contains considerable quartz, to which mineral there is no objection if not present in excess of about 20 per cent. Other minerals occurring in association with feldspar are for the most part iron-bearing minerals and are consequently highly objectionable in feldspar intended for pottery use. The most abundant and generally present are the micas. These minerals must be completely eliminated from feldspar intended for pottery use, and this can be done successfully only in the case of the coarse-textured, feldspathic rocks called pegmatites. The albite pegmatites, or deposits of soda feldspar, are practically free of quartz but contain deleterious iron minerals chiefly in the form of hornblende.

In most pegmatites there is no regularity in the distribution of the minerals and their relative quantities vary greatly from place to place in the same deposit. There is also great variation in the size of the grains of the same mineral. Quartz and feldspar crystals range from a few inches to several feet across. The larger masses of quartz can be rejected and the free silica content of the commercial product reduced in this way. Much of the quartz occurs in intergrowths with the feldspar which, on account of the quartz forming a pattern on certain faces of the feldspar crystals which resembles the ancient cuneiform inscriptions, are known as graphic granite. The quartz and feldspar in the intergrowths show a nearly constant ratio of 20 to 30 parts of quartz to 70 to 80 parts



Index map of northeastern Maryland showing the positions of plates giving the location of Feldspar Quarries.

Scale, one inch equals eight miles

of feldspar, or only a little more than the permissible allowance of quartz in commercal feldspar.

The commercial source of feldspar is then the rock known as pegmatite, which is nearly always more or less closely associated with areas of granite, and which appears to be genetically related to the granite. Pegmatites represent the solidified portions of the more highly mineralized and aqueous phases of the granitic magma. They are intrusive rocks, most commonly in the form of bands and dikes though occasionally in large irregular or stock-like forms. The texture of the larger pegmatitic masses is generally not as coarse and irregular as that of the dikes but tends to approach that of a coarse-grained granite and consequently they can not be successfully exploited as sources of feldsapr. The bands and dikes are generally more or less lens-shaped and range in width from a few inches to tens and even hundreds of feet and in length from tens of feet to a mile or more. In general the largest deposits are too fine and too evenly grained in texture to permit of sorting out a high-grade feldspar and are either wholly unworkable for that purpose, or only certain parts are workable. The rocks into which the pegmatites have been intruded are usually foliated and intrusion has taken place parallel to, or nearly parallel to, the planes of foliation. Further the pegmatitic material may occur as a single mass along a definite plane, or in the form of a group of bands and lenses along a number of planes of foliation.

Distribution

The genetic relations existing between pegmatite and granite make the area of occurrence of the former approximately the same as that of the latter. The pegmatites of Maryland are consequently confined to the eastern portion of the Piedmont region, that is to a belt extending across northern Cecil County, Harford County, the southern half of Baltimore County, southeastern Carroll County, Howard County, and eastern Montgomery County. The feldspar deposits that have been developed are not alone those most easily worked and of best quality, but to an equal degree those most accessibly located with respect to transportation facilities. For these reasons the valley of the Patapsco River in

Baltimore and Howard counties and the southeastern corner of Carroll County, an area served by the main line of the Baltimore and Ohio Railroad, has always been the most productive area of the State.

As previously stated, the pegmatities of Maryland are of two distinct types—the quartz-rich potash-soda dikes which have wide distributions in Baltimore, Carroll, Howard, and Montgomery counties, and the quartz-free soda dikes of the northwest corner of Cecil County and the portion of Harford County immediately contiguous to it. It may be remarked in passing that these two types of pegmatities may not be as genetically distinct as their mineralogic composition and geologic relations might suggest. In the region of the potash-soda pegmatites there are deposits in which the amount of albite is in excess of the potash feldspar as, for instance, the Frost quarry in Howard County and the Weetenkamp quarry at Marriottsville in Carroll County, in which quartz and mica are not abundant and green hornblende occurs; while, on the other hand, in Cecil County the Worth Brothers quarry shows some quartz and a little tourmaline and the Riley quarry considerable orthoclase. The intimate association of the soda dikes with the gabbros and serpentines, however, lends plausibility to the view that they are differentiates from the same parent magma and hence genetically distinct from the potash-soda pegmatites.

The albite deposits of Maryland are all of small size, although over the line in Pennsylvania much larger deposits have been worked. There is also no evidence that they are numerous so that they will never be of importance as contributors to the feldspar production of the State. The potash-soda deposits include many of large size, are extremely numerous, and will always be the basis of Maryland's feldspar industry.

The feldspar deposits of Cecil County are all of the soda type and are confined to the northwest corner of the county between Octoraro Creek and the Susquehanna River. The only quarries that have furnished a large production are those at Bald Friar. The Weiant quarry on Conowingo Creek was the most actively worked in the last decade but it has been idle for several years.

Only one feldspar quarry has been operated in Hartford County. It is of the soda type and is situated across the Susquehanna River from the Bald Friar quarries. Pegmatitic material is exposed on the east wall of one of the flint quarries of the Husband Flint Milling Company on Deer Creek, but there has been no production from this locality.

In Baltimore County there are two areas in which feldspar deposits have been worked. There has been a small production from a few quarries in the east central portion in the vicinity of the Maryland and Pennsylvania Railroad, of which the only important producer has been the Bonaparte quarry on the Harford Road. The most productive area of the State has been the southwestern corner of the county along the Patapsco River and its tributaries from Hollofield to the Carroll County line. The deposits in the vicinity of the granite outcrop at Granite have been particularly constant and large producers.

Feldspar quarries in Carroll County are confined to the extreme southeastern corner. The Weetenkamp quarry at Marriottsville was at one time a large and regular producer. Though it has produced but little feldspar, the occurrence on the DeVries property is one of the largest in the State.

With a single exception the feldspar quarries of Howard County are confined to the valley of the Patapsco River and its tributaries, an area contiguous to that in which they occur in Baltimore and Carroll counties. There is one group of quarries between Gray and Orange Grove and a second group extending from Jonestown and Hollofield to Henryton. Of these the Frost quarry south of Davis was for many years the largest producer. In 1915 the Baltimore Feldspar Company quarry at Ilchester was a large producer. In 1916 and 1917 the Baugh and Sons Company quarry south of Marriottsville produced on a large scale. Three small quarries were opened in 1917 on the Clarksville road, 2 miles northwest of Clarksville.

Several small quarries were opened in 1911 by the Earth Products Company in the eastern corner of Montgomery County, 4½ miles northwest of Laurel for the production of chicken grits and ground feldspar, but operations were suspended before there had been a large production.

The individual occurrences are described by counties in a subsequent section of the report.

QUARRYING

Since the feldspar quarrying operations are chiefly on a small scale the methods used are comparatively simple. The excavations are either open cuts or open pits. At Marriottsville a small tonnage of feldspar was mined. In most of the smaller quarries the pegmatite is much decayed near the surface and can be easily excavated with picks, shovels, and crowbars. As a result of the disintegration that the rock has undergone the feldspar has to a large extent been freed from the mica and the larger masses of quartz. By picking up the loosened materials on a fork the dirt and smaller pieces of impure rock remain behind, the larger pieces of quartz are easily thrown aside, and the coarser pieces afford a feldspar that is usually cleaner than the average obtained from the solid pegmatite. The laborious and expensive hand cobbing is greatly reduced in amount in this type of deposit. Such disintegrated material is especially characteristic of the zones and areas of highly pegmatized schist in which the numerous planes of schistosity afford ready access to the pegmatitic material for the weathering agencies. These quarries are either hillside cuts or a series of shallow pits out of which the loose material can be thrown by hand. At several localities, particularly in Baltimore County to the southeast of Granite, areas of a number of acres have been worked over by numerous small pits and have yielded a constant, though moderate, output of feldspar.

In most of the quarries in solid rock drilling is done by hand. After blasting the largest blocks are broken up to sizes readily handled and the whole of the rock is piled in long rows to be sorted. For this purpose it is broken with hammers into pieces a few inches in diameter in such a way as to remove as much of the excess quartz as possible and particularly to get rid of mica and other iron-bearing minerals. This process, known as cobbing, is slow and labor-consuming and adds materially to the cost of production. A number of the larger quarries have been provided with steam drills and in one instance a steam shovel was used. There still remains the necessity, however, of breaking up the larger masses of rock and of hand cobbing to get a marketable grade of material.

Deep pits from which the rock must be hoisted are unusual among Maryland feldspar quarries as in the few instances where the large openings take the form of a pit, a gentle incline provides a road for wheelbarrows or carts, according to the size of the operation. The rock is removed from the open cuts in the same way. If the quarry is located near the shipping point and carts are used, it is hauled at once to the cars. If the haul is a long one or if the stone is taken out in wheelbarrows it is accumulated on a stock pile and hauled by wagons and trucks to the shipping point. Motor trucks are used for the longer hauls but their use is not always feasible because of the small scale of most of the quarrying, its intermittent character, and the fact that generally at least part of the haul is over a bad dirt road. Several of the larger quarries located near a railroad have their own siding but most of the feldspar is shipped from the public sidings at the railroad stations.

MILLING

Feldspar for pottery use is ground dry and the grinding process is essentially the same throughout the eastern United States. The crude rock from the quarries may or may not be further broken up in a jaw crusher. It is then fed to chaser mills. As it comes from the chasers it is screened and the oversize returned to the chasers while the undersize goes to tube mills for final grinding. Four to six hours grinding reduces most of it to a fineness of under 200 mesh. The finished product is shipped either in bulk or in bags.

Mills for making poultry grit and roofing material require only crushing and screening apparatus, for which purpose a jaw or gyratory crusher and rolls, and vibrating or revolving screens are best adapted.

There are two mills in Maryland grinding feldspar, that of the Seaboard Feldspar Company, known also as the Product Sales Company, and that of the Spa Nola Products Company near Ilchester. The only mill that has been erected for the production of poultry grit, that of the Earth Products Company near Laurel, has been idle for 13 years. These mills are described in a subsequent section of the report.

ECONOMIC ASPECTS OF THE MARYLAND FELDSPAR INDUSTRY

Most of the feldspar quarries are operated on a royalty basis and the royalties charged range from 25 cents to $1.00 per ton. With few exceptions, however, the price is 50 cents per ton which is fixed irrespective of the size of the deposit, the quarrying conditions, its location, and the quality of the rock. It is the established price for pottery grade of feldspar. For the No. 2 grade that is used for other purposes the usual royalty is 25 cents. As a much lower grade rock can be utilized for poultry grit and roofing and there is less cobbing and waste in rock used for potash extraction, a lower rate will doubtless be established if a regular demand develops for feldspar for these uses.

So many conditions enter in determining the cost of quarrying feldspar that there is a wide range in the cost of production at different quarries. In the first place there is the cost of actual quarrying. The loose disintegrated pegmatite can be quarried at a lower rate than the firm rock, and the cost of quarrying the latter is naturally less in the quarries equipped with power drills and with a large steady production than in the small hand-worked quarries not in constant operation. A disadvantage of the quarries in the loose rock is that they are small and shallow and hence a relatively greater percentage of overburden must be handled in them, so that production costs are not as low as might seem. An equally important factor in determining cost of production is the quality of the rock. Mica and other deleterious minerals may be present in such abundance and so thoroughly disseminated through the pegmatite that an excessive amount of cobbing is required to produce a marketable feldspar. Many quarries must be abandoned for that reason. At the favorable extreme are the soda pegmatites which are free of quartz and carry only a little hornblende and practically no mica. Very little sorting is necessary in such deposits. In most cases the deposit consists of much rock that requires a prohibitive amount of cobbing and which consequently is avoided in quarrying, and local masses of higher-grade rock that requires a moderate amount of cobbing. The average condition is that one-half of the rock quarried can be shipped and the other half must be rejected as waste. The large and steady producers have been those in which this ratio is more favorable. It is not only the amount of rock rejected that must be considered however, but also the extent to which it is necessary to break up the rock to secure a clean product. At most of the small quarries the output averages one ton per man per day. The wages for labor are about $3.50 per day. To this must be added a few cents per ton for supplies, equipment, and the royalty but there is no charge for superintendence as the operator or foreman is one of the workmen. In the larger quarries with greater efficiency and more uniform production the costs are lower, though not much lower for pottery grade of feldspar. Hence the average cost of producing pottery spar would be around $4.00 not including the cost of hauling to the railroad.

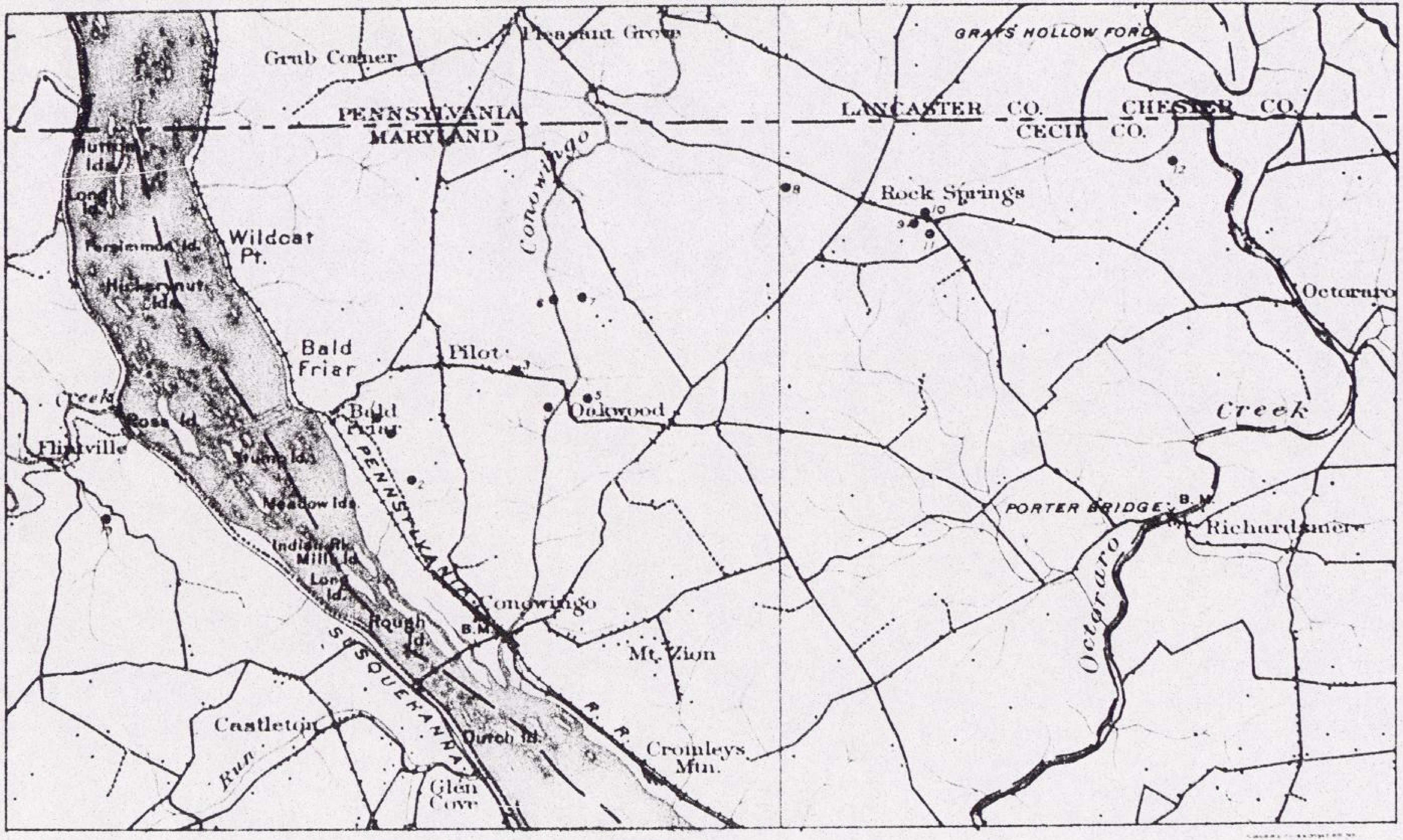
Few quarries have been so situated that the feldspar could be loaded directly on the railroad cars and none of the quarries now in operation are so located. The usual length of haul is between a half and 3 or 4 miles. In a few instances it is longer and in one case as much as 7½ miles. In general the rate per mile is lower for the long hauls than for the short hauls on account of the time consumed at each end in loading and unloading. The grade of the road and the character of the road bed are also important factors in determining the cost of hauling since they determine the weight of the load that can be hauled. Under average conditions a four-horse team can haul 3 tons of stone and will make three to four trips on a two-mile haul and two trips on a four-mile haul each day. The charges for hauling are 30 to 50 cents per ton for hauls up to 3 or 4 miles in length. Longer hauls can be had at a lower rate. A long haul by motor truck over an improved road could be secured at about 20 cents per ton per mile.

The principal and usually the only market for Maryland feldspar has been the mills that grind for pottery use. The chief purchasers of the Maryland production have been the Eureka Flint and Spar Company and Golding Sons Company with mills at Trenton, New Jersey. The Seaboard Feldspar Company purchases a small quantity for its mill near Baltimore. Its purchases at present are chiefly of second-grade spar for use in glass manufacture. Most of the production of soda feldspar was quarried or purchased by the Brandywine Summit Kaolin and Feldspar Company for its mill at Brandywine Summit. The small present production is purchased by Golding Sons Company. The price paid for Maryland feldspar of pottery grade is $6.00 or more per ton f. o. b. cars. The soda spar commands a higher price than the potash spar. Second-grade spar sells at $3.00 to $3.50 per ton f. o. b cars. During 1915 and 1916 a large amount was sold to the fertilizer companies in the vicinity of Baltimore at prices ranging from $2.75 to $3.25 per ton f. o. b. cars for feldspar averaging 7 per cent or better K_2O but the use of feldspar as a source of potash was discontinued by these companies and this market is no longer available.

Ground feldspar of pottery grade under 200 mesh is quoted at about $22.00 per ton. Second-grade spar ground to pass 30 mesh for glassware sells at $11.00. The small amount of chicken grits produced some years ago sold at prices ranging from $4.50 to $6.50 per ton, the price being determined largely by the quantities in which sold.

Maryland has been an important producer of pottery grade feldspar for a number of years and the production could be maintained indefinitely. The output comes largely from small operations conducted by farmers and laborers who engage in feldspar quarrying chiefly in those seasons of the year when farm work is slack. In many instances the necessary capital is supplied by the purchasers of the feldspar in the shape of advance payment for the production. After a deposit is worked for a while it is frequently abandoned for another more favorably located. The number of small deposits of the type that have been worked in the past is almost limitless and new ones are being opened constantly but the large deposits in which the rock as a whole is suitable for quarrying pottery material alone are not numerous. One of the greatest drawbacks to the expansion of the feldspar industry has been the abundance of mica in the deposits and this has prevented the exploitation of the largest pegmatites in the State, most of the rock in them not being sufficiently coarsely crystalized to permit of the easy separation of the mica.

A market of considerable importance has developed through the use



Location of Feldspar Quarries in Cecil and Harford Counties, showing conditions before Conowingo Dam erection.
Scale, one inch equals one mile

of feldspar in the manufacture of certain kinds of heavy glassware For this use a feldspar high in alumina and low in iron is required. Maryland feldspars have not been able to make much headway in the market because of their iron content due largely to the presence of iron-bearing mica.

Through the application of more capital the utilization of the pegmatites of Maryland could be greatly augmented. There are several large deposits most admirably situated with respect to quarrying and transportation but which require an excessive amount of cobbing to produce a high-grade feldspar. If these deposits were provided with a mill for producing poultry grits, roofing, and other coarse products the waste rock could be utilized. In such an operation the cleaner rock could be used for pottery feldspar after a minimum of cobbing, a second-grade feldspar for glass manufacture could easily be sorted out, and the remainder sent to the mill. The cost of producing pottery feldspar from these deposits would thereby be greatly decreased.

At some future time the pegmatites of Maryland may be in demand as sources of potash. The cement plants in Maryland and neighboring states have seriously considered the use of feldspar in the cement mixture and the recovery of the potash by precipitation of the flue dust. Considerable experimentation in the extraction of potash and alumina from feldspar has been carried on with a view to its commercial use. If these prospective demands for feldspar materialize the Maryland deposits will be an important source of raw material. Therein also lies great possibilities for the expansion of the production of pottery feldspar for in working these quarries the cleanest rock can be thrown aside at a minimum expense and sold at the highest prices of pottery feldspar without materially reducing the potash content and value of the remainder. Maryland pegmatites that might be used as sources of potash are numerous and large and information regarding their potash content is of considerable value for that reason. Sorted material that was recently used in fertilizers is said to have run as high as 9 to 11 per cent in potash in carload shipments. The unsorted rock averaged between 7 and 8 per cent potash. These figures agree with analyses of numerous samples of unsorted rock taken by the author from many of the larger Maryland deposits and are regarded by him as representative of the potash content of rock that can be quarried on a large scale from these pegmatites. The enormous masses of finer grained pegmatites that approach coarse-grained granites in texture occurring along the Patapsco River between Orange Grove and Ilchester, though of no value as commercial sources of pottery feldspar, are equally high in their potash content and afford an unlimited quantity of pegmatitic rock suitable for the extraction of potash. Maryland is in a position, therefore, to furnish any desired quantity of potash-bearing rock containing from 7 to 8 per cent potash that can be quarried and placed on railroad cars at minimum cost and situated within 15 miles of tidewater points about Baltimore.

DESCRIPTION OF DEPOSITS

The more important feldspar quarries that have been worked in Maryland, are described in this section. The list of old quarries is by no means complete, but all recently active quarries are described. The localities at which new quarries can be opened are far more numerous than those at which feldspar has been worked. The deposits described serve to indicate in more detail the nature of the feldspar deposits and the quarrying industry and are not to be considered a complete tabulation of the feldspar resources of the State.

CECIL COUNTY

Bald Friar quarries (Plate II, 1, 2)

On the hill overlooking the Susquehanna River at Bald Friar, considerable feldspar was quarried over 20 years ago and shipped to Worth Brothers at Brandywine Summit, Pennsylvania. Subsequently soapstone was quarried from the same openings by the Deland Mining and Milling Company for their grinding mill at Bald Friar. A small amount of feldspar was obtained at the same time from stringers and branches of the main dikes that had penetrated the serpentine wall rock. The small amount of feldspar lying about the openings is white in color and free of mica and quartz. The largest opening extends 200 feet in a direction N. 40° W., is 120 feet wide, and was worked to a depth of about 40 feet. A short distance to the southeast is a second large opening over 100 feet long, 50 feet wide and 30 feet high at the upper face. These deposits are practically worked out. Other pegmatitic masses in the vicinity have been worked on a small scale by F. S. Weiant.

Farther south in the same hill slope, F. S. Weiant has been extracting feldspar from a number of small openings. The largest quarry is on a pegmatitic dike striking N. 50° W. and dipping 50° S. in talc schist country rock. The quarry has followed the strike of the dike 100 feet. At the northwest end the dike terminates against the schist but at the southeast end it continues beyond the limits of the opening. The maximum width of the dike is about 20 feet. The feldspar is white and carries some black mica and black tourmaline. The mica is more widespread than the tourmaline but neither mineral occurs in such quantity as to impair the value of the spar.

Mr. Weiant has been operating the Deland Mining and Milling Company property since 1922 and has produced about 7000 tons of feldspar. The operations are carried on under the name of The Maryland Mineral Company.

Worth Brothers quarry (Plate II, 3)

One-half mile east of Pilot is a small opening with a length of 100 feet in a direction N. 70° W. and 20 feet wide, owned by Worth Brothers which has been idle for nearly 15 years. This feldspar contains more or less quartz in fine graphic intergrowths, small flakes of white mica, and a little tourmaline. There is also some coarse striated feldspar with large blades of mica. The large piles of rejected material indicate an unusually poor grade of rock. The wall rock is serpentine.

Caldwell quarries (Plate II, 4, 5)

A quarter of a mile south of the Worth Brothers quarry is a small quarry owned by Charles Caldwell and formerly worked under lease by Thomas Weaver. The deposit is now worked out but apparently was a narrow dike of feldspar with a strike N. 25° W. that was followed for about 80 feet. On the east side of Conowingo Creek are two small quarries also owned by Charles Caldwell and last worked by Thomas Weaver, but originally opened for Worth Brothers. One of these deposits was a small dike 40 feet long, 4 feet wide and 6 feet deep with a strike N. 55° E. which yielded 150 tons. Fifty feet southeast of it was another similar one also worked out. The wall rock of these deposits is serpentine.

Weiant quarry (Plate II, 6)

Ten years ago F. S. Weiant opened a feldspar quarry on the west bank of Conowingo Creek, 1 mile northeast of Pilot which has now been idle several years. When first opened a dike about 18 feet wide in serpentine with a serpentine horse in the middle was exposed. The feldspar was practically free of mica and contained no quartz, but occasionally showed radiating tufts of actinolite. The rock was being shipped to Golding Sons Company. The opening as it stands today is about 75 feet long in the direction N. 15° W. and about 50 feet wide. The center is full of water to within 25 feet of the top. At the north end the dike split to 2 branches separated by about 12 feet of serpentine. The west branch is 15 feet wide and the east branch 25 feet wide. The quarry has produced about 3500 tons of feldspar.

Conowingo Marble and Mineral Company (Plate II, 7)

Two carloads of feldspar have been shipped from the serpentine quarry of this company on the east bank of Conowingo Creek and a core drill hole is said to have encountered 20 feet of feldspar in depth.

Schofield quarry (Plate II, 8)

About one-half mile west of Rock Springs is a small opening 30 feet in diameter and 8 feet deep, owned by Henry Schofield and worked about 15 years ago by Thomas Weaver. Small quantities of both feldspar and soapstone were quarried.

Dawson quarry (Plate II, 9)

A quarter mile east of Rock Springs on Edward Dawson's place is a small quarry 30 feet in diameter full of water that has not been worked for over 20 years. There is also a small opening opposite on the north side of the road.

McVey quarry (Plate II, 10)

East of the Dawson quarry is another old quarry, 50 feet by 30 feet and filled with water, on Charles McVey's place.

Riley quarry (Plate II,

Two hundred yards south of the McVey ry is a quarry on the old Kennard Riley place now owned by Milford Richardson. The opening is about 150 feet by 30 feet and filled with water. It was worked over 20 years ago by Riley and later to a small extent by Thomas Weaver. The dike is no longer exposed but considerable orthoclase on the dump is an unusual feature for the soda feldspar deposits. A little talc was taken from this opening about 14 years ago for the Bald Friar mill.

Taylor quarry (Plate II, 12)

Two miles east of Rock Springs on William Taylor's farm, is a quarry 150 feet long, 30 feet wide, and 25 feet deep that has been idle for years. The wall rock is a basic gneiss striking N. 40° E. The small amount of feldspar now exposed in the sides of the opening is a white semi-kaolinized material.

HARFORD COUNTY

H. Clay Whiteford and Company quarry (Plate II, 13)

A small quarry situated a mile southeast of Flintville which had produced a few carloads of feldspar about 3 or 4 years before, was reopened in the spring of 1917 and several carloads of stone were shipped to Golding Sons Company. The opening is 50 feet long, 20 feet wide, and 20 feet deep with its long dimension in the direction N. 75° W. The deposit can be followed only a short distance ahead of the opening and is apparently not a large one. The wall rock is serpentine. The feldspar is of the white soda variety with no quartz and nearly free of mica.

BALTIMORE COUNTY

Gilmor quarry (Plate III, 14)

A quarter mile southwest of Summerfield Station on the Maryland and Pennsylvania Railroad is a quarry with a face 120 feet long, 20 to 30 feet high, that has been worked into the nose of the hill about 20 to 30 feet and which was served by a railroad siding. The quarry was opened on the end of a pegmatite dike that can be traced as a low ridge for over a mile to the northeast beyond Notch Cliff Station, and which has been intruded into and parallel to the belt of limestone forming the valley followed by the railroad. Excellent exposures are afforded of the contact of pegmatite and limestone in this quarry and in the limestone quarry adjoining it on the northwest side in which a smaller dike is exposed. Except for very local and limited development of tremolite there seems to have been no development of contact silicates. Any marmorization that the intrusives may have caused is not distinguishable from the regional metamorphism that the entire belt of limestone has undergone. The dike consists of light-colored feldspar and quartz with here and there flesh-colored patches of feldspar, is of finer grain than typical pegmatites and has a great deal of mica scattered through it. There is also an occasional garnet crystal. The rock is not well adapted for the production of pottery feldspar and the quarry was worked some years ago as a stone quarry. It is situated on the Gilmor farm.

Pierce quarries (Plate III, 15, 16)

A continuation of the dike exposed in the Gilmor quarry extends across the Pierce farm north of Summerfield. About sixteen years ago Cavey and Whalen blasted out a small amount of rock from ledges of the dike that outcrop to the northeast of the house but no shipments were made. The rock ranges from white to pink in color, is medium to fine grained in texture, and is chiefly a graphic intergrowth of feldspar and quartz with considerable mica.

A small opening 25 feet long, 10 feet wide, and 5 feet deep was made at the same time on another dike on the north side of the road. A car load of the rock quarried at that time was sorted and shipped in 1916.

Notch Cliff quarries (Plate III, 17)

The only productive locality on this dike has been at Notch Cliff on the property of the Sisters of Notre Dame which was also worked by Cavey and Whalen about 17 years ago. A small knoll of pegmatite has undergone disintegration and weathering so that it yielded to cheap mining and also produced a better grade of feldspar than the solid rock. In spite of the favorable location at the railroad station the deposit was worked only a short while.

There are a number of other pegmatite dikes in this valley but they do not have the coarsely crystalline structure essential to profitable production of the best grade of pottery feldspar.

Gwynn quarry (Plate III, 18)

A mile and a half east of Glenarm David Gwynn worked a quarry in the winter of 1916 which is 50 feet long and 20 feet deep. The dike has a strike N. 30° E. and a width of 6 to 10 feet and is enclosed in gneiss. The feldspar is cream to pink in color and contains only a little white mica.

Pearce quarry (Plate III, 19)

A mile and a half southeast of Glenarm, on the James Pearce farm, James Goodwin has quarried a small amount of feldspar. Two openings have been made at the end of a dike, outcropping at the northeast nose of a small ridge, which can be traced for several hundred feet to the southwest along the ridge. The dike has a width of 20 to 30 feet and consists of feldspar varying from pink through cream to white in color and mixed with quartz and a moderate amount of white mica.

Bonaparte quarry (Plate, III, 20)

Two miles west of Glenarm, on the Charles J. Bonaparte farm, a quarry was worked for about 6 years by James Goodwin. The opening is 140 feet long, 30 to 40 feet wide, and 30 feet high at the face. The total width and length of the pegmatite dike is not exposed. The feldspar is of a distinctly pink to cream color and contains only a small amount of white mica. The quarry has been operated extensively and at one time was equipped with machine drills and a cobbing shed so that cobbing could be continued without interruption during inclement weather. It has been idle for about 10 years except for a small amount of disintegrated rock that is taken out for road use.

Hollofield quarries (Plate IV, 21)

Considerable feldspar has been quarried in the past from several openings on the upper slopes of the hill overlooking the Patapsco River, a half mile south of Hollofield. These deposits were last actively worked by E. E. Fagan about 19 years ago. The Products Sales Company again took out a carload in the winter of 1917. The two larger openings at this locality have the dimensions 100 feet long by 30 feet wide by 20 feet deep and 60 feet long by 30 feet wide and 20 feet deep. The feldspar has a pronounced pinkish color, has associated with it the usual amount of mica, and considerable quartz much of which occurs in large enough masses to be separated from the feldspar.

Wilt quarry (Plate IV, 22)

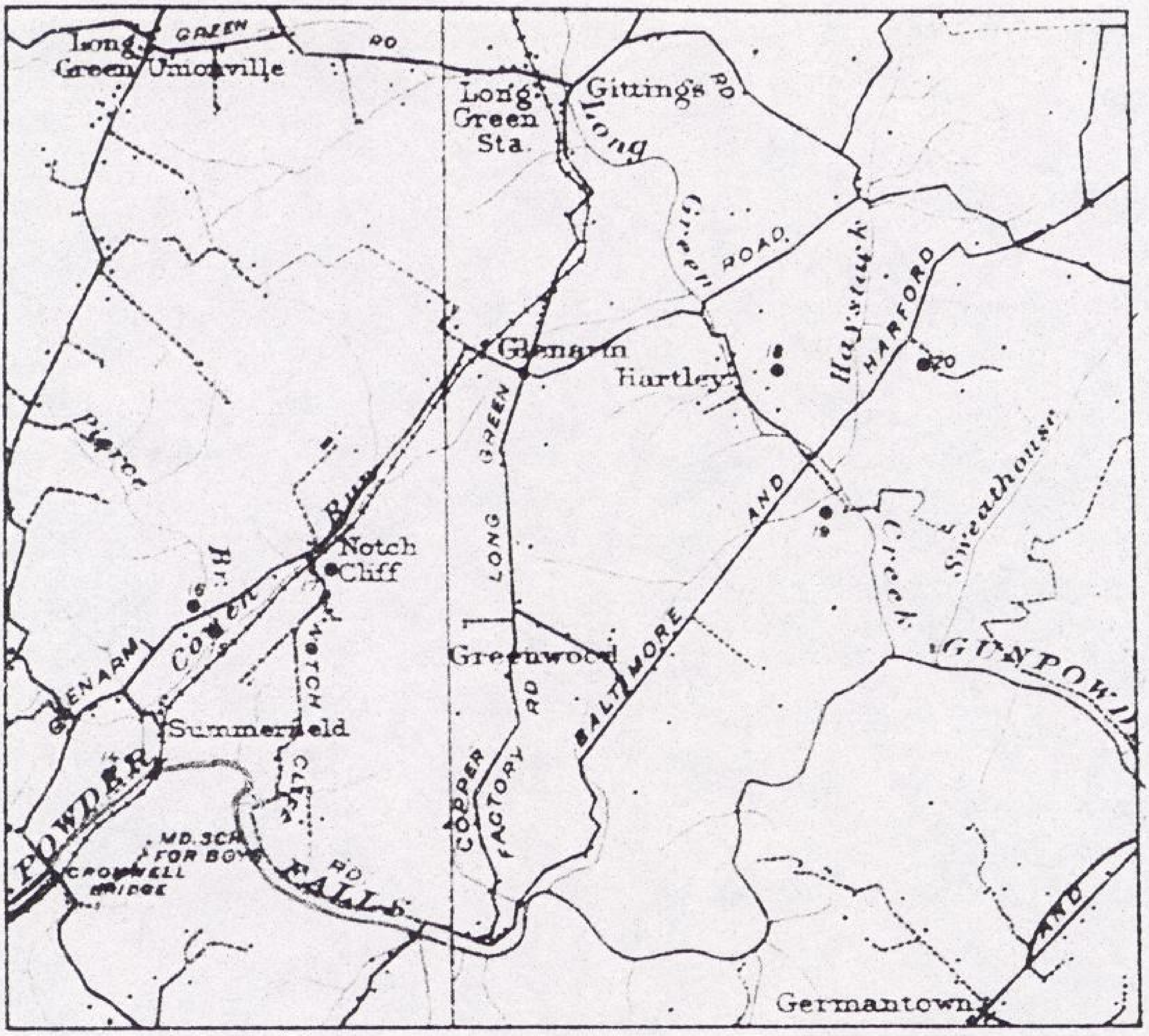
One-half mile north of Hollofield, on the G. L. Wilt farm, is an idle quarry on a pegmatite dike with a N. 60° E. strike and steep easterly dip and width of 20 to 30 feet. The rock now showing on the quarry face contains considerable white mica. The dike can be traced for some distance to the southwest and higher on the hill slope is a second prominent dike. The quarry was worked for several years, successively by Rich and Sunderland, William French, and Donaldson and Knapp, but has been idle for about 15 years.

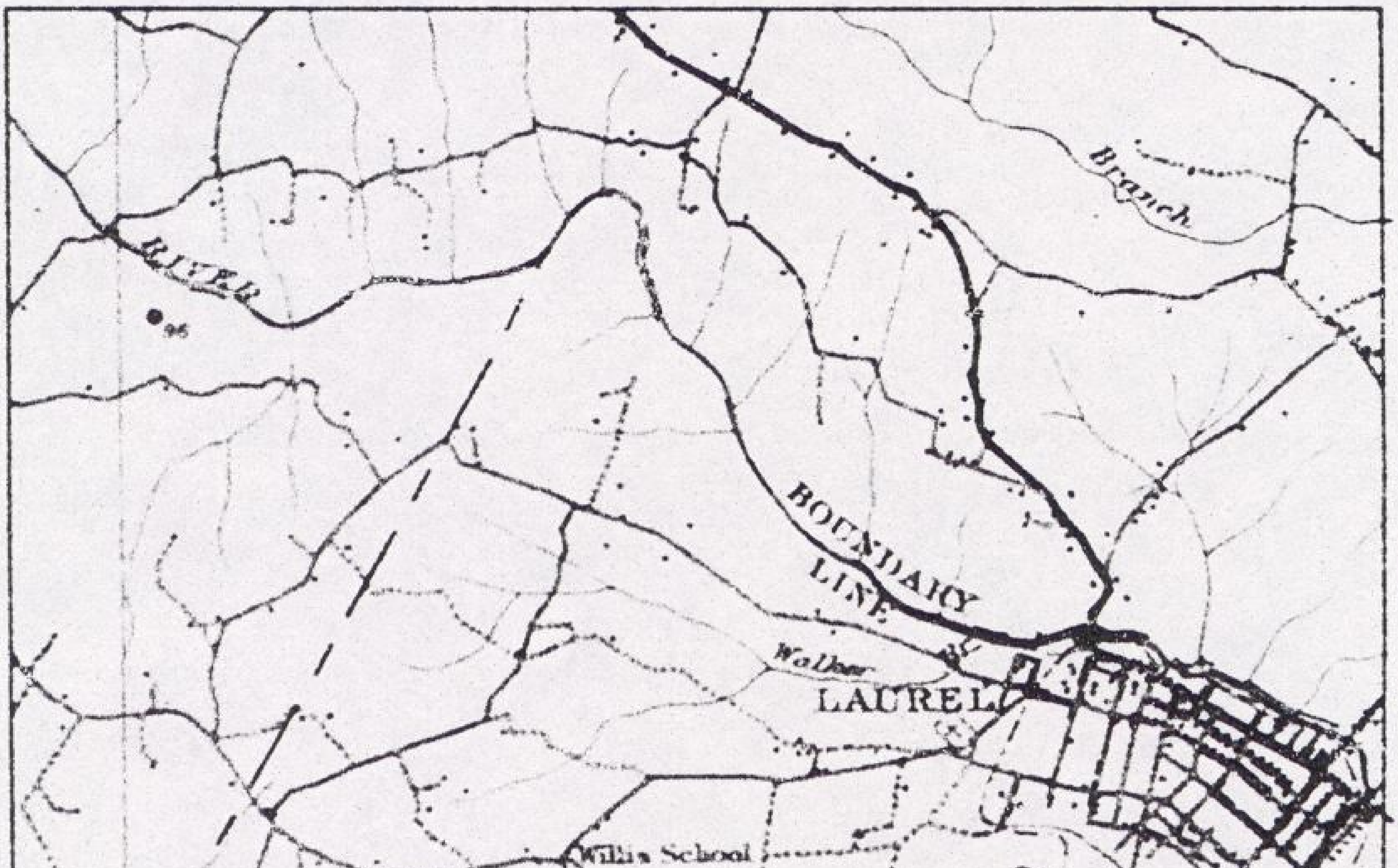
Humphrey quarry (Plate IV, 23)

Adjoining the Wilt quarry on the southwest is a small quarry on the Charles Humphrey farm that was worked by Donaldson and Knapp at the same time they were operating the Wilt quarry.

Picnic Woods quarries (Plate IV, 24)

Feldspar was worked for a number of years in what are known as the picnic woods, three quarters of a mile northeast of Alberton. The





Location of Feldspar Quarries in part of Baltimore County and in Montgomery County.

Scale, one inch equals one mile

older opening is over 100 feet wide and has been extended nearly 100 feet into the nose of the hill with a quarry face 30 feet high. The rock is more or less weathered so that considerable gravel spar is produced. Mica is present in moderate amount and some of the feldspar shows excellent graphic intergrowth with quartz. A smaller old opening lies about 200 feet west of the one just described, and on the east side of it is a newer opening. The Feeney and Atherton Feldspar Company were the last active operators.

Alberton quarry (Plate IV, 25)

Across the river from Alberton is an old limestone quarry in which the beds strike N. 60° W. and dip to the north. On the north contact of the limestone is a pegmatite dike characterized by the presence of considerable greenish plagioclase. In 1917 the Feeney and Atherton Company shipped one carload of this rock to the Eureka Mining and Operating Company and had quarried some additional rock when further shipments are said to have been refused by the Eureka people.

Feeney and Atherton Feldspar Company quarries (Plates IV, 26)

The largest operations of this company were centered on the nose of the hill running south over the Baltimore and Ohio Railroad tunnel, a mile west of Alberton. A number of openings were made on several dikes with a N. 70° W. strike, the largest of which has a width of 30 to 40 feet and the smaller ones 10 to 20 feet. In 1917 about 25 men were employed and 4 one-horse carts were engaged in hauling the daily output of about 30 tons to the railroad siding three-eights of a mile distant. On account of the poor road the carts could haul only one-half ton per load. When work was started two years earlier the rock was hauled to the siding for the Dietz quarry at the west portal of the tunnel but the company later had its own siding at the east portal. The rock is a good quality pinkish feldspar and was sold to the Eureka Mining and Operating Company. The quarries are on the James S. Gary and Son property.

Dietz quarry (Plate IV, 27)

A mile and a half west of Alberton are a series of openings extending for a distance of 100 yards along a dike with a strike N. 70° W. The full width of the dike is not exposed, but the openings indicate that it is more than 30 feet. The property is owned by John Dietz and was worked by O. B. Gibbons who after producing 1200 to 1500 tons of rock over a period of three years abandoned the deposit in 1915. The rock was hauled to a siding at the mouth of the ravine in which the quarry is located.

Minckins quarries (Plate IV, 28, 29)

Feldspar was produced for a number of years from the David Minckins farm. The openings were shallow pits on the outcrop in gravel spar spread over on area of several acres on both sides of a small run. There were often several leasers at work on the property at one time as it yielded a good grade of feldspar that was easily worked in small scale operations. The location is a mile and a half north of Alberton but the haul to that point is 2 miles. The output was very irregular and rarely exceeded a carload or two per month. It was sold to the Eureka Mining and Operating Company.

Rupp quarries (Plate IV, 30)

Several openings of small size have been made on the John C. Rupp farm, a mile and a half northwest of Alberton which were worked under lease by the Eureka Mining and Operating Company. About 2000 tons of feldspar were shipped in a period of 2 to 3 years. No stone has been quarried here for over 10 years.

French quarries (Plate IV, 31, 32)

Two quarries on the farm of James French, 2 miles northeast of Granite, which were leased by the Eureka Mining and Operating Company, have been idle for over 10 years. The stone was hauled to Granite for shipment. The older opening extends for 200 feet along a pegmatite dike striking N. 30° W. which has a width of about 20 feet and has been worked to a depth of 30 feet.

The newer opening, which lies to the northwest of the other, is 100 feet long, 30 feet wide, and 30 to 40 feet deep and was equipped with a derrick for lifting out the rock. The deposit was a lenticular mass of pegmatite that was opened on the outcrop but as the quarry was driven into the hill the deposit was covered with an increasing thickness of gneiss until the overburden at the face was 20 feet thick. The feldspar is whitish in color and does not contain much mica.

Offutt quarry (Plate IV, 33)

One mile northeast of Granite on the Mary Offutt farm is an opening 50 feet in diameter and 20 feet deep that was worked for 2 seasons 13 to 14 years ago by O. B. Gibbons.

Guilford and Waltersville Granite Company quarries (Plate IV, 34, 35, 36)

Three-quarters of a mile southeast of Woodstock along the Patapsco River are three large openings worked at one time by the Guilford and Waltersville Granite Company, the westerly one of which was worked again in 1916 by Jack Cavey. The deposits represent long narrow lenses intercalated in highly pegmatized gneiss with a strike N. 70° W The feldspar is whitish in color and contains less than the usual amount of mica.

The largest of these openings has a length of 150 feet and is 40 feet wide and 40 feet deep at its eastern end and extends 100 yards farther to the west as a narrow shallow opening. The shape of the opening indicates that a comparatively wide lens pinched toward the west. The quarry was opened in 1906 and for several years was an active producer, ten men being employed and air drills used. The rock was loaded by means of a chute directly into the railroad cars from the quarry.

Farther down the hill toward the river is an opening 100 feet long on a dike about 15 feet wide. West of this opening is the third which is about 80 feet long on a dike 6 to 8 feet in width.

James Peach quarries (Plate IV, 37, 38)

Another very productive locality on the Guilford and Waltersville Granite Company's property was an area of several acres in the vicinity of James Peach's house, 1 mile south of Granite. A great number of shallow openings and pits have been dug here that yielded chiefly disintegrated feldspar apparently resulting from the weathering out of lenticular enlargements of pegmatitic material in a highly pegmatized gneiss.

Quarries three-quarters of a mile south of Granite (Plate IV, 39)

Several openings have been made on rock in place southeast of the intersection of the Granite railroad and the county road, three-quarters of a mile south of Granite. One of these close to the road extends for 60 feet in a direction N. 60° W. on a dike about 15 feet in width. A hundred yards to the south is another opening about 40 feet long and 20 feet wide on a small dike.

U. F. Peach quarries (Plate IV, 40)

U. F. Peach quarried feldspar for about 10 years prior to 1917 on his farm three-quarters of a mile southeast of Granite. The output was very irregular and averaged about 2 cars monthly. Several small openings were confined chiefly to the loose gravel spar near the surface. In some of the holes the feldspar is nearly white in color, in others distinctly pink, and occasionally a little black mica is mixed with it.

Kemp quarries (Plate IV, 41)

A quarter of a mile northeast of the Peach quarries on the Simon J. Kemp farm are several small openings that have not been worked for a long while.

Worthington quarries (Plate IV, 42)

There are several openings on the Dall Worthington farm 1 mile southeast of Granite which have produced over 3000 tons of feldspar. The last work was done about 13 years ago by Oliver Putney. The largest of the openings is on the west side of Granite Branch.

Patterson quarries (Plate IV, 43)

There are two small feldspar quarries on the Lesley Patterson property, three-quarters of a mile north of Woodstock, that furnished about 100 tons of rock 13 years ago and that were again opened in the summer of 1917 by Henry Fairbanks. The larger opening is on a dike striking N. 25° W. with an easterly dip, consisting of white feldspar without much mica which has a band of quartz on the hanging wall side several feet in width. The other opening is on a dike 6 feet wide that has been exposed 20 feet along the strike.

Poole Farm quarries (Plate IV, 44)

In 1917 O. B. Gibbons and O. Cavey prospected the Poole farm one and a half miles north of Woodstock. A small amount of feldspar was shipped from this property years ago and Gibbons and Cavey made a number of new openings, none of which yielded much spar. There were no indications of the presence of a large deposit, but rather of numerous lenticular intercalations in the schsits. There are also many large blocks of quartz lying about on the surface.

Hamilton quarries (Plate IV, 45)

One and a half miles northwest of Granite on the Lewis Hamilton farm, a number of openings have been made on lenticular masses of pegmatite. The feldspar is cream to white in color without much mica but the mica is chiefly the black variety. These deposits were worked some years ago and again produced a carload monthly in 1917 when they were worked under lease by Tony Delrage for the Eureka Mining and Operating Company. The stone was hauled to the siding at Granite for shipment.

August Sandusky quarry (Plate IV, 46)

On the August Sandusky farm 2½ miles northeast of Marriottsville, is a large quarry that was being worked 10 years ago by O. B. Gibbons for the Eureka Mining and Operating Company. A force of 4 to 6 men was then employed and the feldspar hauled to Marriottsville in a motor truck that made four trips daily carrying a load of four to five tons. The quarry was later worked by John Weetenkamp but has been idle for 6 or 7 years. The opening is 100 by 60 feet and was extended to a depth of over 40 feet. The north wall of the quarry is a smooth surface with the direction N. 65° E. 55 S. and consists of fine-grained pegmatite with disseminated mica. Near the south end of the east wall is a horse of decomposed mica schist. The upper 10 feet of the dike is completely disintegrated and the rock beneath has also suffered some alteratic The feldspar produced from this quarry was white in color and carried more or less white mica.

CARROLL COUNTY

Weetenkamp quarry (Plate IV, 47)

A quarry was operated for a number of years by John Weetenkamp at Marriottsville on a pegmatite dike with a strike N. 70° W. which cuts across a limestone and enters a schist overlying it on the west. The dike has a width of 50 feet and has been followed into the hill for 150 feet where the quarry has a face of 50 feet. The feldspar is of white color and contains less than the average amount of mica for the region so that it easily furnished a good grade of pottery spar. The rock seems to be closely related to that at the Frost quarry in Howard County, that is, to occupy an intermediate position between the ordinary granite pegmatites and the soda feldspar dikes. The overburden of the quarry became so deep and the walls so high that no more feldspar could be obtained without removing an excessive amount of waste rock.

Tunnel mine (Plate IV, 47)

Albert Sandusky worked the southward extension of the Weetenkamp quarry at Marriottsville on the opposite side of the hill facing the railroad by tunneling into the hill. The mine was operated only one winter but is of interest as being the only place in the State where feldspar has been mined.

DeVries quarries (Plate IV, 48, 49, 50)

The farm of the late Octavius DeVries which lies mainly to the north and east of Henryton, contains one of the largest and most easily accessible pegmatite dikes of the State. The principal dike on this property comes in from the Howard County side of the Patapsco River, passes through the Baltimore and Ohio Railroad tunnel, and extends for over half a mile beyond in a direction N. 40°E. with a steep westerly dip. It has a width of from 50 to 100 feet. In addition there are smaller dikes on each side of it. Taking the dike as a whole it carries too much mica to be quarried successfully for pottery-grade feldspar although there are local patches from which limited quantities can be sorted without excessive cobbing. The deposit would be more attractive as a source of rock for the extraction of potash or the production of coarse products.

John Wallen quarry (Plate IV, 51)

John Wallen has been operating intermittently a small quarry a half mile northwest of Marriottsville. The opening is 40 feet in diameter and 30 feet deep on the uphill side. The pegmatite has the direction N. 50° E. and dips steeply to the west. It yields pockets of first class pottery spar in more micaceous rock with tufts of pale greenish mica several inches square. The west wall of the quarry is mica schist. A number of small prospect pits have been dug in the vicinity. The output has been shipped to the Eureka Flint and Spar Company.

Oursler quarry (Plate IV, 52)

H. I. Oursler opened a small feldspar quarry on his farm 1 mile north of Marriottsville 10 years ago. The opening was 40 feet long by 10 feet wide and 6 feet deep but has since been filled up. The rock was white feldspar with much white mica.

HOWARD COUNTY

O'Connor Farm quarries (Plate IV, 53)

The Mineral Potash Company was organized 10 years ago to extract potash and alumina from feldspar. It acquired the John A. O'Connor farm 1 mile southwest of Orange Grove. The main mass of feldspathic rock here is a deep pink with numerous local pegmatitic facies that constitute 10 per cent of the rock. The deposit covers about 10 acres of the O'Connor farm and extends along the run through the State Forest to the Patapsco River. It is one of several such highly feldspathic granitic intrusions of pronounced pink color with prominent pegmatitic facies that are found along the Patapsco River between Ilchester and Relay. There are also several pegmatite dikes higher on the hill, northwest of the granitic rock, from which a small amount of feldspar has been taken. The amount of mica at this locality is less than the average for the Patapsco Valley region.

The rock has been quarried since 1925 by the Spa Nola Products Company for the mill which it erected on the property. This company produces crushed feldspar for stucco finish and ground feldspar for a cleanser, stucco, and composition flooring. The run-of-quarry rock is suitable for the products of its mill so that expensive hand cobbing with the attendant rejection of rock is not required.

Cordy quarry (Plate IV, 54)

H. Cordy shipped two cars of feldspar in the winter of 1916 for the Baltimore Feldspar Company from an opening adjoining the O'Connor place on the Margaret Stecker farm. The rock was hauled to Ilchester for shipment, a distance of 3 miles.

Pindell quarries (Plate IV, 55, 56)

A number of openings have been made on the Pindell farm a mile south of Ilchester, the largest of which are on two parallel dikes of pegmatite about 500 feet apart. The feldspar is pink in color and the dikes consist of patches of coarse material in rock with a more fine-grained granitic texture. These quarries have yielded about 250 cars of feldspar. They were formerly worked by L. W. Waterman and later leased to Daniel Leonard of the Amesite Stone Company near Ellicott City. No shipments have been made since 1917. The stone was hauled in wagons to Ilchester and sold to the Eureka Mining and Operating Company.

Baltimore Feldspar Company quarry (Plate IV, 57)

This quarry, located immediately south of Ilchester, has been opened for a distance of 750 feet along the road following the Patapsco River and shows a pinkish rock ranging in texture from coarse pegmatitic to granitic. Mica is abundant and in places garnet is present. Opera-

Location of Feldspar Quarries in part of Baltimore County and in Carroll and Howard Counties.

tions were commenced in April, 1915, with an equipment of machine drills and a crushing plant, but after producing over 4000 tons of stone this plant shut down in less than a year and has been idle since. The company sold pottery feldspar and rock to the American Agricultural Chemical Company on a potash basis. The potash content of carload lots is said to have ranged from 6 to 9 per cent potash. Operations were suspended when the fertilizer company ceased to purchase the rock.

Mount St. Clement College quarry (Plate IV, 58)

One-half mile northwest of Ilchester on the grounds of the Mount St. Clement College, is a small opening on a pegmatite dike which affords unusually fine specimens of graphic granite. The rock is somewhat disintegrated and may have been used only for road metal. No feldspar has been quarried here in years.

Wharton quarry (Plate IV, 59)

One mile west of Ilchester is a quarry that was worked during two seasons ab[illegible] years ago by James Wharton. The opening is 40 feet long, 30 f[illegible] and 10 feet deep. The material thus far encountered is a flesh-co[illegible] to pink disintegrated pegmatite of good quality.

Weber quarry (Plate IV, 60)

One mile south of Gray on the Charles Herman farm Henry Weber opened a quarry in 1916 on a dike striking N. 45° E. The quarry face is 150 feet long, 15 feet high and has been extended 20 feet across the dike without exposing the full width. The rock is pink in color, most of it approaching granitic in texture, and contains considerable light and dark-colored mica.

Fisher and Carozza quarries (Plate IV, 61)

There are several small quarries on the Fisher and Carozza property one-half mile south of Gray, some of which were worked by George Wheatley. The rock is mostly of a deep-pink color and carries a light greenish mica. The deposits seem to be large pegmatitic to granitic masses rather than well defined dikes.

Streker quarry (Plate IV, 62)

One-half mile northeast of Jonestown a feldspar quarry was operated under lease from John Streker by William Theis a number of years ago. Later Thompson and Doyle purchased a 1¾ acre tract about the quarry but they suspended operations about 17 years ago. The quarry is located on a pegmatite dike with an east-west strike and a dip of 45° to the south and a width of 20 feet. It has been worked along the strike for 150 feet with a maximum height on the foot-wall side of about 30 feet. The feldspar is light flesh-colored and contains tufts of white mica. Quartz occurs in irregular patches and in graphic intergrowths with the feldspar. Fragments of feldspar are very abundant in the soil about the Streker house and barns.

Highe quarries (Plate IV, 63, 64)

Two prominent pegmatite dikes are exposed in the bed of a run and the bordering hill slopes 1 mile south of Hollofield, on property belonging to Fred C. Highe. The first dike in the upstream direction has a width of over 100 feet in the stream bed, the second about 50 feet, and both cross the stream from the west to the east side at a very acute angle. The feldspar has a pink color but carries a great deal of white and light-green mica. About 20 years ago a siding was constructed here, steam drills installed, and quarries opened on both dikes on the west side of the run, but little rock was taken out and the enterprise soon abandoned. The large amount of mica in the rock doubtless was the reason for the failure of the project. In 1916 the Products Sales Company did a little work here.

Fagan quarries (Plate IV, 65)

Openings have been made on a pegmatite dike that can be traced for several hundred feet back of E. E. Fagan's house in a southwesterly direction. One of these was operated in 1917 on contract by Fagan for William French who sold to the Eureka Mining and Operating Company. Three men produced an average of 2 carloads monthly.

Theis quarries (Plate IV, 66, 67, 68)

Several openings on the hill west of Hollofield on property of F. C. Highe were made some years ago by William Theis. None of them has yielded more than a few carloads.

Perry quarries (Plate IV, 69)

About 5 years ago Harry E. Perry opened several quarries high up on the hillside on both sides of the ravine a half mile east of Alberton on the James S. Gary property. For a short while he shipped as much as 3 cars a week. The openings were small and the walls have slumped so that little can be seen of the nature of the dikes that were worked.

Gary quarry (Plate IV, 70)

A quarry was opened in 1917 one-half mile south of Alberton on The James S. Gary property by the Feeney and Atherton Feldspar Company. The opening exposed 50 feet of pegmatite without showing the wall rock. The color of the rock ranges from light flesh to light buff, the amount of mica present is not large but the rock is rather fine grained. The exposures along the road from the quarry to Jonestown show most excellently the occurrence of pegmatitic material as dikes, intercalations, nests, and stringers in the gneisses and schists of the region.

Dorseys Run quarries (Plate IV, 71, 72)

Opposite their quarries in Baltimore County at the old Dorseys Run Station, the Feeney and Atherton Feldspar Company opened a quarry on Thomas Brown's land. The dike is 15 feet wide and the rock of the same character as on the Baltimore County side. Northwest of this opening on the railroad right-of-way there is a dike of pegmatite in granite on which a little work has been done.

Arrington quarries (Plate IV, 73, 74)

In the spring of 1917 William Moody opened a quarry on the land of Frank Arrington one-half mile southeast of Davis. The pegmatite dike varies from 6 to 20 feet in width, strikes parallel to the run on which the quarry is located, and dips to the northwest. The wall rock is limestone. The feldspar is white in color. Four men produced 2 carloads monthly.

Moody also took out 2 carloads from a dike that cuts across the next run to the east with an east-west strike and steep southerly dip. The wall rock of this dike which is only 4 to 5 feet wide is gneiss. A small opening was made on each side of the run.

Frost quarry (Plate IV, 75)

This quarry located on the Fannie Frost farm one-half mile south of Davis, has been a small irregular producer for 15 years, after having been the largest producer of the region during the preceding 15 years. It was operated under lease by Mitchell and Cummins and produced 4 to 5 carloads per month. The feldspar was loaded at a railroad siding at the mouth of the run in which the quarry lies. The principal production now is of second grade feldspar sorted out of the large dump by Leslie Moody.

The deposit is described by Bastin[1] who visited the quarry while it was actively operated. It was about 450 feet long, 100 feet wide, and 65 feet deep, its greatest dimension trending about N. 60° E. A steam drill was used and the rock hoisted with a derrick. It was shipped to the Golding Sons Company plants at Trenton and Wilmington.

This pegmatite differs from the usual granite pegmatites characteristic of the region in that it represents a transition between them and the soda dikes such as occur in Cecil County. Mica is almost entirely absent and quartz is not abundant whereas green hornblende, a characteristic of the soda dikes, occurs. Light-gray to flesh-colored orthoclase and microcline occur in about the same quantity as the white albite, the former, however, are more coarsely crystallized than the latter, Bastin mentioning orthoclase crystals as much as 4 feet across and albite crystals not more than 1 foot. The great depth the quarry had reached finally prevented further profitable operation.

[1] Bastin, E. S., Economic Geology of the Feldspar Deposits of the United States. Bull. 420, U. S. Geol. Survey, 1910, pp. 75–76.

Moody quarry (Plate IV, 76)

A quarter of a mile south of the Frost quarry, about 1 mile south of Davis, Leslie Moody has been working a pegmatite dike containing orthoclase, quartz, and black mica. The quarry has followed the dike for 80 feet along the strike which is N. 20° E. and 40 feet into the hill side where it has a face 15 feet high. At the top of the face is granite gneiss with a low dip into the hill, indicating that the deposit is a thick lens with an easterly dip. The rock is weathered and friable toward the top and 8 feet of gravel spar has been stripped for a distance of 40 feet beyond the southwest end of the quarry.

Shipley quarry (Plate IV, 77)

A quarter mile south of Davis on the Mollie Shipley place is a quarry 100 feet long by 50 feet wide, and 40 feet deep that was formerly worked by John Cummins and from which John Weetenkamp took about 8 carloads of feldspar monthly from his farm one-half mile east of Woodstock in 1917. There are two openings on dikes striking northeast, one 50 feet long by 15 feet wide by 20 feet deep, the other about 100 yards to the south is 50 feet long by 30 feet wide by 20 feet deep. The workings are in loose weathered outcrop rock and yielded a whitish gravel spar. The output was shipped from Woodstock to the Eureka Mining and Operating Company.

Brown quarries (Plate IV, 79)

One mile southeast of Woodstock on the farm of Mrs. Frank Brown are a number of shallow openings that produced feldspar for 2 or 3 years over 15 years ago. They were worked by Frank Brown and John Cavey. The largest opening is a narrow east-west trench 150 feet long. The nature of the débris about the openings indicates that they were gravel spar deposits.

Baltimore Feldspar Company quarries (Plate IV, 80)

The Baltimore Feldspar Company quarried a small amount of feldspar at several places on a property on which they had more extensive flint quarries about 1 mile northwest of Woodstock. A large amount of feldspar had previously been taken from this property by William Theis from numerous small shallow openings that yielded chiefly gravel spar.

Quarry near Marriottsville (Plate IV, 81)

John Weetenkamp took out a few carloads of feldspar over 10 years ago from a small opening a quarter of a mile east of Marriottsville on the property of Wade Warfield.

Warfield quarry (Plate IV, 82)

A larger quarry on the property of Wade Warfield on the west side of Marriottsville was worked by John Weetenkamp. The opening is 150 feet long in the direction parallel to the creek. No work has been done for over 10 years and the caving of the overburden has covered the rock. The quarry is located on the westerly one of the two westerly-dipping dikes that run parallel to the creek more or less continuously for a distance of 2 miles south of Marriottsville on either contact of a belt of limestone that underlies the valley of the creek. The next 7 quarries described are located on one or the other of these dikes. Much of the feldspar that was used by the fertilizer companies in the vicinity of Baltimore during the war came from quarries located on these dikes.

Product Sales Company quarry (Plate IV, 83)

One mile south of the Warfield quarry on the Pete Zepp farm the Product Sales Company worked a quarry on the same pegmatite belt that was originally opened by John Weetenkamp. The opening is 150 feet long and the dike has a width of 20 to 30 feet.

Baugh and Sons Company quarry (Plate IV, 84)

The most extensively worked of these quarries was that on the Marcellus Wright farm 1¼ miles south of Marriottsville, leased by the Baugh and Sons Company fertilizer manufacturers and operated for them under contract by H. O. Firor. The property was leased in January, 1914, by Sarah G. Mitchell and subleased in October, 1915, to the Baugh and Sons Company who took out over 10,000 tons of feldspar. At first the rock was used at their own plant for its potash content but later the company ceased using feldspar and sold its output to Golding Sons Company. For a while operations were conducted on a large scale, a steam shovel was used, a force of 12 or more men employed at the quarry, and 3 motor trucks and 3 teams engaged in hauling the stone to Marriottsville for shipment. Recently John Hackett took out a few car loads of second-grade spar which he sold to the Seaboard Feldspar Company.

The dike has a strike N. 25° E. and a steep westerly dip. It has been worked 250 feet along the strike with a face 40 feet high and 30 to 40 feet into the hill. As the dike is not over 30 feet wide, the quarry face has more than 25 feet of hanging wall schist overburden. The footwall of the dike is limestone. The feldspar is nearly white in color, carries less mica than most of the deposits of the region, and has yielded pottery-grade rock with less hand sorting than is usually required. One thousand tons of the rock used for fertilizer purposes is stated to have averaged 10 per cent potash which is a surprisingly high potash content for a feldspar so light in color from this region.

Quarry near Marriottsville (Plate IV, 85)

John Weetenkamp opened a quarry on the Wade Warfield property at the south edge of Marriottsville in the pegmatite zone paralleling the limestone valley on its east side which he worked for a while in 1916. An opening was made on each side of the county road, the deposit extending under the road, and the larger opening on the west side is 30 feet in diameter and 20 feet deep. The feldspar is of light-buff to cream color.

Zepp quarry (Plate IV, 86)

The pegmatite belt continues along and under the county road from the quarry last described to a second opening a half mile farther south on the west side of the road which was made by John Weetenkamp in 1916 and is located on the Pete Zepp farm. The quarry is 50 feet long, has a face 25 feet high, and has been worked into the hill toward the road more than 20 feet without reaching the opposite wall of the dike.

Mathews quarry (Plate IV, 87)

On the continuation of the same belt, 1¼ mile south of Marriottsville, John Weetenkamp worked a quarry on each side of the road in 1915. That on the east side, owned by George Mathews, is 100 feet long, has a face 20 feet high, and has been extended 30 feet into the hill slope without cutting through the dike. The other, on the Marcellus Wright farm, has been worked for 50 feet along the strike lower down on the dip of the same dike.

Wright quarry (Plate IV, 88)

Another quarry that has been opened on this dike lies a quarter of a mile farther south, immediately back of the Marcellus Wright house. The dike outcrops here as a small knoll with a width of 30 to 50 feet. Years ago William Theis worked this quarry and later John Weetenkamp took out a small amount of stone.

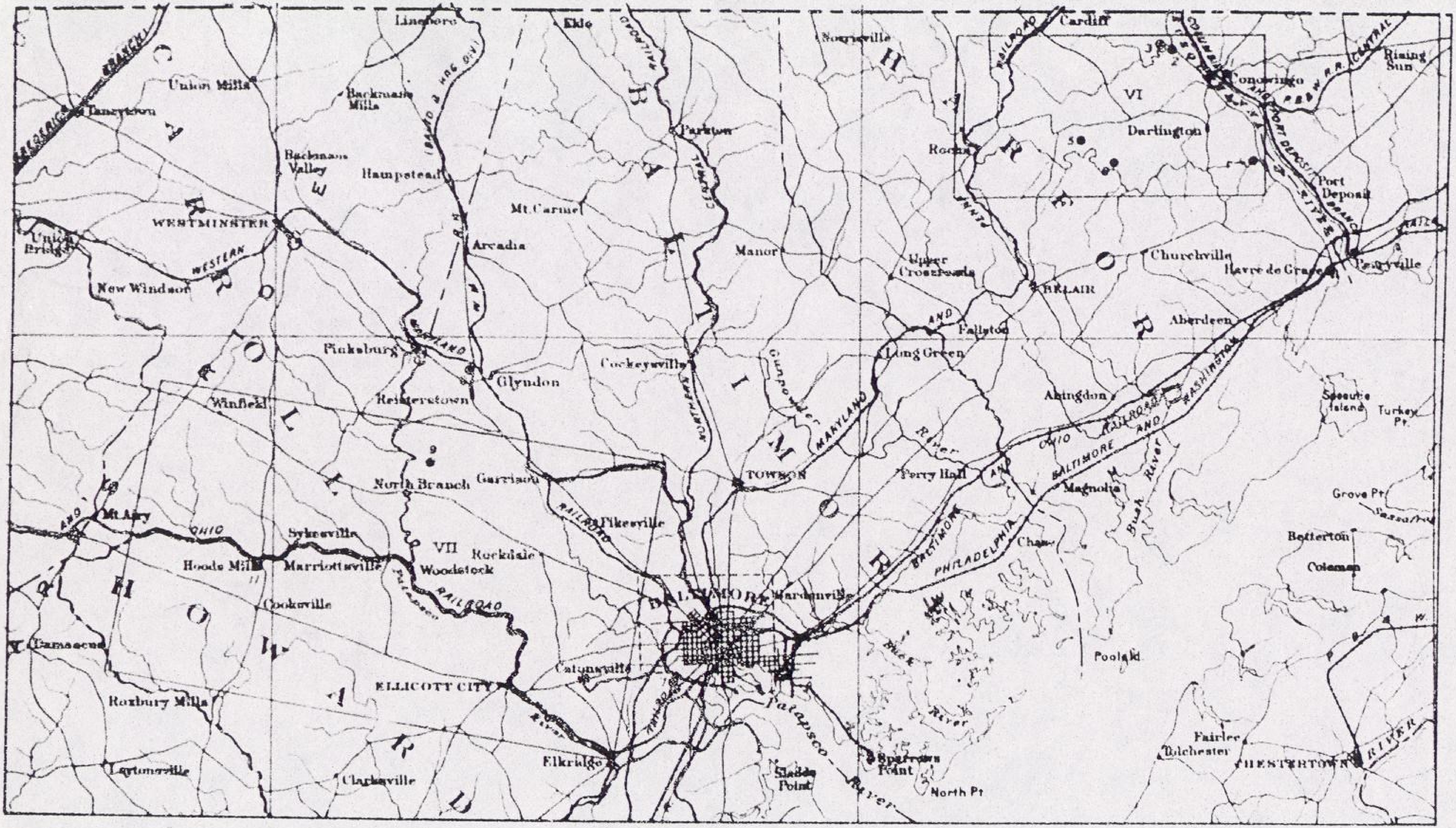
Harold Stromberg quarry (Plate IV, 89)

One mile southwest of Marriottsville on the Harold Stromberg farm is an old feldspar quarry 50 feet long, 30 feet wide, with a 20-foot face from which a highly micaceous feldspar containing white mica was quarried. About 2 years ago Albert Sandusky shipped 20 carloads of No. 2 grade from it.

Albert Sandusky quarries (Plate IV, 90)

A quarter of a mile west of Marriottsville on the Wade Warfield property, Albert Sandusky has been working feldspar for several years. The westerly of the two quarries produced 2,800 tons of first and second grade feldspar about 4 years ago. The opening followed a dike in the direction S. 30° W. into the hillside until the face was 30 feet high. The sides have caved and the dike is no longer exposed.

One hundred yards to the east, on the opposite side of a small ravine, is the opening that is being worked now. The quarry is 50 by 20 feet and 15 feet deep and is on a dike which strikes N. 40° E. and dips to the west. The east wall, or footwall side of the quarry, is fine-grained pegmatite of granitic texture. The west wall is mica schist. The



Map showing the locations of present and past Flint Mills, and positions of plates giving the location of Flint Quarries.

Scale, one inch equals eight miles

feldspar is of No. 2 grade and is sold to the Seaboard Feldspar Company of Baltimore.

Hanna quarry (Plate IV, 91)

Three-quarters of a mile southwest of Henryton on the hillside east of the State Road is a large outcrop of fine-grained micaceous pegmatite with minute red garnets. The rock was quarried for use in fertilizers during the war. The Products Sales Company, John Weetenkamp, and a Mr. Lachman successively operated the quarry.

Feazer quarry (Plate IV, 92)

A quarter of a mile southwest of Henryton on the Charles Feazer farm, Sarah C. Mitchell opened a quarry in 1917 on the outcrop of a pegmatite dike that can be traced across the Patapsco River into Baltimore County.

Melvin quarries (Plate IV, 93, 94, 95)

Three openings were made during the war on the farm of James Melvin, 2 miles southwest of Elioak, by Sarah C. Mitchell from which small tonnages of feldspar were produced. An opening beside the road, which has the dimensions 30 feet long by 20 feet wide by 12 feet deep, shows a more or less disintegrated pegmatite consisting of cream-colored graphic granite without much mica. Across a small ravine to the north is a smaller opening on another dike which has a width of 15 feet and has been worked about 30 feet up the hill slope along its strike. The rock shows an excessive amount of black mica in numerous small bunches. The northeasterly extension of this dike on the opposite side of the creek shows a much better grade of rock in which there is but little black mica. This dike has a strike N. 30° E., dip of 60° W., and a width of 30 feet. The opening at this point extends 40 feet along the strike with a face 12 feet high. On the hanging-wall side there is about 30 feet of highly pegmatized gneiss, some of which appears to be really banded pegmatite, on which work has been done in the hope of finding workable feldspar. The feldspar of this dike ranges from nearly white to deep-cream in color, and is mostly of the graphic granite variety.

The feldspar was hauled in a motor truck to Ellicott City, the nearest railroad point, a distance of 7½ miles. This is the longest haul that has been attempted for feldspar in the State.

MONTGOMERY COUNTY

Earth Products Company quarries (Plate III, 96)

Four and a half miles northwest of Laurel the Earth Products Company opened several small quarries in 1911 which they operated a short while to supply stone for a mill at the same locality. The main quarry at the foot of the hill slope on which the mill is located has a face 50 feet in length and 20 feet high. It was opened on the outcrop of a pegmatite dike which contains a large horse of contorted and crumpled schist of the same character as that forming the wall rock of the dike. The dike can be followed up the hill toward the mill in an easterly direction for about 50 feet. On the opposite side of the creek are two smaller openings and in the fields to the east and south are several pits that were sunk on small lenticular masses of pegmatite. The prospecting has revealed no deposits of any size. The feldspar is from white to pink in color and contains the usual quantity of quartz but carries much mica. Operations have been suspended since 1914.

DESCRIPTION OF FELDSPAR MILLS

Products Sales Company mill

The mill of the Eastern Flint and Spar Company on the Baltimore and Ohio Railroad at Claremont, in the southwestern suburbs of Baltimore was taken over in 1915 by the Products Sales Company and has since been thoroughly reconstructed so that it is equipped to grind a number of products including feldspar. It has a daily capacity of 65 tons. The entire mill is driven by electricity. The feldspar grinding section consists of 2 jaw crushers, a Hardinge mill, 2 Schmidt continuous-feed and discharge finishing mills, and an air separator that takes the under 200-mesh product. Besides Maryland feldspar Virginia feldspar is also ground at this mill.

Spa Nola Products Company mill (Plate IV, 53)

The mill of this company was erected in 1925 at the quarries on the John A. O'Connor farm 1 mile southeast of Ilchester in Howard County.

It is equipped with a Reliance crusher set to crush the rock to pass ¼-inch mesh. The crushed rock is elevated to a trommel with ¼-inch mesh and ¼-inch circular screens, 5-mesh, and 12-mesh screens. The oversize is returned to the crusher. The undersize of the ¼-inch screens is used for coarse pebble-dash finish on stucco buildings. The 5-mesh undersize is ground in a Griffin mill to pass 70- to 180-mesh screens. The ground product is shipped by trucks to the company's plant in Baltimore where it is used in making its Vol-K-No Mineral Cleaner, Non-Pareil composition flooring, and Carnation asbestos magnesite stucco. It is planned to enlarge the mill building and manufacture these products at the mill instead of in Baltimore. The capacity of the mill is 40 tons daily, but it has not been run continuously. It is driven by electric power.

Earth Products Company mill (Plate III, 96)

The mill of this company was located at the quarries, 4½ miles northwest of Laurel. Its output consisted of 3 sizes of chicken grit, flake mica, and pulverized feldspar. The mill was erected in 1913 and run only a short while. It is the only attempt thus far made in the State to produce chicken grit from feldspar. The mill was run by steam generated in a wood-burning boiler. The stone was brought from the quarry to the mill by an elevator that dumped into the crusher. The crushed product was elevated to the top floor and sized in a trommel with 3-, 5-, 8-, and 14-mesh screens. A Wilson tubular dust collector on this floor caught the dust and the mica flakes. On the floor below the flake mica was sacked and on the next lower floor were bins for the three sizes of grits produced by the trommel. On both of these floors and the next lower floor was a Hartz reel provided with 36-mesh wire screen, 60-mesh and 110-mesh cloth screens respectively. The main floor was used for packing the products.

THE QUARTZ (FLINT) INDUSTRY IN MARYLAND

The trade name of the variety of vitreous quartz found in veins and pegmatite dikes is flint and it is with the occurrence, quarrying, and milling of this material that the present report deals. Flint in the mineralogic sense is a cryptocrystalline form of quartz of entirely different appearance and geologic occurrence and is not considered in this report. Other commercial forms of silica, as sand, quartzite, tripoli, and diatomaceous or infusorial earth, are also of different geologic occurrence and are not included under the trade name flint, and hence are not discussed here. This last statement is not strictly true of sand, sandstone, and quartzite as these materials are now also finely ground and put on the market in competition with ground flint.

Quartz is an oxide of silicon of the formula SiO_2. Its hardness is greater than that of steel or of glass, both of which it scratches readily. It is a brittle mineral without well-defined cleavage that fractures on crushing into irregular, sharp-edged fragments. It is translucent to transparent and has a pronounced glassy luster. The common varieties range from colorless to dark-gray. The flint of the trade is massive crystalline quartz, usually white in color.

PRODUCTION

Maryland was for a number of years the most important flint-producing state. On account of fluctuations in demand and the small scale of the individual operations, the production is subject to great variation from year to year. Much of Maryland flint has been ground in mills

FLINT PRODUCTION IN MARYLAND AND THE UNITED STATES FROM 1916 TO 1926

Year	Maryland						United States					
	Crude		Ground		Total		Crude		Ground		Total	
	Tons	Dollars	Tons	Dollars	Tons	Dollars	Tons	Dollars	Tons	Dollars	Tons	Dollars
1926	*	*	*	*	4,681	47,507	22,230	159,052	5,513	115,281	27,743	274,333
1925	2,823	8,869	2,188	43,980	5,011	52,849	23,312	143,851	3,132	61,515	22,444	205,376
1924	800	2,400	1,553	32,205	2,353	34,605	20,570	124,099	3,191	89,078	23,761	203,177
1923	—	—	2,119	42,125	2,119	42,125	14,159	66,723	6,442	126,907	20,601	193,630
1922	1,416	5,256	—	—	1,416	5,256	5,085	23,093	5,568	78,254	10,653	101,347
1921	111	444	150	1,950	261	2,394	8,570	39,660	2,682	45,297	11,252	84,957
1920	875	4,798	1,386	25,790	2,261	30,588	59,423	142,397	8,767	177,953	68,190	320,350
1919	3,787	12,323	4,122	76,390	7,909	88,713	51,774	135,187	11,558	238,384	63,332	373,571
1918	6,826	22,969	2,189	24,827	9,015	47,796	61,008	121,988	10,732	137,442	71,740	259,330
1917	957	3,796	2,294	18,831	3,251	22,627	126,575	120,856	16,098	197,213	142,673	318,069
1916	4,482	13,428	2,721	18,284	7,203	31,712	70,417	78,283	18,097	164,503	88,514	242,786

* Crude and ground flint not segregated in order not to disclose production of individual operators.

within the State. Within the last decade the number of active flint-grinding mills within the State has been reduced from 5 to 1. This has resulted in a considerably reduced demand for the crude stone and complete cessation of production in some formerly active districts.

The table on page 132 gives the amount and value of crude and ground flint produced in Maryland and the United States since 1916.

USES

The principal uses of quartz are in the manufacture of pottery, as an abrasive, and as a filler. It is used in the body of pottery to diminish the shrinkage of the ware and also in many glazes. For these purposes it should contain very little iron or it will discolor the ware in burning. The angularity of the grains of finely-ground quartz makes it superior to silica sand in the manufacture of wood filler and for paints. Finely-ground quartz is used in paints in proportions up to one-third of the total pigment used.

Its hardness, brittleness, and lack of cleavage resulting in sharp angular fragments on crushing makes quartz an excellent abrasive. Crushed and sized to various degrees of fineness it is extensively used for sandpaper, sand belts, sand blasts, scouring soaps, in lithographing, etc. There is also a demand for the crude lump rock as a filler for acid towers, and in the metallurgical industry for the manufacture of alloys of silicon especially with iron and copper. Fused quartz can be molded into tubes, crucibles, and dishes that can be used in the chemical laboratory instead of porcelain and platinum utensils. On account of the small coefficient of expansion such wares do not crack when rapidly subjected to extremes in temperature.

Gravel-sizes of crushed flint are also used for roofing and stucco and to a small extent for poultry grit.

OCCURRENCE

The quartz deposits of Maryland occur as veins and dikes intersecting the country rock and as lenticular masses intercalated in schists and gneisses. In most of the deposits that have been worked the quartz occurs unmixed with other minerals. Frequently, however, it occurs as a distinctly quartzose facies of a pegmatite dike in which case it has associated with it more or less feldspar and mica. A further approach to the normal pegmatites is represented by those occurrences in which quartz is not present in predominant amount, but has segregated in part from the feldspar into masses sufficiently large to make it possible to sort out quartz at the same time that feldspar is being quarried. Little quartz has been produced in this way in Maryland, the great bulk of the production having come from the quartz dikes, veins, and lenticular masses in which other minerals occur at most as accessory constituents.

There is no sharp line of demarcation between the dikes and veins on the one hand and the lenticular intercalations. In fact all the workable deposits of the state are of limited longitudinal extent and take on the shape of a lenticular mass irrespective of what their geologic relations to the wall rock may be. In size the deposits that have been worked range from a few feet in width to masses having a width of 50 to 100 feet but the more common width is 20 to 40 feet. Most of the deposits pinch out or narrow down within a short distance along the strike—in exceptional cases only have they been worked for over 100 yards. A notable exception is the dike between Castleton and Flintville in northeastern Harford County on which there is a series of openings for a distance of more than half a mile. Quarrying operations are usually suspended before the bottom of the deposit is reached on account of the waste rock that has to be handled with increasing depth. A few of the smaller lenticular deposits have pinched out in the bottom of the quarry and some of the deposits have so flat a pitch that the depth to which they can be worked is not much greater than their width.

DISTRIBUTION

Quartz deposits of workable size are found in Cecil, Harford, Baltimore, Howard, and Montgomery counties. That is, in the eastern part of the Piedmont region. The area of occurrence is approximately the same as that of the pegmatite dikes that are worked for feldspar. These dikes are confined to this portion of the Piedmont area on account of their genetic relations to the granites of the State which occur only in that belt. Mention has been made of the transition occasionally observed between the feldspar deposits and certain of the quartz deposits. The close areal correspondence of the quartz deposits and the pegmatites suggests that such genetic connection is general. If there be any difference in areal distribution of the two types of deposits it is that the quartz deposits are a little more remote in their relationship to the granitic intrusions.

With two exceptions the largest known quartz deposits are in Harford County. The most productive section of this county and of the entire State has been that northwest of Castleton which furnished the crude stone for the Indian Rock Flint Company mill at Conowingo and that of H. Clay Whiteford Company at Flintville. Six miles to the southwest in the vicinity of Deer Creek is another group of deposits which, however, are not as large and have not been worked with the same regularity. Remoteness from railroad facilities has been a serious drawback to the Deer Creek deposits.

The producing deposits of Baltimore County are limited to the southwest corner. Only one of them, that on the Warner farm 3 miles west of Owings Mills which supplied the crude rock for the Maryland Quartz Company mill at Glen Morris, is of important size.

In Carroll County most of the flint quarries are in the southeast corner of the county in the valley of the North Branch of the Patapsco River, that is in a belt adjacent to the Baltimore County deposits. Others are in the vicinity of Hoods Mills. The only large deposit that has been discovered in this county is that to the southeast of Louisville which has been idle since the mill at Finksburg shut down in 1910.

The flint deposits of Howard County are widely scattered but on account of the position of the county with reference to railroad transportation the quarries are confined to the northern half. Most of them are small, the only large producer having been that of the Baltimore County Feldspar Company northwest of Woodstock. The largest known occurrence and a very striking one is the Annapolis Rock near the Patuxent River in the western part of the county. This is a hugh mass of white flint 250 feet long and 100 feet wide that projects abruptly above the surface to an elevation of 70 feet.

A detailed account of the individual occurrence is given by counties in a later section of the report.

QUARRYING

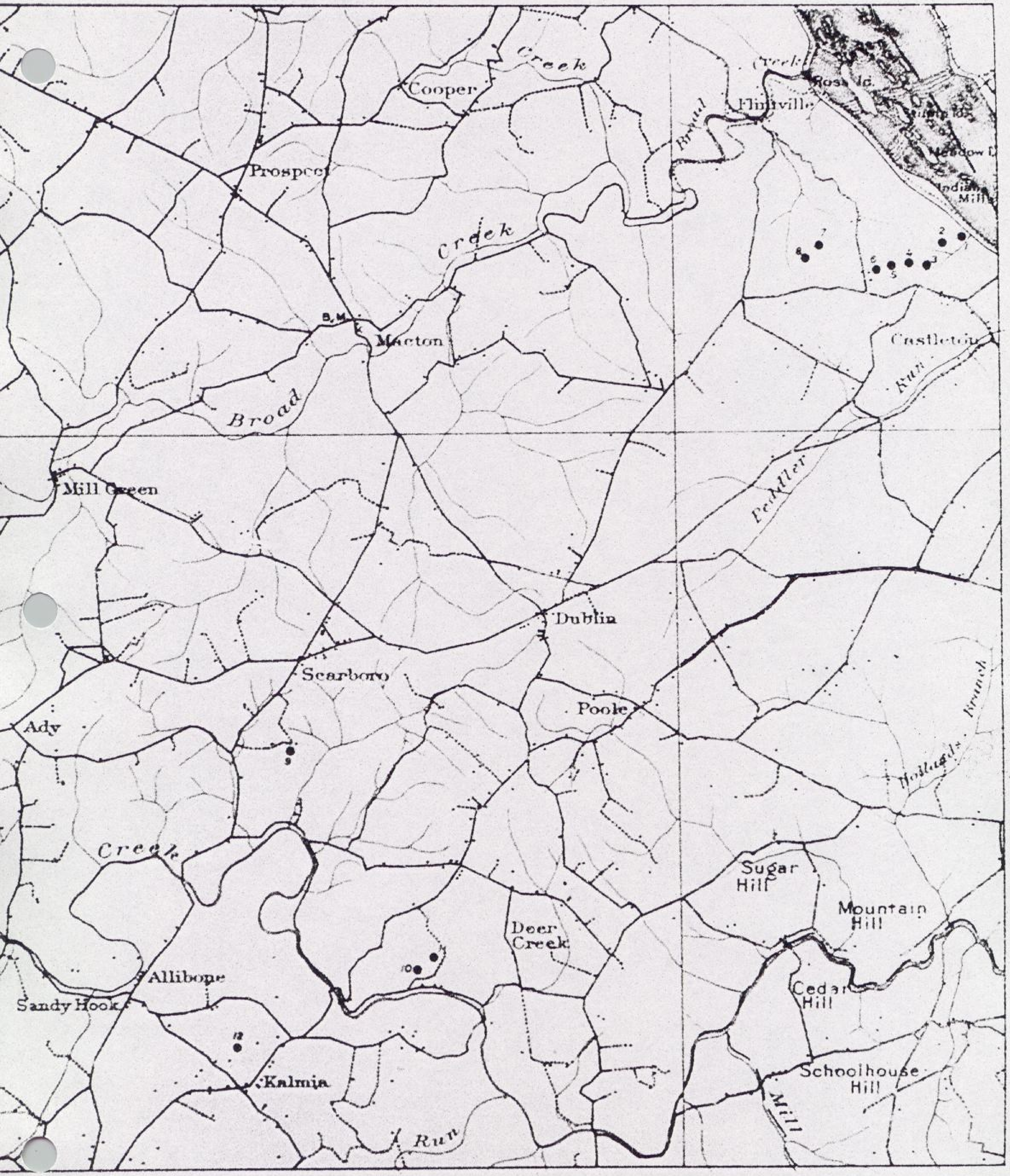
On account of the relatively small size of most of the quartz deposits the quarry equipment and the quarrying methods in use are of the simplest and most inexpensive sort. With few exceptions the prospective output from a given deposit has not been sufficient to justify a large outlay of capital. The smallest and simplest operations are those in which loose boulders of flint scattered over the surface are quarried. At many localities where there is no deposit large enough for regular quarrying operations there are numerous small intercalations and veins in the gneisses and schists. As these rocks undergo decomposition and are removed by erosion the flint remains behind and accumulates at the surface, generally partly buried in the soil. Such blocks, frequently weighing many tons, are easily broken up by blasting and sledging and at many localities are so numerous that they can be quarried on a small scale for a number of years before becoming exhausted. At other localities deposits of somewhat larger size are worked that represent material *in situ* but near the surface, which has been so thoroughly fractured and jointed that it consists of a mass of blocks that can be pried loose and broken up in the same manner. Much of the quartz output of the State has come from operations of these types. They are of course spasmodic and irregular producers.

The larger deposits require more systematic quarrying methods. Though cut by some fractures and joints they are so massive that drilling and blasting must be resorted to. In one or two instances steam drills have been installed but the usual method is by hammer and moil. The large blocks are then broken up with sledges to sizes easily handled.

In the smaller quarries the broken rock is taken out in wheelbarrows to a stock pile. When a car load has accumulated it is hauled to the nearest shipping point. In large operations carts are used for hauling

Location of Flint Quarries in part of Harf

Scale, one inch equals one mile



Flint Quarries in part of Harford County.

Scale, one inch equals one mile

the stone out of the quarry to the stock pile. Several of the largest quarries have been provided with tramways for removing the rock from the quarry to the stock pile. Recently motor trucks have come into use for hauling the stone to the railroad but as a rule the operations are not on a scale sufficiently large or continuous to keep a motor truck regularly employed.

A small amount of cobbing has to be done to remove stained and discolored portions of the rock. That intended for pottery use must be more carefully cleaned than the rock used for sandpaper and abrasive purposes. The sorting is done at the time the larger blocks are broken up by sledging but the amount of material rejected is not nearly so great as in the feldspar quarries.

Milling

Two processes are in use for the preparation of ground quartz, the wet and the dry. Though there is more or less variation in the machinery used and in the flow sheet of the different mills the general mode of procedure is similar in all mills using the same process.

In the mills using the wet process the quartz is usually highly heated in kilns in order to induce incipient fracturing and thereby facilitate the subsequent crushing and grinding. In that event a crusher may be dispensed with and the quartz fed at once to chaser mills. Only enough water is added to the rock to keep down the dust. If the mill produces "bitstones" or grits, the product of the chasers is screened into the desired sizes, the oversize is returned to the chasers, and the undersize goes to the grinding pans. If none of the coarser products are made the crushed material goes at once from the chasers to the grinding pans. The grinding pans are shallow vats with a pavement of flat-faced blocks of quartz over which several large blocks of the same material move. These grinding surfaces require renewal about once in six months. The charge of the grinding pan is about ¾ ton and is ground about 24 hours. Whatever power may have been used for the rest of the mill the grinding pans in all the Maryland mills were run by water power. When the grinding is completed the pulp is run into a trough, the settlings from which are usually reground, and then into a settling tank or series of settling tanks according as one or more grades of ground flint are produced. From the settling tanks the material is shoveled on drying floors a common type of which is a horizontal coil of steam pipes. Shipment of the ground quartz is made either in bulk or in bags.

In the mills using the dry process the quartz is usually crushed first in a jaw crusher and then between rolls. If a large quantity of the coarser sizes is desired, the grits and bitstones, screening and bolting may follow immediately and the oversize recrushed. If a larger percentage of finely-ground material is desired the crushed quartz is first ground in tube mills, of which both the continuous and the intermittent types are in use. The powdered material is sized either in some form of bolting apparatus or by a pneumatic process whereby the quartz is carried by a strong air current to distances dependent upon its fineness.

In a subsequent section details are given of the equipment of Maryland flint mills.

ECONOMIC ASPECTS OF MARYLAND FLINT INDUSTRY

Except in the case of several of the companies operating flint mills which also owned their own flint quarries, the quarries are worked on a royalty basis. Though the royalty paid ranges from 20 to 50 cents per ton the rate is almost uniformly established at 25 cents per ton, irrespective of size of the deposit, quarrying conditions, and location.

On account of the small scale and intermittent character of the operations it is difficult to arrive at figures for the cost of quarrying. When the quarrying is done by contract the contract price usually includes the charge for hauling, without attempting to separate the two items. Among the factors that play an important rôle in determining the cost of quarrying are the size of the deposit, the scale of the operations, the amount of overburden to be handled, and the amount of cobbing necessary. Under the average conditions existent at Maryland flint quarries the cost of quarrying is from $1.00 to $1.50 per ton.

The cost of hauling the quartz from the quarry to the railroad or to the mill shows considerable variation. As a rule the shorter the haul the higher the rate per mile since the delays incident to loading and unloading are incurred irrespective of the length of the haul. The grade of the roads is an important factor. Hauls over steep roads are far more expensive than over more level roads since the loads must be much lighter. Where an improved road is available the cost is lower than over a dirt road which during a part of the year may even be almost impassable for heavy teams and trucks. The rapid construction and extension of the system of improved roads is of immense value in making available flint deposits that otherwise would be of no value on account of their inaccessible location. Several of the larger flint deposits are located so far from a railroad or mill that they can not now be successfully worked. Improved roads making possible the utilization of motor trucks will reduce the haulage charges sufficiently to make these deposits available. The prices paid for the shortest hauls, that is, less than one mile, range from 30 to 50 cents per ton. For hauls of 2 to 4 miles about 40 cents per mile is charged. For hauls of greater length, up to the maximum that has been attempted, about 10 miles, as much as $2.00 per ton has been paid. Motor trucks operating over good roads can reduce the cost of long hauls to 20 cents or less per ton.

The value of the crude flint depends to some extent on the uses to which it is put. At the Maryland mills it has a value of $3.50 to $4.00 per ton. The principal extra-state purchasers have been the Eureka Flint and Spar Company of Trenton, Golding Sons Company of Trenton, and sandpaper factories at Williamsport and Philadelphia. The prices paid by these companies are $2.75 to $3.00 per ton f. o. b. cars. Flint intended for sandpaper manufacture need not be so carefully sorted as that intended for the mills that grind pottery flint, and the former are now the chief purchasers of the crude flint shipped out of the State. The lump flint used in packing acid towers brings a higher price, usually $4.00 to $6.00 per ton and even as much as $8.00 largely for the reason that the demand is seasonal and hence the operator in a position to supply the demand can command a higher price. The usual range in size of flint used for this purpose is from a minimum of 4 to 6 inches to a maximum of 10 to 14 inches, though smaller sizes are also used. The requirements are simply for a moderately clean material.

The value of the milled product depends to a large extent on its degree of fineness. The coarser sizes, the grits and bitstones, sell for about \$18.00 to \$22.00 per ton. The finer sizes, or ground quartz, sell from \$20.00 to \$25.00 per ton. The price obtained seems to depend to a large extent on the operator's ability to find the higher-price market.

Quartz flint has had a keen competitor in recent years in sand flint produced from sand and sandstone which is marketed at lower prices. It can be used for many of the purposes for which quartz flint has been used and has restricted the market for the latter. Hence no immediate improvement in the Maryland flint industry can be expected.

DESCRIPTION OF DEPOSITS

The localities described in this section of the report by no means include all the flint deposits of the State, but represent the present or recently active quarries together with some of the more important older quarries. There are many other deposits in the regions in which these occur and Maryland can easily maintain and even exceed her production in the past for an indefinite period.

HARFORD COUNTY

Indian Rock Flint Company quarries (Plate VI, 1, 2, 3, 4, 5, 6)

The quarries of the Indian Rock Flint Company are situated about a mile north of Castleton and extend westward from the Susquehanna River in a belt about a mile long. The quarry nearest the river has not been worked for several years. It is located at the east end of a mass of flint elongated in the direction N. 70° W. The quarry is about 50 feet wide and has been driven about 50 feet into the hill to a face 30 to 40 feet high. Flint is still exposed in all the walls. The next quarry has also been idle for a long time. The opening extends for 200 feet in the direction N. 80° W., is 50 feet wide and 50 feet deep, and likewise has flint exposed on all the walls. The flint in this opening has a more glassy luster than most of the flint of this locality.

The third opening has been the active one. Its long dimension has the direction N. 65° W. and its size is 300 feet by 100 feet by over 50 feet deep. The flint exposed in it shows considerable variation in appearance, ranging in color from dark shades to white and in texture from glassy to granular though not friable. The output has been used for the mill at Conowingo and for packing acid towers. The stone for the acid towers was sorted from the material on the dump. The quarry was active until a year ago and several hundred tons of flint are accumulated on the stock piles.

West of the quarry last described is a very old quarry known as the Stokes quarry which has a long dimension of 200 feet in the direction N. 50° W., a width of 50 feet and was worked in two levels each about 25 feet deep. Another very old quarry west of the Stokes quarry extends 300 feet in an east-west direction and is 75 feet wide and 40 feet deep. Both of these quarries were at one time equipped with tramways. At the west edge of the quarry is an outcrop of very saccharoidal flint that weathers like quartzitic sandstone, which has a width of over 100 feet. On the opposite side of the outcrop is a sixth large opening about 200 feet long, and beyond it is a smaller one.

H. Clay Whiteford and Company quarries (Plate VI, 7, 8)

The quarries of this company are located about a mile west of the Indian Rock Flint Company quarries. The old quarry which was abandoned in 1916 is about 500 feet long, 30 feet wide, and was worked in two levels to a depth of 50 feet. The stone was brought out of the quarry on a tramway. On the west side of the knoll on which this quarry is located is the new quarry which was opened in 1916. When visited in 1917 it extended into the hill 100 feet, was 30 feet wide and the face 15 feet high. The rock has a bluish tone and a distinctly vitreous luster. That from the old quarry is said to have been of the same character, which is quite different in appearance from that of the Indian Rock quarries. The wall rock of the old quarry is a talcose schist. In the new quarry the wall rock was not yet exposed. Four men were employed at the quarry and it was producing at the rate of 1000 tons annually in 1917. The stone was ground at the mill at Flintville to which it was hauled in wagons.

Klondike quarry (Plate VI, 9)

The Klondike quarry, located 1 mile south of Scarboro, was worked for a short time about 25 years ago to supply stone to the Klondike mill which was located a quarter of a mile west of the quarry. It is a narrow opening several hundred feet long, the width varying from 10 to 30 feet and the depth from a few to 20 feet. The deposit seems to have been a narrow flint vein with a strike N. 80° W. near the top of the south slope of the hill. The flint is of the common white vitreous type.

Husband Flint Milling Company quarries (Plate VI, 10, 11)

The quarries of the Husband Flint Milling Company are situated on the hill above the site of the company's mill and consist of two large openings with several small pits between them. They are located on a quartz vein with a strike N. 60° E. and a steep southeast dip of about 30 feet. The larger opening runs into the hillside about 300 feet and at the face is 40 feet deep of which 10 to 15 feet is overburden. The vein shows several horses and intercalations of the country rock, to the schistosity of which it is parallel. The wall rock consists of sericitic and more basic chloritic schists together with some fine-grained pegmatite on the south wall. The other large opening lies to the northeast and has a length of 200 feet. The quartz is of the usual whitish vitreous type. The quarries were worked on contract to supply stone for the company's mill on Deer Creek.

Lochary quarry (Plate VI, 12)

On the farm of T. W. Lochary, one-half mile north of Kalmia, is a large knob of flint in which there is an opening about 100 feet in diameter and 30 feet deep. The flint outcrops without overburden and is exposed in all the walls of the quarry. It is of the white glassy type, here and there somewhat iron stained near the surface but white and clear in the lower part of the quarry. The quarry was opened over 45 years ago to supply stone for the Husband mill. Later crude stone was shipped, and when worked last about 22 years ago it supplied stone for the Klondike mill.

Crowl quarry (Plate VI, 13)

One mile northeast of Fern Cliff Station on the Maryland and Pennsylvania Railroad is a flint quarry on the farm of James M. Crowl. The opening which is 125 feet long, 25 feet wide and 30 feet high at the face, was made on the eastern edge of a knob of flint about 300 feet long in an east-west direction and 150 feet wide. Numerous large flint boulders and outcropping ledges across the gully on the west side of the knoll indicate an extension of the deposit in that direction. The flint is a good grade white vitreous material. The quarry was worked about 40 years ago under lease by Stokes for his mill at Stafford on the Susquehanna River. This necessitated hauling the flint to the railroad at Fern Cliff, shipment north on it, and then by boat down the Susquehanna and Tidewater Canal to Stafford. After the canal was abandoned a small quantity of rock was shipped to Trenton but the quarry has been idle for the last 38 years.

BALTIMORE COUNTY

Minckins quarry (Plate VII, 14)

In the midst of feldspar openings on the David Minckins farm, now owned by Oval Smoot, is a ledge of vitreous flint with a low dip into the hill. A thickness of 8 feet is exposed. The rock shows a tendency to banding due to streaks with sparsely disseminated minute grains of garnet. A small amount of flint was quarried here several years ago. The location 1½ miles north of Alberton.

Smoot quarry (Plate VII, 15)

On the Franklin Smoot farm, 1½ miles northwest of Alberton, are a series of large outcrops of white vitreous quartz in a line N. 30° E. which appear to be residual masses from the weathering out of a zone of quartz lenses interbedded with the schists. A car load of flint was quarried from these in 1916.

Worthington quarry (Plate VII, 16)

A small amount of flint has been quarried on the Dall Worthington farm three-quarters of a mile southeast of Granite, by O. B. Gibons.

Sandusky quarry (Plate VII, 17)

August Sandusky shipped a small quantity of flint in 1917 from loose blocks on his farm 2½ miles northeast of Marriottsville.

Baer quarries (Plate VII, 18)

There are two flint quarries on the Gottlieb Baer farm 2 miles northeast of Marriottsville. The older opening has the dimensions 100 feet long by 40 feet wide by 30 feet deep and was apparently a mass of quartz intercalated in the country rock. It is now worked out. Adjoining this opening is a second, 40 feet long by 25 feet wide with a 20-foot face. The deposit is a wide lens of flint with thin schist intercalations in a wall rock of contorted schist. The quarry was at one time producing 10 to 15 cars annually which were shipped from Marriottsville to the U. S. Sandpaper Company at Williamsport, Pennsylvania. In the last few years it has been worked only occasionally on a small scale.

Green quarry (Plate VII, 19)

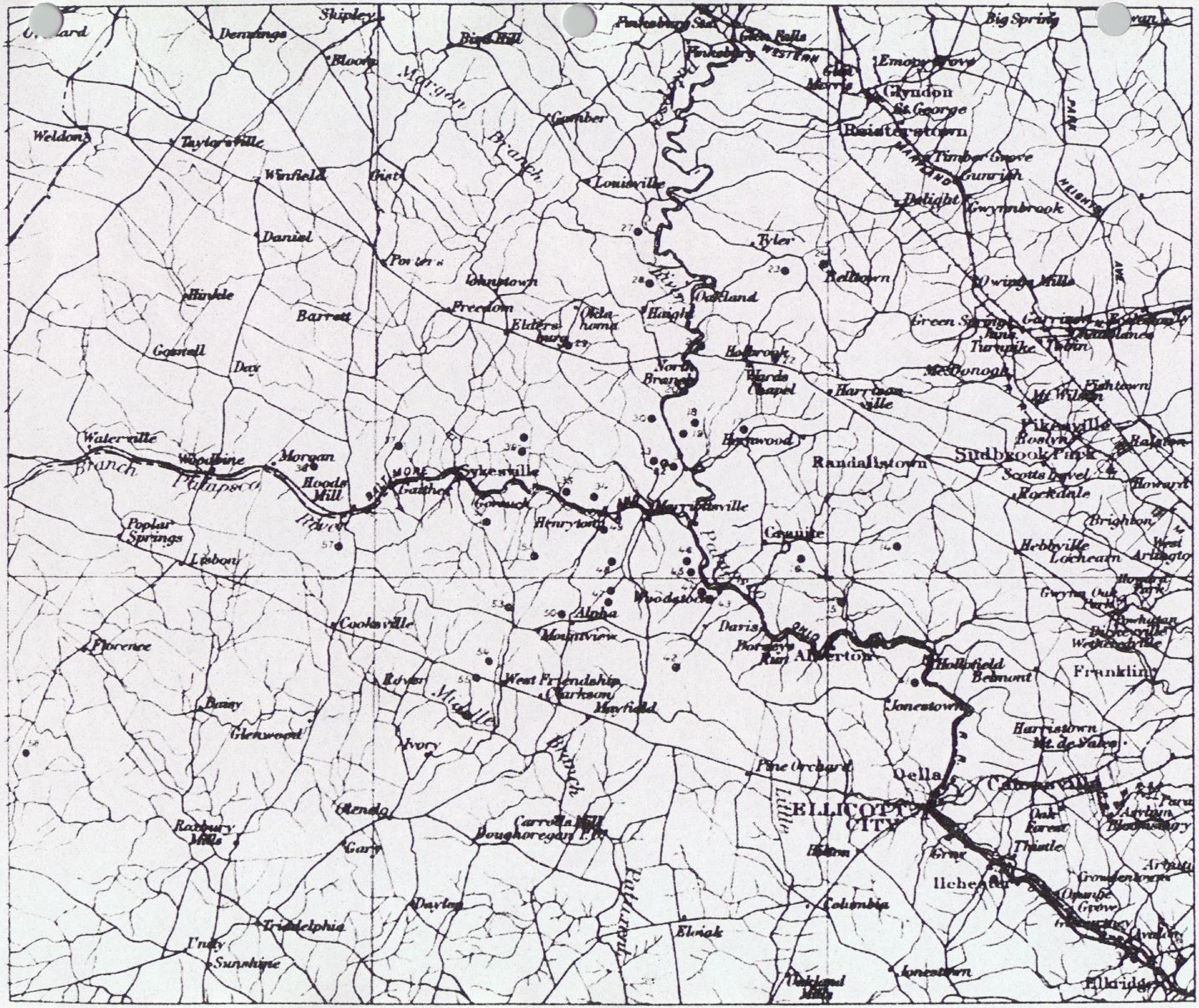
D. W. Green, half a mile west of the Baer quarries, shipped a small amount of flint in 1916 from loose blocks scattered over the surface of his farm.

Anton Reisberg quarry (Plate VII, 20)

Flint has been worked at several places on the Anton Reisberg farm along the hillside overlooking the North Branch of the Patapsco River, about one mile south of North Branch. The quarry now being worked has been recently opened on a vein showing a width of 30 feet without exposing either wall. The quartz is cut by parallel planes of parting with the direction N. 45° E. 75°. It is a white vitreous flint with somewhat coarse granular texture. The outcrops along the strike can be followed up the hill beyond the limits of the opening.

Koiner quarry (Plate VII, 21)

A quarter of a mile northeast of North Branch, on the D. M. Koiner farm, August Sandusky opened a flint quarry in the spring of 1917 from which he shipped a few carloads. The opening was 25 feet wide and 20 feet high at the face. The rock was hauled in a motor truck to


Shipley
Dennings
Big Hill
Finksburg Sta.
Finksburg
Glen Falls
Glyndon
St. George
Reisterstown
Timber Grove
Gunrith
Delight
Gwynnbrook
Big Spring
Emory Grove
Glen Morris
Western
Maryland
Morgan
Branch
Gamber
Weldon
Taylorsville
Winfield
Louisville
Daniel
Porters
Tyler
Reltown
Owings Mills
Johnstown
Freedom
Eldersburg
Oklahoma
Hugh
Oakland
Hinkle
Barrett
Gosnell
Day
North Branch
Holbrook
Wards Chapel
Harrisonville
McDonogh
Green Spring
Garrison
Turnpike
Mt Wilson
Pikesville
Roslyn
Sudbrook Park
Scotts Level
Rockdale
Brighton
Ralston
Waterville
Woodbine
Morgan
Hoods Mill
Patapsco
Branch
River
Baltimore
Sykesville
Gaither
Gorsuch
Henryton
Marriottsville
Hollywood
Randallstown
Granite
Hebbville
Lochearn
West Arlington
Poplar Springs
Lisbon
Woodstock
Alpha
Cooksville
Mountview
Davis
Alberton
Hollofield
Belmont
Franklin
Florence
West Friendship
Clarkson
Mayfield
Jonestown
Harrisstown
Mt. de Sales
River
Middle
Branch
Daisy
Glenwood
Ivory
Pine Orchard
Oella
Catonsville
Ellicott City
Little
Glenelg
Carrolls Mill
Doughoregan P.O.
Roxbury Mills
Gary
Ilton
Thistle
Ilchester
Oak Forest
Orange Grove
Dayton
Columbia
Triadelphia
Unity
Sunshine
Elioak
Patuxent
Oakland Mills
Jonestown
Elkridge

Sykesville, a distance of 7 miles, and shipped to the U. S. Sandpaper Company at Williamsport, Pennsylvania.

Allens Lane quarries (Plate VII, 22)

John Baer and Walter O'Dell have been quarrying residual masses and loose boulders of flint in several fields north of the Liberty Road, half a mile east of Wards Chapel at Allens Lane. No ledge in place has been encountered. The individual openings have yielded several hundred pounds to several tons of flint.

Warner quarry (Plate VII, 23)

The Warner quarry, 2½ miles northeast of North Branch, was leased by the Maryland Quartz Company and worked to supply flint for its mills at Glen Morris, 4½ miles northeast of the quarry. The flint vein has a strike N. 35° E. and dips nearly vertical. It is 35 feet wide and the opening on it has a depth of 30 feet and a length of 125 feet. The quartz is in bands parallel to the strike and dip, ranging in thickness from a few inches to several feet, and between which there are occasionally narrow horses of country rock schist. A smaller opening immediately to the northeast has followed the vein for 75 feet to a depth of 15 feet, but it shows a width of only 4 to 5 feet. The wall rock is a soft green talcose rock which is foliated parallel to the vein walls.

Yox quarry (Plate VII, 24)

William Yox has been quarrying flint about 2 miles southwest of Soldiers Delight. A vertical vein with a strike N. 65° E. has been followed for 150 feet. It has a width of 20 feet. The quartz is white, vitreous, and massive to coarse granular in texture. Locally there is a small amount of blackish-green tourmaline that follows irregular undulating surfaces traversing the quartz. The vein cuts the schistosity of the mica schist wall rock.

Charles B. Gillett quarries (25)

Charles K. Hughes is producing a small amount of flint from a number of small openings in a tract of woodland 1 mile east of Glyndon and five-eighths of a mile northeast of St. George. It is a clear-white flint with vitreous luster. About 150 tons have been shipped to the Glen Morris mill. The flint occurs as residual masses at the surface and in stringers and small lenses closely spaced in decomposed mica schist. The locality is outside the area of Plate VII.

Fritch quarry (26)

A mile and a half east of the bridge across the Gunpowder Falls on the north side of the Ashland-Jacksonville road, on both sides of a small ravine, are abundant outcrops of white vitreous quartz indicating the existence of a large flint deposit. Due to an abundance of iron-stained fractures in most of the float the outcropping flint is of an inferior quality. A Mr. Fritch of Glyndon shipped a small quantity to the Glen Morris mill in the summer of 1927 but the iron stain proved objectionable. It is probable that if the deposit were opened up to greater depth flint free of iron stain would be encountered. The locality is outside the area of Plates VI and VII.

CARROLL COUNTY

Brauning quarries (Plate VII, 27)

A large deposit of flint on the John Brauning farm, 1¾ miles north of Haight, was the principal source of raw material for the mill of the Maryland Silicate Mills Company, formerly located at Finksburg Station, over 5 miles to the north. The two largest openings are at the southwest end of the deposit, and for a distance of half a mile in the direction N. 30° E. the ground is thickly strewn with large blocks of flint and outcropping ledges. The deposit appears to consist of a group of quartz bands and lenses with flat easterly dip, intercalated in mica schist. The lower opening at the southwest end is 100 feet long, 30 to 40 feet wide, and has a face about 20 feet high. The upper opening is a little longer but is now filled to a large extent with waste rock. A few smaller openings have been made along the outcrop farther to the northeast. The quartz is for the most part a clear vitreous white rock. At the surface it is more or less stained but the rock beneath is of good quality. The quarries have not been operated since the mill shut down in 1910.

Bennett quarry (Plate VII, 28)

Three-quarters of a mile north of Haight on the Frank Bennett farm, R. H. Williams opened a small flint quarry about 20 years ago and shipped 4 or 5 car loads to Golding Sons Company. In the spring of 1917 August Sandusky again took out a car load which he shipped to the U. S. Sandpaper Company. There are two small openings, a lower one 30 feet by 15 feet by 6 feet deep, and the upper one 12 feet in diameter by 4 to 5 feet deep at the nose of a ridge showing a great deal of loose flint at the surface. The stone in the openings consists of closely spaced loose blocks. It is the usual white vitreous flint.

Ruch quarry (Plate VII, 29)

A mile and a quarter east of Eldersburg, Paul Ruch and Sons commenced quarrying flint in the winter of 1917 shipping several cars to the U. S. Sandpaper Company. The deposit consists of an aggregate of large boulders of pure white vitreous quartz scattered over an area about 200 feet in diameter. The greatest difficulty in quarrying is that the boulders lie in a marshy flat where the water is a great impediment. The rock was hauled to Sykesville in a motor truck, a distance of 4½ miles. The capacity of the truck was 3 to 4 tons and it made 4 to 5 trips daily.

Flint quarry woods (Plate VII, 30)

Considerable flint has been shipped from time to time from a locality 2 miles north of Marriottsville, known as the flint quarry woods. There are no large openings here and most of the output appears to have come from loose blocks found on or near the surface.

Oursler quarries (Plate VII, 31, 32, 33)

H. I. Oursler opened three flint quarries on his farm 1 mile north of Marriottsville from which he was shipping about 3 cars monthly in 1917 for use in sandpaper factories. The easterly one of these was 30 feet wide and extended 40 feet into the hillside. Flint was exposed on all the walls of the opening in large blocks but was not encountered in place. The middle opening was on a large mass of quartz in a pegmatite dike 30 feet wide with a strike N. 35° E. and characterized by an abundance of mica. The westerly quarry was on a lenticular body of quartz with N. 30° E. strike and 70° W. dip which had a length of 40 feet and a maximum width of 6 feet. Numerous loose blocks of flint scattered over the property were also gathered up and shipped.

Richardson quarry (Plate VII, 34)

H. I. Oursler shipped in 1917 several carloads of flint from the J. R. Richardson farm, one-half mile west of Henryton. This came chiefly from loose blocks on the slopes of the hillside of a small ravine. It was loaded at a siding at the mouth of the ravine from which soapstone quarried on this property is shipped.

Wesley Baker quarry (Plate VII, 35)

One mile down the river from Gorsuch on the east side of the ravine on the Wesley Baker farm is a small quarry on an 8-foot quartz vein which strikes east and west and dips steeply to the north. About 50 cars of flint are said to have been taken from this quarry and residual masses in the fields in the vicinity in the last 3 years.

Emma Feazer quarry (Plate VII, 36)

Residual masses of flint have been quarried during the last 2 or 3 years at a number of places on the farm of Mrs. Emma Feazer 1½ miles east of Sykesville.

Ruby quarry (Plate VII, 37)

Three-quarters of a mile north of Gaither on the J. H. Ruby farm, is a flint quarry 150 feet long, 60 feet wide, and 20 feet deep that was worked years ago and from which a number of car loads were obtained in 1916 and 1917 by R. E. Day, J. H. Ruby, and George Wheatley. These were shipped to the Products Sales Company, the Eureka Mining and Operating Company, and the U. S. Sandpaper Company. The deposit consists of a mass of closely crowded loose blocks of flint. Many such blocks are also scattered over a wide area about the opening. The rock is whitish vitreous flint of good quality. An unusual feature of some of it is that it carries small flakes of molybdenite, the only locality at which this mineral was seen in Maryland quartz deposits.

Trayer farm (Plate VII, 38)

One mile northwest of Hoods Mills on the Trayer farm is an old flint quarry that was worked 30 years ago for the flint mill then operated at Hoods Mill. A little stone was again quarried here 10 years ago.

HOWARD COUNTY

Lawyers Hill quarry (Plate VII, 39)

A quartz vein at least 10 feet wide and extending in a direction S. 30° W. up the slope of the hill, with a northwest dip, has been worked for a distance of about 150 feet along the strike. It appears to be a local lens intercalated in the gneiss, with other smaller ones occurring in the vicinity. There are also a number of large flint blocks in the bed of the stream at the foot of the hill. The stone was hauled to Avalon, half a mile north of the quarry, for shipment. The quarry was worked in 1917 by George Wheatley.

Thomas quarry (Plate VII, 40)

About 2 carloads of flint were shipped in 1915 by John Thomas from a small quartz vein one-half mile west of Ilchester. The vein has an east-west strike and flat southerly dip and is only 2 to 4 feet wide.

Fagan and Highe quarries (Plate VII, 41)

A few carloads of quartz have been shipped from several small deposits on properties owned by E. E. Fagan and F. C. Highe 1 mile southwest of Hollofield. One of these is a vein less than 2 feet wide in mica schist, with a direction N. 20° E. 40° E. The others are merely lenticular pockets in the schist.

Howard Smith quarry (Plate VII, 42)

Two miles south of Woodstock on the farm of Howard Smith, John R. Oursler quarried a small amount of flint from residual masses in the spring of 1927.

Zepp quarries (Plate VII, 43, 44)

John Cavey shipped about 500 tons of flint in 1917 from several openings on the J. B. Zepp farm west of Woodstock. An opening near the top of the hill exposed a quartz vein with a strike N. 45° E. which had a width of 10 feet at the surface but pinched out in a depth of 20 feet. It was followed 140 feet along the strike. Northwest of this opening, lower down the slope of the hill on the line between Zepp and George Cavey, another dike was opened for a distance of 40 feet. It had a width of 20 feet. Considerable cream-colored feldspar was associated with this quartz. Several carloads of quartz have also been taken from pockets of residual flint in the field at the top of the hill.

Baltimore Feldspar Company quarries (Plate VII, 45, 46)

The Baltimore Feldspar Company worked a flint quarry 1 mile northwest of Woodstock about 1915. The deposit consists of a quartz vein with a strike a little east of north and dip of 30° west, a dip in the same direction as the hillslope down which it was worked for about 60 feet. At the north end of the quarry the vein is 6 feet wide and at the south end 1 foot. It would appear that the deposit was a flat-lying lens of quartz of which only the narrow peripheral portions remain in the walls of the quarry. The quarry was equipped with steam drills.

A short distance above this quarry on the top of the ridge is a small quarry in which more or less feldspar is associated with the quartz. About three-eights of a mile to the north and also on the top of the ridge are two openings about 25 feet in diameter which seem to be located on lenticular pockets of quartz. In 1917 Harry E. Perry had the property under lease and was shipping about a carload a month to sandpaper manufacturers.

Herbert Crooks quarry (Plate VII, 47)

One mile east of Alpha, on the Herbert Crooks farm, Albert Sandusky has been quarrying flint. Most of the production came from isolated outcropping masses in the fields. The main opening is on an outcrop of clean, white, vitreous quartz. This quarry is 15 feet in diameter and 7 feet deep.

Harold Stromberg quarry (Plate VII, 48)

A small amount of flint has been taken out by Albert Sandusky in the woods on Harold Stromberg's farm, 1¼ miles southeast of Marriottsville.

Lee Rendu quarry (Plate VII, 49)

A half mile southwest of Henryton on the east side of the State Road is an old flint quarry on an 8-foot vein of massive vitreous quartz which has the direction N. 30° E. 75° W. The walls are mica schist. Near the walls the quartz includes streaks of mica and at the walls is a thin band of quartz, mica, and tourmaline needles. A small amount of rock was quarried here about 3 years ago by Lee Rendu.

Richard Williams quarry (Plate VII, 50)

On the Richard Williams place at Alpha, John Hackett has been quarrying residual masses of flint exposed in the fields.

Day quarry (Plate VII, 52)

R. E. Day opened a quarry 1¼ miles southeast of Sykesville in the fall of 1916 which he still works intermittently. The quarry extends for 75 feet along the strike of the vein which is N. 70° E. It dips 60° S. into the hillside. The face is 15 feet high and shows mica schist at the top or on the hanging walls. The footwall is not exposed. The width of the vein is over 12 feet. The quartz is of the massive, white, vitreous variety.

Iglehart quarry (Plate VII, 53)

A half mile northwest of Mountainview Albert Sandusky has recently quarried flint on the Iglehart farm. An opening on the east side of the road has been filled in. On the west side, south of the house, is a quartz vein striking N. 55° E. on which two pits 8 to 10 feet deep expose massive, white vitreous quartz. On the Ed. Ridgely place adjoining the Iglehart farm on the north, John Hackett quarried residual masses of flint that outcropped in the fields.

Harry Akers quarry (Plate VII, 54)

A quarter of a mile north of West Friendship on the Harry Akers farm, Ed. Haskett recently quarried outcropping masses of quartz in the fields.

Ridgely quarry (Plate VII, 55)

In the fall of 1916 R. E. Day opened a small flint quarry on the F. Ridgely farm a half mile west of West Friendship from which he shipped 3 carloads of flint that was hauled by motor truck to Sykesville, a distance of 5 miles. The rock here is not *in situ* but there are a number of huge blocks of flint sticking out of the ground over an area of 150 feet in diameter. The quartz is coarsely granular and somewhat friable.

Hudson quarry (Plate VII, 56)

A half mile southwest of the Ridgely quarry and on the F. Ridgely farm James Hudson got out a carload of flint in the fall of 1916. There are numerous ledges of flint outcropping here none of which seem to represent masses of any longitudinal extent though some are 10 feet or more in thickness. The rock is more or less granular with a tendency to be friable and some of it has a yellowish tone.

Beck quarry (Plate VII, 57)

Three-quarters of a mile south of Hoods Mills on the William Beck farm the Products Sales Company was operating a flint quarry in 1917. The quartz vein strikes N. 40° W. and dips 40° W. and had been opened for 150 feet along the strike to a depth of 30 feet. It is enclosed in a talcose schist country rock and has a total width of about 25 feet. The quartz occurred in several bands which swelled and pinched and branched irregularly, separated by horses of schist. The rock was taken out of the quarry on an inclined tramway. Work was not carried on continuously but only when there was a demand for rock for packing acid towers for which purpose the output of this quarry was chiefly used. The production had been about 40 carloads in 2 years.

Annapolis Rock White Quartz quarry (Plate VII, 58)

By far the largest deposit in Howard County and one of the largest in the State, is that known as Annapolis Rock 2½ miles south of Florence near the Patuxent River. It is a large mass of white vitreous quartz with a length of 250 feet in the direction N. 25° E., 100 feet wide, and

with a sheer rise above the surrounding rocks of about 70 feet. The mass terminates abruptly at each end and seems to be an enormous lenticular body. The striking character of the deposit is shown in the photograph, Plate VIII. The quality of the rock is excellent and the quarrying conditions ideal but unfortunately the deposit lies 7 miles from Woodbine, the nearest railroad point. A 6-acre tract which includes the deposit was purchased in 1916 by W. I. Dunkel who worked it for a short while at that time, supplying lump flint for packing acid towers. Thirty or more years ago the deposit was worked by S. P. Dunkel who then had a flint mill at Hoods Mills under the name Patapsco Flint Mill Company.

DESCRIPTION OF FLINT MILLS

The recently-active flint mills are here described and in addition a brief account is given of some of the older mills no longer in existence. Ten years ago 5 mills were grinding flint in Maryland. One was located in Cecil County but ground flint from Harford County, 2 in Harford County, and 2 in Baltimore County. The mills in Cecil and Harford counties have since suspended operations. One of the Baltimore County mills was devoted only in part to flint grinding and no longer grinds flint. The mill at Glen Morris, Baltimore County, is the only one now in operation. The locations of the mills are given in Plate V.

CECIL COUNTY

Indian Rock Flint Company mill (Plate V, 1)

This mill was located at Conowingo. It was equipped for operation by steam and by water power. After being roasted in kilns the flint was passed successively through a jaw crusher, a chaser, and over screens. The screens separated three sizes of roofing material called Nos. 6, 8, and 12, corresponding to material held on 8, 10, and 20 mesh screens respectively. This material was bagged for shipment. The fines went to 2 grinding pans, each of which ground a 2-ton charge for 24 hours. There was also a tube mill with flint lining and flint pebbles for grinding the fines. The discharge from it fed one grinding pan continuously and the pan was emptied as soon as filled. The coarse part of the discharge from the pans was settled in a trough and reground. The pulp from the trough was run to settling tanks for dewatering, after which it was dried on steam coils and sacked for shipment. The mill has been dismantled recently as its site is to be flooded by the Conowingo dam.

HARFORD COUNTY

H. Clay Whiteford and Company mill (Plate V, 2)

The mill was located on Broad Creek at Flintville. The rock was burned overnight in a wood-fired kiln, the charge for which was 10 tons of stone and 3 cords of wood. This furnished sufficient material for 2 days run when operating at full capacity. After burning the stone went through a jaw crusher and thence to the grinding pans which were operated by water power. There were 9 pans in the mill but usually only 3 or 4 were in operation. A charge was ground for 24 hours and then run into a trough in which the coarser material was allowed to settle for regrinding. The pulp passed on to settling tanks for dewatering. The dewatered pulp was shoveled on driers heated by wood fires and thence into the storage bin from which it was shoveled into wagons for shipment and hauled to Conowingo, a distance of 3 miles. A six-mule team made 2 loads daily of 3 tons each. When running at full capacity the mill required a crew of 3 men. This mill was in operation over 30 years. It shut down about 1919 and was recently dismantled as its site will be flooded by the Conowingo dam.

Trenton Flint and Spar Company mill (Plate V, 3)

This company operated a mill for 15 or 20 years on Broad Creek which was shut down and abandoned about 26 years ago. The stone was obtained from the present Indian Rock Flint Company property which was leased from E. M. Allen, now head of the latter Company.

Stokes Mill (Plate V, 4)

A mill that shut down when the Susquehanna and Tidewater Canal was abandoned, was operated by a man named Stokes at Stafford. The rock was secured largely from the Stokes quarry on the Indian Rock Flint Company property and also from the Crowl quarry near Fern Cliff. The ground flint was shipped on the canal and also by rail from Port Deposit.

Klondike mill (Plate V, 5)

The Klondike mill, located 1 mile southeast of Scarboro, was built about 25 years ago and operated only one or two years. The stone was at first obtained from the company's quarry one-half mile east of the mill and later from the Lochary quarry near Kalmia.

Husband Flint Milling Company mill (Plate V, 6)

This mill was located on Deer Creek 1½ miles northeast of Kalmia. The original mill built many years ago by Joshua Husband passed through several hands and was acquired about 1909 by George J. Kroeger. As rebuilt by him it was one of the best equipped mills in the State. The flint was burned in a wood-fired kiln and crushed dry in a chaser. The crushed material was screened dry: the oversize was returned to the chaser, the undersize went to the grinding pans, and 2 intermediate sizes were sacked and sold under the name "bitstone." No. 1 bitstone was under 6 mesh and No. 2 bitstone between 4 and 6 mesh. The undersize of the screens was wheeled by hand to 10 grinding pans. The capacity of the pans was 1500 pounds each and the charge was ground 24 hours. The ground flint was run through a series of settling tanks for sizing. The settlings from the first tank were called No. 1. Those of the second tank on standing about 12 minutes yielded grade M. The next finer grade, No. 0, was obtained by settling for 24 hours in the tank. The tanks were cleaned out daily. The overflow from the last tank was at one time run into a fourth tank which was cleaned out annually and yielded a small quantity of a still finer product known as No. 00. The wet flint was dried on horizontal coils of steam pipes from which it dropped into bins. It was sacked for shipment after volting through an 80-mesh screen. The relative quantities of the different products were 1 ton No. 1 bitstone, ½ ton No. 2 bitstone, 5 tons

No. 1 ground flint, 1 ton No. M ground flint, 2 tons No. 0 ground flint. Shipments were made from Conowingo and Bynum. A 3-ton Packard truck could haul 4 loads to Bynum daily, the distance being 6 miles. About 8 years ago the property was taken over by the Husband Flint Products Company and operated about 3 or 4 years. The mill has since been completely dismantled.

BALTIMORE COUNTY

Products Sales Company mill (Plate V, 7)

At Claremont on the Baltimore and Ohio Railroad is a feldspar-grinding mill at which an occasional lot of flint was formerly ground. The grinding process is the same as that employed there for feldspar, the successive stages being through jaw crusher, chaser, screens, and tube mill.

Maryland Quartz Company mill (Plate V, 8)

The mill of this company is located at Glen Morris on the Western Maryland Railroad. It was completely rebuilt about 10 years ago and subsequent minor improvements have been installed. The daily capacity is 20 to 25 tons of flint. A section of the mill is equipped for the production of "Adamas," which is finely-ground black flint the crude stone for which came from without the State. None of this has been ground for over 5 years.

The rock is fed by hand to a jaw crusher and elevated to a bin from which it is fed automatically to a set of rolls. At this point three coarse sizes, $2\frac{1}{2}$–2-inch, 2–1-inch and 1-1/2 inch, for use in filters may be screened out. The under $\frac{1}{2}$-inch size or the entire roll product is reelevated to a screen with $\frac{3}{16}$-inch circular holes. The oversize passes through a second set of rolls and $\frac{3}{16}$-inch screen, the oversize of which goes to a third set of rolls. The undersize of the two screens and of the third rolls passes through three screens, the first of which has 3 sections and the next two 2 sections, the oversizes of which make 7 finished products of the following sizes respectively: over $\frac{3}{16}$-inch, $\frac{3}{16}$–$\frac{1}{8}$-inch, 8–10 mesh, 10–12 mesh, 12–16 mesh, 16–20 mesh, 20–24 mesh. These sizes are used for filters and pottery. The 20–24-mesh size is also used in lithographing. The undersize of these screens, the under 24-mesh, goes to a bolting machine that makes 9 oversizes of the following screens: 30-mesh, 34-mesh, 40-mesh, 54-mesh, and 72-mesh grit gauze screens, and No. 9, No. 10, No. 11, and No. 17 bolting silk; and a tenth product which is the undersize of the last bolting cloth. These products are used in lithographing, as abrasives, and for polishing. A fourth set of rolls is used to regrind sizes that are produced in excess of the demand. All of the apparatus is connected with air suction and the elevators and chutes tightly boxed so as to reduce the dust to a minimum. The power for the plant is steam.

The mill was acquired from the Pitcher estate in 1926 by M. M. Goodman of Baltimore.

Ware mill (Plate V, 9)

A flint mill was operated until about 35 years ago on a small stream south of the county road 1 mile east of Oakland and 1½ miles northeast of North Branch, near the western edge of Baltimore County. Only remnants of the stone walls of the building mark the site of the mill. The quartz is said to have been rolled and sieved dry.

CARROLL COUNTY

Maryland Silicate Mills Company mill (Plate V, 10)

The mill of this company which was located at Finksburg station, was sold in bankruptcy in December, 1910, and subsequently dismantled. E. S. Bastin[2] states that the quartz was crushed in a jaw crusher and then between crushing rolls and in a centrifugal crusher. It was further ground in continuous feed tube mills and graded to various finenesses by air separators. The flint for this mill was obtained chiefly from the Brauning quarries located 5 miles to the south.

Patapsco Flint Mill Company mill (Plate V, 11)

This mill situated at Hood Mills was operated about 30 years ago by S. P. Dunkel. The flint was obtained from deposits in the neighborhood and from the Annapolis Rock deposit.

[2] Bastin, E. S. Mineral Resources of the U. S., U. S. Geol. Survey, 1907, Pt. II, p. 848.

THE CHROME INDUSTRY IN MARYLAND

INTRODUCTORY

Though the element chromium occurs in a number of minerals chromite or chromic iron ore, is practically the sole commercial source of the metal. The theoretical composition of the mineral is $FeO \cdot Cr_2O_3$, corresponding to 68 per cent chromic oxide and 32 per cent ferrous oxide. In many cases, however, the ferrous oxide is replaced in part by magnesia and the chromic oxide by alumina and ferric oxide. In this way, in extreme cases, the chromic oxide content may be reduced to a very low percentage, the iron oxide greatly reduced and the percentages of magnesia and alumina may reach considerable figures. The usual range of chromic oxide in commercial ores is 40 to 60 per cent.

Chromite is an opaque iron-black to brown-black mineral with high luster. It is scratched with difficulty by a knife, yielding a brown streak. The crystal form is the octahedron but it usually occurs massive and breaks with an uneven fracture.

BRIEF HISTORY OF MARYLAND CHROME INDUSTRY

An interesting account of the discoveries of chrome ore in Maryland was written in 1895 by William Glenn.[3] Chrome mining in Maryland commenced with the discovery of chromite on the farm of Isaac Tyson, Jr. at Bare Hills near Baltimore at a date usually placed at either 1808 to 1810 or about 1827. From the fact that most of the work at Bare Hills had been done and the workings abandoned for some time prior to 1833, the latter date would seem to be a little too late. The Soldiers Delight region about 10 miles west of Bare Hills and the Reed Mine near Jarrettsville in Harford County were discovered in 1827 and the Line Pit in Cecil County soon after. Even the more remote Montgomery County occurrence was found in this early period. The discoveries were made by Isaac Tyson, Jr. who is credited with having been the first to recognize the mineral and its association with serpentine. Tyson's prospecting was guided also by his prompt recognition of the comparative barrenness of vegetation of the serpentine terrane. His

[3] Glenn, Wm. Trans. Amer. Inst. Min. Engineers, vol. xxv, 1895, pp. 487–492.

keenness in recognizing the geologic occurrence of the chrome deposits and by the aid of this knowledge ferreting out nearly all the known chrome deposits in the belt of serpentine rocks that extends across the State is deserving of great credit.

It seems that in this early period of chrome mining as each new district was discovered it aroused hopes and excitement and the older localities were abandoned in favor of it, only to be again taken up later on as the excitement abated.

The chrome ore mined at the Maryland localities, as well as in the portion of Pennsylvania adjacent to Cecil County where important mines were also developed, was brought to Baltimore; and from 1828 until 1850, most of the world's supply of chrome ore came from this city. In 1848 the larger and richer deposits in Turkish Asia Minor were discovered and exports to Europe began to fall off and practically ceased by 1860. In recent years a small tonnage of sand chrome has been shipped to Europe for special use in high-grade pottery manufacture.

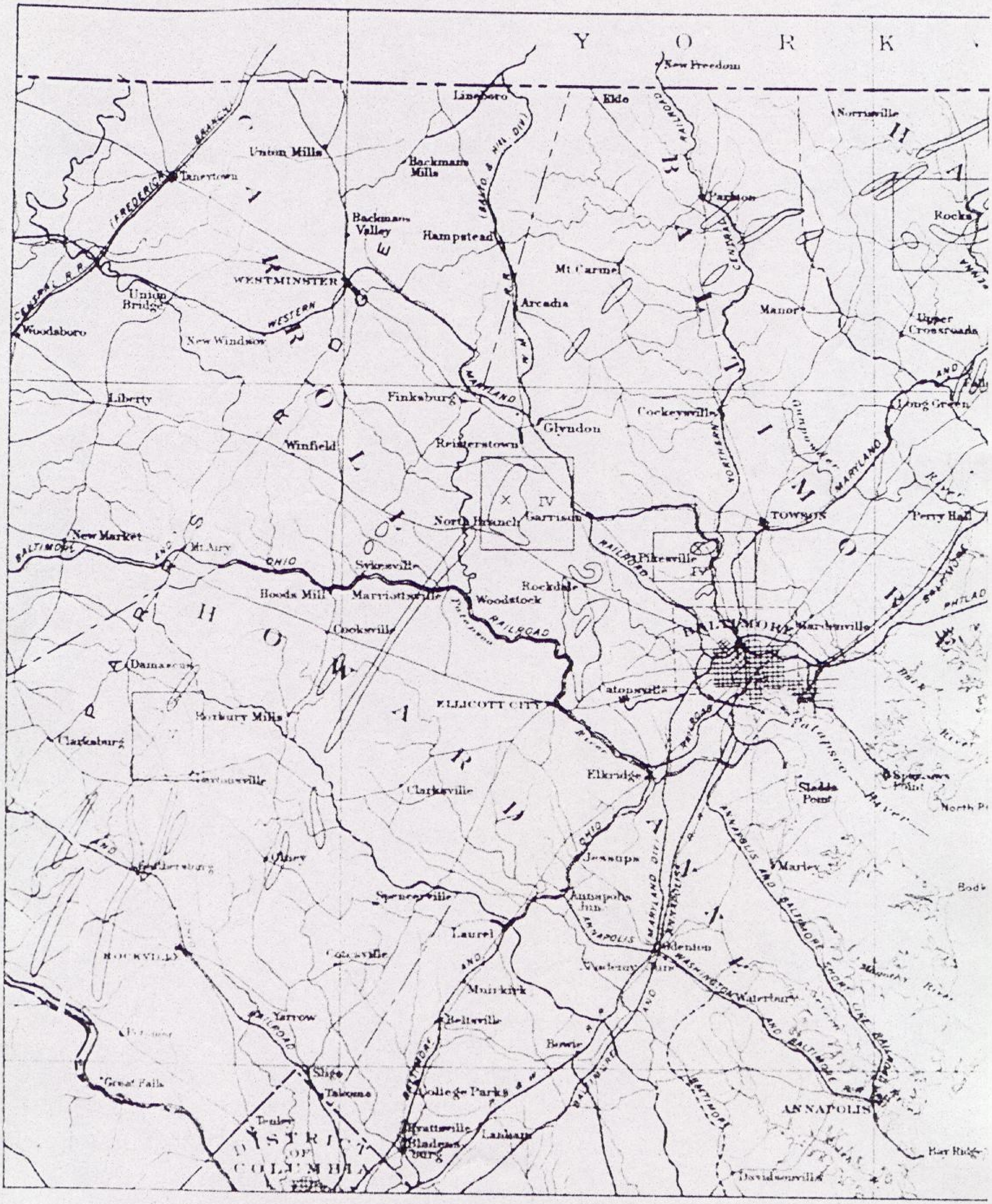
The Tysons did not rest content with securing a virtual monopoly of chrome mining in the United States through their operations in Maryland and Pennsylvania, but also set out to do the same in the chemical industry. In 1833 Isaac Tyson, Jr. made an unsuccessful attempt to establish a chrome plant at Baltimore but finally achieved success in 1845 and the Tyson chrome works monopolized the manufacture of chrome compounds in this country for over 40 years. Repeated attempts to establish competitive plants at Philadelphia, New York, and Boston during 1870 to 1880 met with disastrous financial failures until finally early in the next decade a successful plant was established at Philadelphia. The Tysons, however maintained the prestige of their Baltimore chrome works until they sold out to the Mutual Chemical Company of America in 1908 and finally withdrew from the chrome business.

After its early boom chrome mining in Maryland seems to have suffered a considerable decline about the middle of the last century. Toward the close of the sixties and during the seventies operations were again active at most of the Maryland deposits. Large quantities of ore were mined, particularly at Soldiers Delight and at the Reed mine in Hartford County, and sand chrome was produced at a number of localities in Baltimore, Harford, and Cecil counties. In the late seventies the Tyson Mining Company commenced operations in California and shipped their ores to Baltimore via Cape Horn at a cost delivered of $35 to $40 per ton. As the Maryland industry became almost extinct in the next few years the deposits were either unable to compete with California ores at that price or were looked upon as exhausted. Since about 1880 there has been only a small and irregular production of sand chrome and, except a small amount between 1917 and 1925, none of rock chrome in Maryland.

PRODUCTION

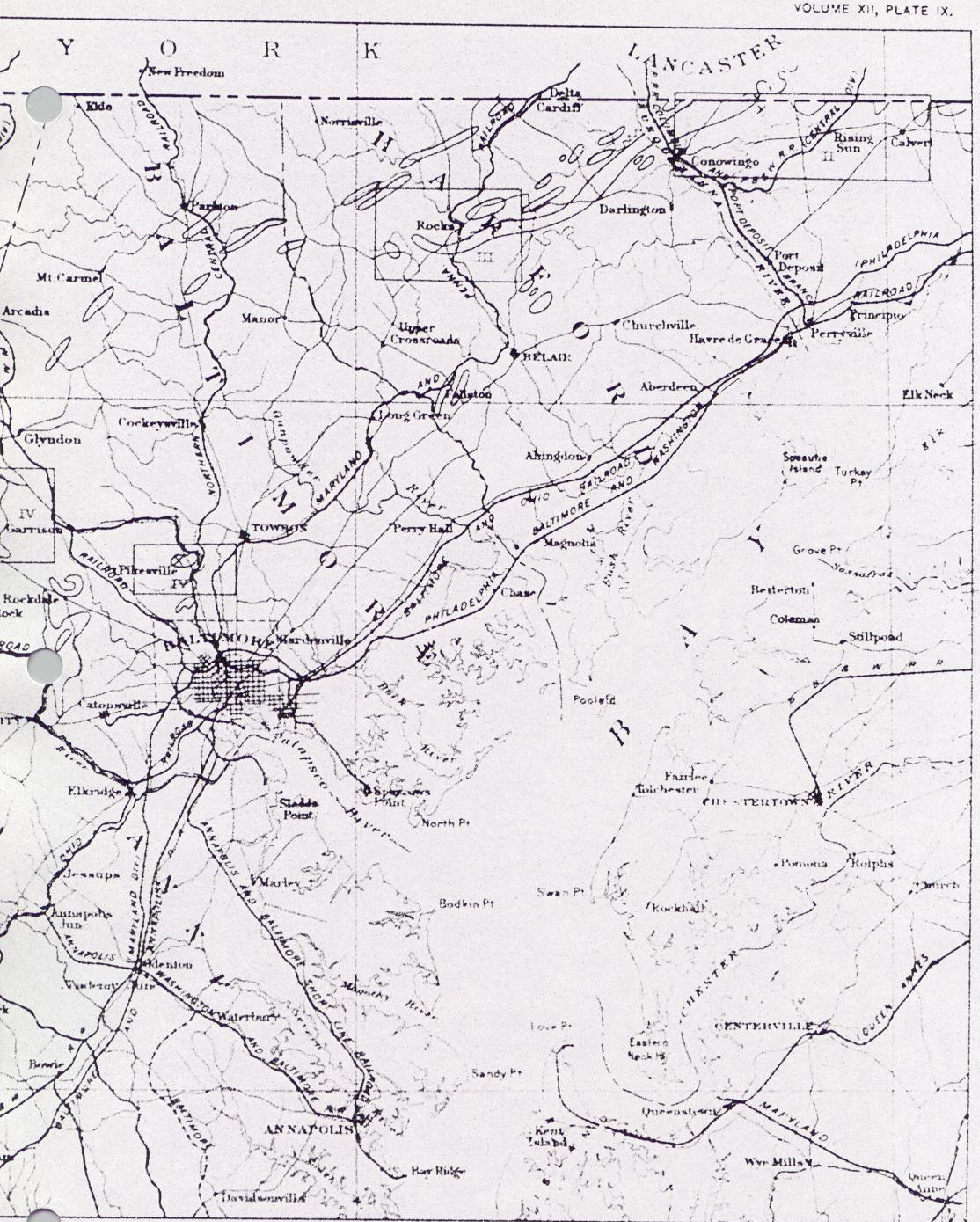
Though chrome mining in Maryland has been in a state of decline for a half century the uses and demands for chrome ores have greatly expanded and the world's production has been increasing. The production of the United States has also been on the decline and this country has been dependent on foreign supplies. During the war the domestic production was considerably increased but Maryland was but a small contributor to the increase. Under post-war conditions chrome mining in Maryland and in the United States again decreased almost to the vanishing point, as is shown by the following statistics:

Year	Maryland Production Long tons	United States Production Long tons	United States Imports Long tons
1926	—	141	214,944
1925	25	108	149,739
1924	—	288	118,343
1923	90	227	128,763
1922	127	355	90,081
1921	—	282	81,836
1920	9	2,502	150,275
1919	59	5,079	61,404
1918	487	82,430	100,142
1917	150	43,725	72,063
1916	89	47,035	115,945
1915	—	3,281	76,455
1914	85	591	80,736



Map of northeastern Maryland showing areas of serpentine rock and position which Chrome Ores have been produced.

Scale, one inch equals eight miles



showing areas of serpentine rock and position of maps giving localities at which Chrome Ores have been produced.

Scale, one inch equals eight miles

The 1914 and 1916 production was sand chrome from the Soldiers Delight area in Baltimore County. In 1917 and 1918 rock chrome was mined in the Soldiers Delight area and in 1918 to 1920 in Cecil County at the Line Pits. In 1922 to 1925 rock chrome production was reported from near Jarrettsville, Harford County. Since 1925 there has been no chrome ore produced in Maryland.

USES

Formerly chromium ores were used chiefly in the chemical industries but the main use of chromium now is in metallurgy. In the chemical industries chromium is used for the manufacture of pigments, dyes, chemical compounds, and in tanning leather. Chrome green, chrome yellow, chrome orange, and chrome red are the common chrome pigments and they derive their value from their strength and permanence. Chromates and bichromates are used as mordants in dying various fabrics and the pigments as dyes. The chromate and bichromate also have many chemical uses. Chromium salts are also used in "tawing" light leather by which process it is rendered tough and resistant to moisture.

The greatest use of chrome ores is in the manufacture of chromium alloys, particularly ferrochrome, that are used in connection with other ferro alloys to impart particular properties in steel. Chromium imparts to steel a marked hardness without producing brittleness and is consequently extensively used in the manufacture of armor plate, armor-piercing projectiles, stellite for high-speed tools, and automobile and other special steels. Rustless or stainless steel is an important alloy. Chromium plating promises an increasing demand for the metal.

Chromium is also used for refractory furnace linings either in the form of chromite bricks or as lump chromite. Chromite bricks consist of crude chromite held together with a binder of coal tar, kaolin, bauxite, milk of lime, or other substances. The bricks are held in place by tar mortar which burns away on heating leaving a solid chromite lining. In some cases fragments of chromite are hammered into place without the use of binding or cementing materials. The desirable properties which a chromite lining possesses are that it is neutral and hence resists corrosion, remains hard and resistant to abrasion at high temperatures, and withstands sudden temperature changes without cracking.

For the chemical uses a high grade ore running not less than 50 per cent Cr_2O_3 is desired. For metallurgical purposes a lower grade ore can be used and quotations are now given for ores running 45 to 50 per cent Cr_2O_3. During the war ores running as low as 34 per cent were salable. Still lower grade ores can be utilized through concentration. Ores as low as 12 per cent Cr_2O_3 were concentrated in Canada during the war.

OCCURRENCE

With few exceptions the world over chromite deposits of economic importance are limited to basic igneous rocks and usually to pyroxenite and peridotite, or to serpentine which is derived from them by alteration. The chromite occurs disseminated in the rock in too widely scattered grains to be of economic importance, as segregations into lean disseminated ores that can be concentrated, and as segregations into bodies of massive chromite of irregular shape from a few inches to several hundred feet in extent. The chromite deposits are extremely variable in size and in distribution so that it is difficult to estimate the extent of a body not fully developed or to predict where to prospect for new bodies if there are no outcrops to assist. All that can be said is that the deposits often manifest a tendency to occur about the periphery of the basic intrusions and that where one body has been found others are apt to occur in the vicinity. As the enclosing rock undergoes decay and disintegration through weathering the more resistant chromite is but little affected and consequently accumulates in the residual products. The small grains of disseminated chromite thus liberated are carried down into the streams of the region and concentrated at favorable points sufficiently to make profitable the washing of such sands.

The chromite occurrences of Maryland are limited to the serpentines and are found in all degrees of concentration. Most of the rock chrome that has been mined consisted of the massive lump chromite but at several of the mines lean disseminated ores were also obtained and concentrated. In almost all the chrome-bearing areas of the State the serpentine has sparsely disseminated through it minute grains of chromite ranging in size from $\frac{1}{25}$ to $\frac{1}{50}$ inch in diameter. The disintegration of the rock has consequently freed large quantities of this finely divided chromite that accumulated in the streams, and the working of these chrome sands has been an important source of the Maryland output.

DISTRIBUTION

Since the chrome ores in Maryland are confined to the serpentines the areas of their probable occurrence are limited to those in which these rocks are found. Abundant outcrops of serpentine in the form of irregular masses and long bands are found in a belt running from the Maryland-Pennsylvania line in Cecil County to the Potomac River in Montgomery County. That is, within a zone about 12 to 15 miles wide along the eastern edge of the Piedmont region extending across the northern part of Cecil and Harford counties, through the central and southwestern parts of Baltimore County, the southeastern corner of Carroll County, and the middle of Howard and Montgomery counties as shown on the map, Plate IX. It is useless to expect deposits of rock chromite outside the areas of serpentine shown on this map. On the other hand chromite deposits have by no means been discovered in all of these serpentine areas but the known occurrences are confined to a few of them.

The serpentine areas within which chromite mines have been worked are designated by a cross mark on the map, Plate IX. They include one locality in Cecil County, two in Hartford County, two in Baltimore County, and one in Montgomery County. A description of the mines is given in a later section of the report.

Chromite-bearing sands are found not only within the serpentine areas but also for a short distance beyond in streams having their source within the areas of those rocks. As in the case of the rock chrome, sand chrome is not found in all of the serpentine areas but is confined to the streams of a few of those areas, though its occurrence is more widespread and it has been worked at a greater number of localities than has the rock chrome. Important sources have been along the Maryland-Pennsylvania line in Cecil County, Cherry Hill in Harford County, and Bare Hills and Soldiers Delight in Baltimore County. The Cecil County occurrences are contiguous to chrome mines in Pennsylvania so that in general it is true that the areas which have yielded rock chrome have also been the most prolific in the production of sand chrome. Cherry Hill in Harford County, which has produced sand chrome but no rock chrome, is the only important exception. Details concerning the sand chrome localities are given in a later section.

MINING

On account of the comparatively small size of the Maryland chromite deposits and the irregularity and uncertainty of their distribution, the mining methods in vogue when they were worked were quite simple and the equipment as inexpensive as would serve the purpose. Many of the deposits proved to be of very shallow depth and limited horizontal extent so that the openings consisted of nothing more than a small pit or trench according to the shape of the outcrop of the ore. This applied particularly to a number of the deposits at Bare Hills, Baltimore County, At several of the Bare Hills workings adits run into the hillside from points below the outcrop failed to find ore, no doubt on account of the failure of the ore body to extend down to the level of the adit.

In the case of the larger bodies of ore the workings consisted of a shaft or incline that followed the ore body in depth and from which drifts were run out on each side to the limits of the deposit. Little or no timbering was used as the walls were held up by leaving occasional pillars of lean ore or rock. These openings reached depths of tens of feet and a few two or three hundred feet.

MILLING

Three concentrating mills, now dismantled, were erected to treat the leaner ores associated with the massive chromite that could be shipped in the crude state. One of these, located near the Reed mine in Harford County, known as the Wetherill mill treated ores from that mine and the adjoining Wilkins mine. Another situated on a small stream in the

Soldiers Delight region in Baltimore County treated ores from the Harris and Weir mines, between which it was located. In the Harford County mill the ore was crushed with stamps and in the Baltimore County mill with crusher and rolls. Both mills used circular buddles and long buddles for concentration. The third mill was set up at the Choate mine at Soldiers Delight in 1918. The ore was ground and then concentrated on James tables.

Washing Sand Chrome

The method of recovering chromite from the sands of the streams in the serpentine areas has remained the same to the present day and though the equipment used is simple and inexpensive it is well adapted for the purpose and more economically feasible than would be a more expensive modern equipment. The sands are dug out of the stream bed or its banks and sifted through a screen of about 8 mesh whereby the chrome-free coarser gravels are removed. The fines are collected in tubs made by sawing a barrel in half and provided with two long handles so that they can be carried by two men to the buddle at which the sand is concentrated.

The buddle is a long narrow trough through which a stream of water is run so that sand fed in the upper end is spread out along the trough and the lighter grains carried out at the lower end. This process is repeated a number of times, each washing increasing the degree of concentration until the sand is sufficiently concentrated. On each side of the trough is a wooden floor and the crude sand is piled on one of these and the concentrate shoveled out of the trough is deposited on the other. The trough or trunk of the buddle has a length of 12 feet, width of 12 inches, and depth of about 12 inches. The fall is about 1 to 1½ inches from the upper to the lower end. The buddle is located close to the bank of the stream from which the sand is obtained and as the flow of the streams is usually not sufficient to supply the requisite quantity of water, a dam is built back of the buddle in which enough water can be collected to make a run. The water from the dam does not flow directly over the sands but is first run through the eye of the buddle which is a small section at the head of the trough cut off by an inclined partition over which the water flows. The slope desired for this partition by chrome washers varies and some think the best results are obtained if it is vertical. Figure 2 shows a cross section and a horizontal section of a buddle. The concentrate is packed in barrels weighing over half a ton for shipment.

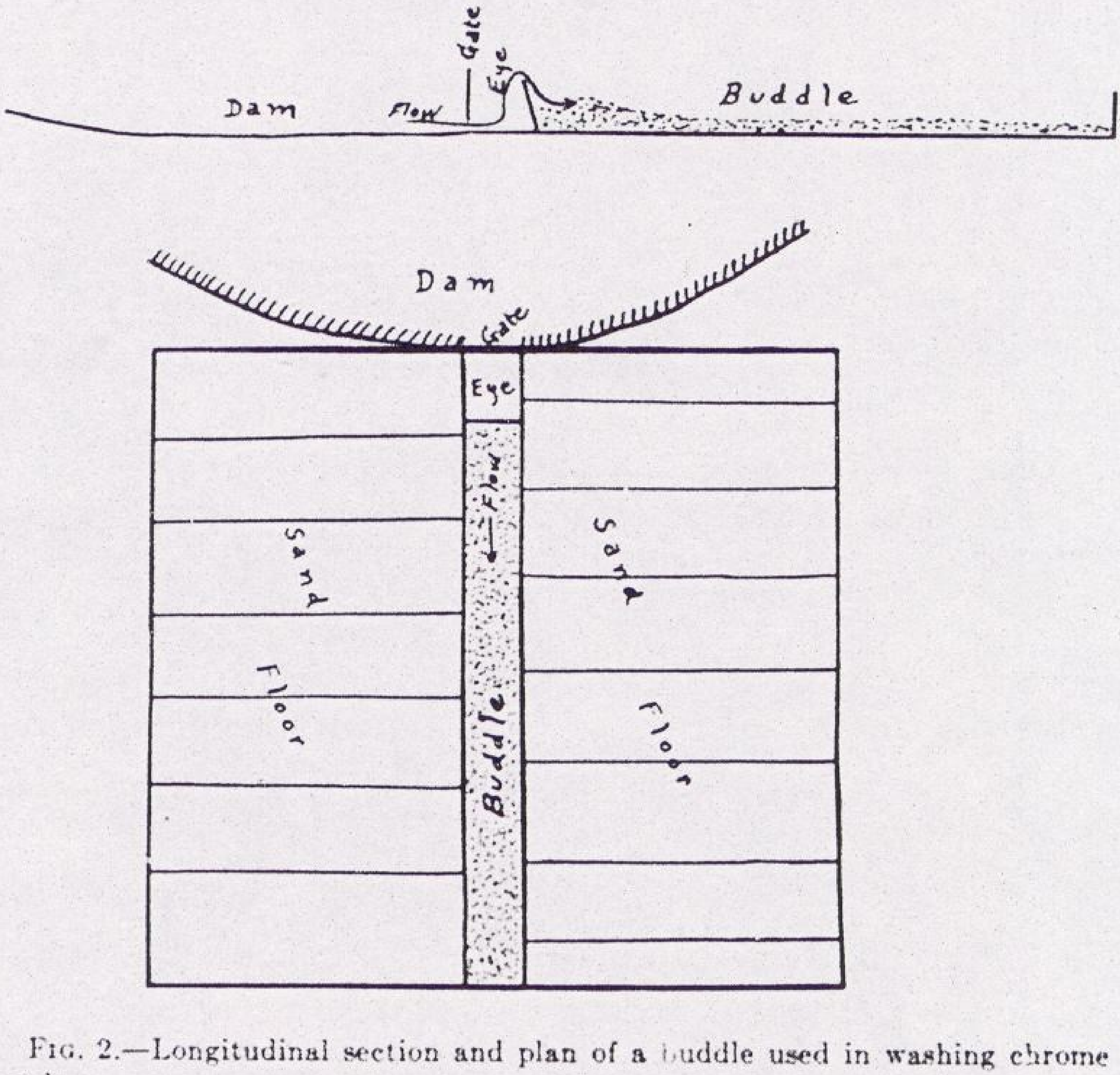


FIG. 2.—Longitudinal section and plan of a buddle used in washing chrome sands.

DESCRIPTION OF SAND CHROME CONCENTRATES

Five samples of sand chrome concentrates were collected in 1917 and subjected to screen analysis and chemical analysis. The chemical analyses were made by Penniman and Browne. Two of the samples were separated into magnetic and non-magnetic portions with a hand magnet and these portions analyzed separately in order to determine to what extent chromic oxide is present in magnetic ore grains. Four of the samples represented concentrates from the four buddles still in existence and which had been in operation within three years. Three of these came from the Soldiers Delight area in Baltimore County, the fourth from near Rising Sun in Cecil County. The fifth sample represents natural concentrate collected from one of the streams in Cecil County. The designations of the five samples are the following:

Sample I. Concentrate from the R. A. Triplet buddle (Plate XII, 42), Soldiers Delight, Baltimore County.

Sample II. Concentrate from the Jay Gore Buddle (Plate XII, 40), Soldiers Delight, Baltimore County.

Sample III. Concentrate from the F. A. Dolfield buddle (Plate XII, 39), Soldiers Delight, Baltimore County.

Sample IV. Concentrate from the Adair and Pyle buddle (Plate X, 4), Rising Sun, Cecil County.

Sample V. Natural concentrate from run west of Rock Springs, Cecil County (Plate X, 2).

A screen analysis of these concentrates through a set of Tyler standard screens yielded the results given in the table below.

SCREEN ANALYSES OF SAND CHROME CONCENTRATES

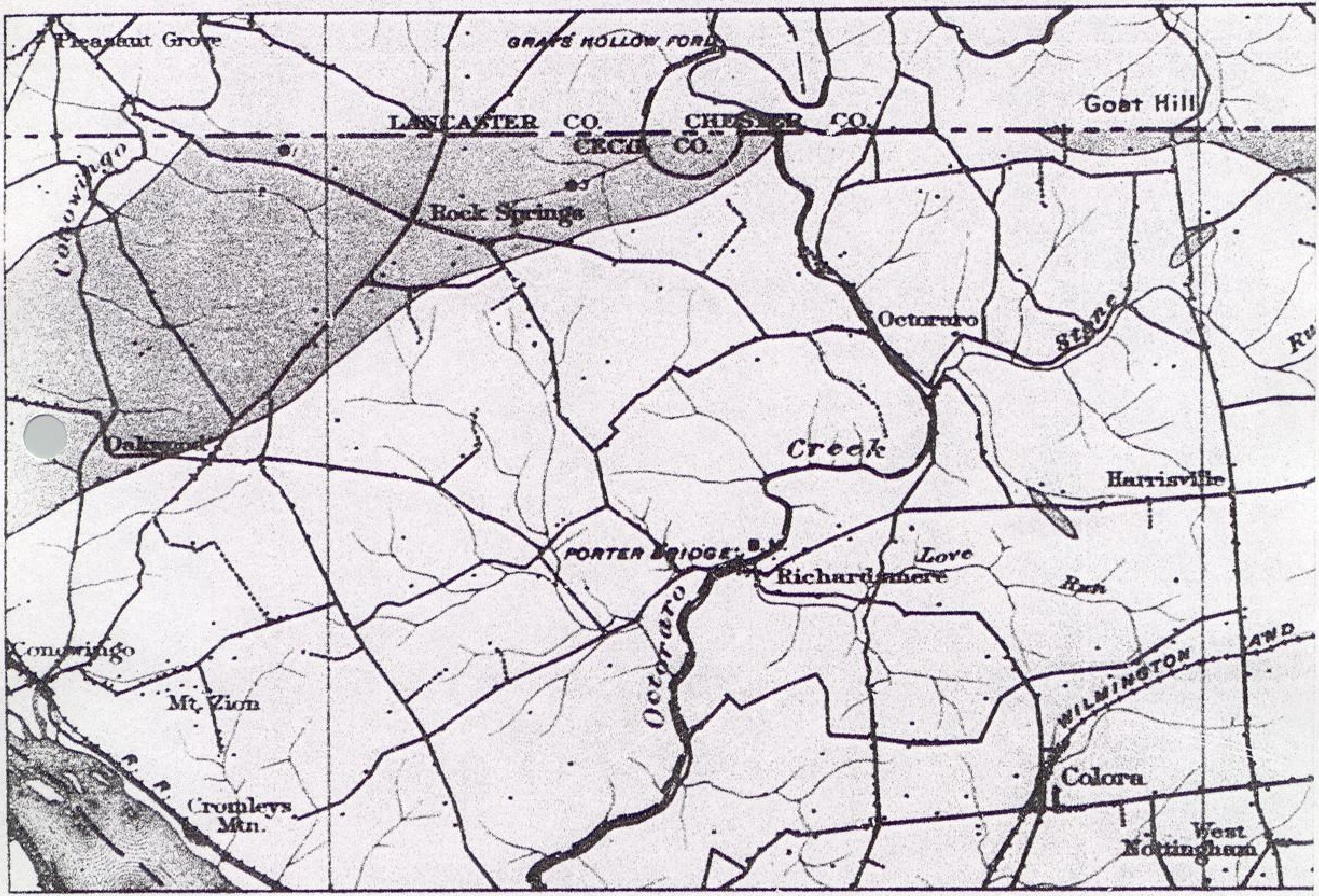
Screen mesh	I %	II %	III %	IV %	V %
Over 10	0.0	1.7	1.5	1.6	0.0
10–14	2.4	3.9	2.7	0.8	2.1
14–20	26.0	8.5	7.1	0.9	4.2
20–28	44.4	17.7	20.0	2.2	16.6
28–35	13.8	29.1	36.5	9.0	40.6
35–48	5.8	22.2	14.9	28.4	25.0
48–65	3.4	9.4	9.4	30.2	7.8
65–100	3.3	6.1	6.1	20.1	2.6
Under 100	0.9	1.4	1.8	6.8	1.0

To bring out more clearly the differences in the sample with respect to the relative quantities of the different sizes of grains which they contain the screen analysis results have been plotted in two sets of broken curves. In the first set, figure 3, the percentage of each size is plotted as the ordinate; in the second set, figure 4, the sum of the percentages above a given size is plotted as the ordinate. Figure 3 indicates the similarity in the sizes of the constituent grains of Samples II, III, and V and that Sample I is considerably coarser and Sample IV considerably finer than they. The same features are more forcibly brought out in figure 4. The results are in complete harmony with the occurrence of the sands from which the concentrates were washed. The sands from which Samples II, III, and V were obtained were taken from points in the courses of the respective streams within the area of serpentine outcrop and where the grade of the stream was low enough to permit the accumulation of thick layers of detrital material on the valley floor. That the sizes of the grains are so nearly alike is, consequently, as it should be. The sands from which Sample I was produced came from a relatively higher point in the stream; that is, where much of the stream bed is exposed and the sands accumulate in the riffles and in thin layers of detrital material. Such sand should be coarser than the preceding sands. Sample IV was washed from sands at a lower point of the stream course and beyond the serpentine outcrop. The valley floor at that locality is quite broad and thickly covered. with detrital material and consequently finer sands are encountered.

The chemical analyses of the samples are given in the following table in which the analyses of Samples I and IV are calculated from those of the magnetic and non-magnetic portions into which they were separated.

CHEMICAL ANALYSES OF SAND CHROME CONCENTRATES

	I %	II %	III %	IV %	V %
Cr_2O_3	28.10	36.12	43.23	2.43	36.44
FeO	47.52	32.54	27.07	38.89	33.12
SiO_2	3.67	9.82	6.28	22.24	9.66
Al_2O_3	13.43	15.82	17.98	23.05	13.28
MgO	3.22	3.05	3.65	2.67	3.64
CaO	0.26	0.10	0.45	1.28	0.23
TiO_2	0.40	0.80	0.48	2.14	0.96



Map of a portion of Cecil County showing serpentine areas and

Scale, one inch equal

ecil County showing serpentine areas and localities at which Chrome Ores have been produced.

Scale, one inch equals one mile

The analyses show that Samples II, III and V are much alike in chemical composition, also, with the exception of a markedly higher chromic oxide content and lower percentage of ferrous oxide, in Sample

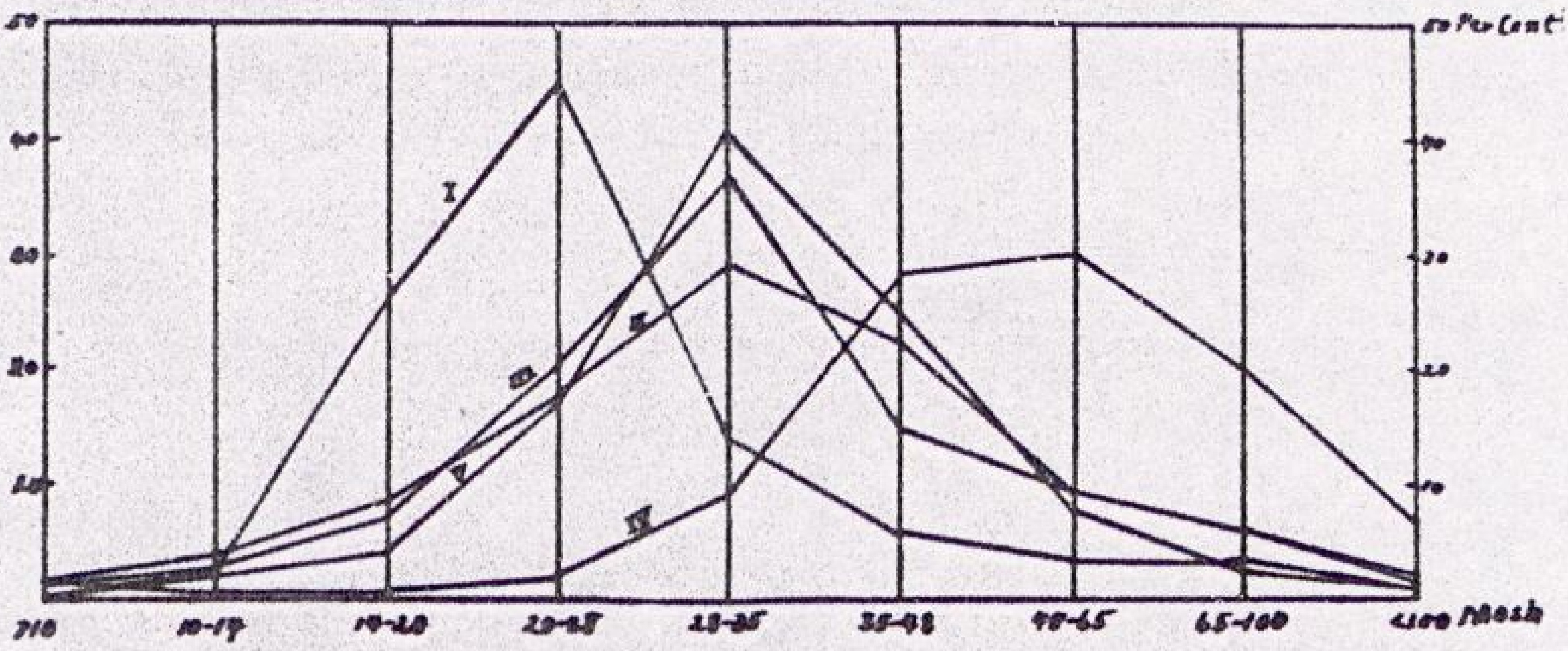


FIG. 3.—Screen analysis curves of five sand chrome samples showing percentage of each mesh size.

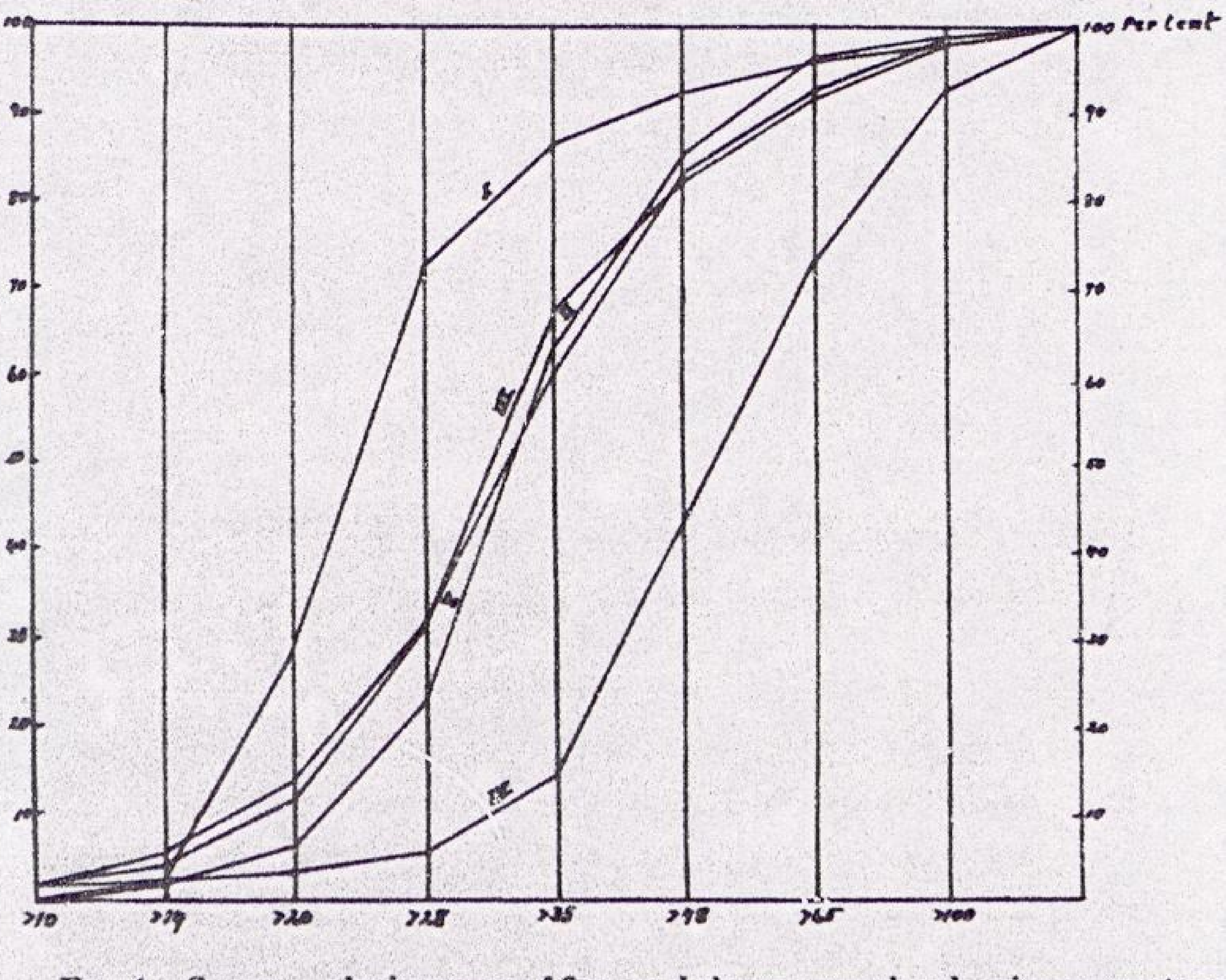


FIG. 4.—Screen analysis curves of five sand chrome samples showing percentage above indicated mesh size.

III. They indicate that the ore minerals consist of chromite in which the trivalent oxide is not alone Cr_2O_3 but to a considerable extent Al_2O_3 and Fe_2O_3, in which the bivalent oxide is represented to a small extent by MgO and mingled with this chromite a small amount of magnetite. The presence of titanic oxide in a highly ferruginous ore derived from a basic igneous rock is not surprising and it is probably there largely as ilmenite intergrowths in the other ore minerals. A large part of the

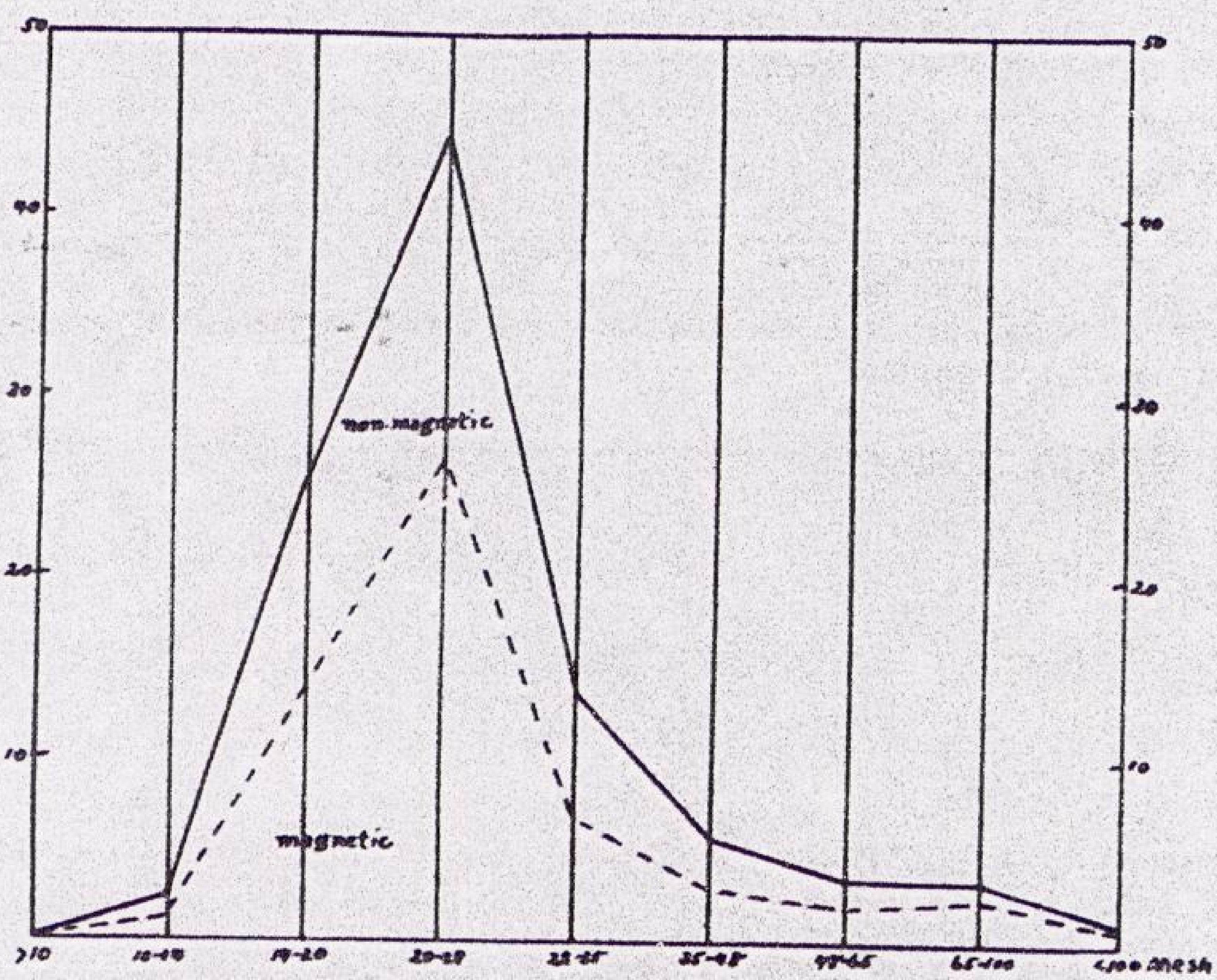


FIG. 5.—Screen analysis of magnetic and non-magnetic portions of sample I.

silica is accounted for by quartz grains in the concentrate. Sample I is anomalous in its lower chromic oxide content and higher percentage of iron which would be explained by the presence of more magnetite. This is not surprising as on the hill west of Triplett's house the serpentine contains small pockets of magnetite. The composition of Sample IV is utterly different. The high silica content is due to the presence of quartz and hence to a poor concentration. To allow for the extra quartz and make a sample more comparable with the others, the amount of the other constituents should be raised 20 per cent and silica correspondingly decreased. The composition calculated on this basis is as follows:

Cr_2O_3	2.90
FeO	46.40
SiO_2	8.67
Al_2O_3	27.50
MgO	3.19
CaO	1.53
TiO_2	2.55

The ore minerals have the same appearance in Sample IV as in the others and they are made up either of a spinel molecule in which Cr_2O_3 has given way almost completely to Al_2O_3 and Fe_2O_3 or a mixture of a spinel in which Cr_2O_3 has given way to much Al_2O_3 with considerable magnetite. The percentage of titanium also indicates a higher percentage of ilmenite.

In order to get a clearer idea of the nature of the ore particles in these concentrates and particularly in the case of the two samples last considered they were subjected to a magnetic separation with a small hand magnet, the results of which are given in the following tables and in figures 5 and 6.

SCREEN ANALYSES OF MAGNETIC AND NON-MAGNETIC PORTIONS OF SAND CHROME ORE CONCENTRATES

Screen mesh	I		IV	
	Magnetic %	Non-magnetic %	Magnetic %	Non-magnetic %
Over 10	0.0	0.0	0.0	100.0
10–14	56.8	43.2	0.0	100.0
14–20	53.4	46.6	2.9	97.1
20–28	60.0	40.0	6.3	93.7
28–35	48.5	51.5	9.0	91.0
35–48	50.2	49.8	7.4	92.6
48–65	56.0	44.0	5.3	94.7
65–100	71.3	28.7	4.7	95.3
Under 100	83.3	16.7	4.7	95.3
Entire sample	56.5	43.5	5.9	94.1

CHEMICAL ANALYSES OF MAGNETIC AND NON-MAGNETIC PORTIONS OF SAND CHROME ORE CONCENTRATES

	I		IV	
	Magnetic %	Non-magnetic %	Magnetic %	Non-magnetic %
Cr_2O_3	21.13	37.16	2.22	5.79
FeO	58.18	33.70	84.82	36.01
SiO_2	3.03	4.50	1.46	23.54
Al_2O_3	9.28	18.86	3.51	24.29
MgO	2.92	3.61	tr.	2.84
CaO	0.22	0.31	0.00	1.36
TiO_2	0.40	0.40	1.89	2.16

The composition of the magnetic and non-magnetic portions of Sample I is important in showing that highly magnetic spinels may have a composition equivalent to less than one-half magnetite, or in other words, over half of the ferric iron in magnetite may be replaced by Cr_2O_3 and Al_2O_3 without rendering the mineral non-magnetic; and that further the non-magnetic portion is practically equivalent to magnetite in which all the ferric iron has been replaced by Cr_2O_3 and Al_2O_3. On the other hand, in Sample IV the magnetic portion consists of magnetite in which about $\frac{1}{10}$ of the ferric iron has been replaced by Cr_2O_3 and Al_2O_3, and the non-magnetic of the equivalent of magnetite in which about $\frac{7}{8}$ of the ferric iron has been replaced by Cr_2O_3 and Al_2O_3. One can safely say, therefore, that the entrance of less than one-fourth of ferric iron into the chromite molecule renders it highly magnetic and that it probably requires a much smaller amount to produce magnetism in chromite low in alumina than in chromite high in alumina. The analyses bring out clearly the complete isomorphism of the trivalent oxides, Fe_2O_3, Cr_2O_3, and Al_2O_3, in the spinel molecule, and the consequent necessity of analyses of even non-magnetic chrome ores to make sure of their chrome content. Thus, though Sample IV consists to such a large degree of a black non-magnetic spinel, it is extremely low in chromic oxide.

To sum up the characteristics of the black sand concentrates from the serpentine areas, the sands are comparatively fine grained. The chrome content of the higher grade sands averages in the neighborhood of 40 per cent. They may consist of a large percentage of magnetic particles and yet have the chrome content comparatively high. They may contain only a small amount of magnetic material and yet through the presence of much alumina be very low in chromic oxide. These same conclusions concerning chemical composition doubtless apply equally well to the rock chrome ores.

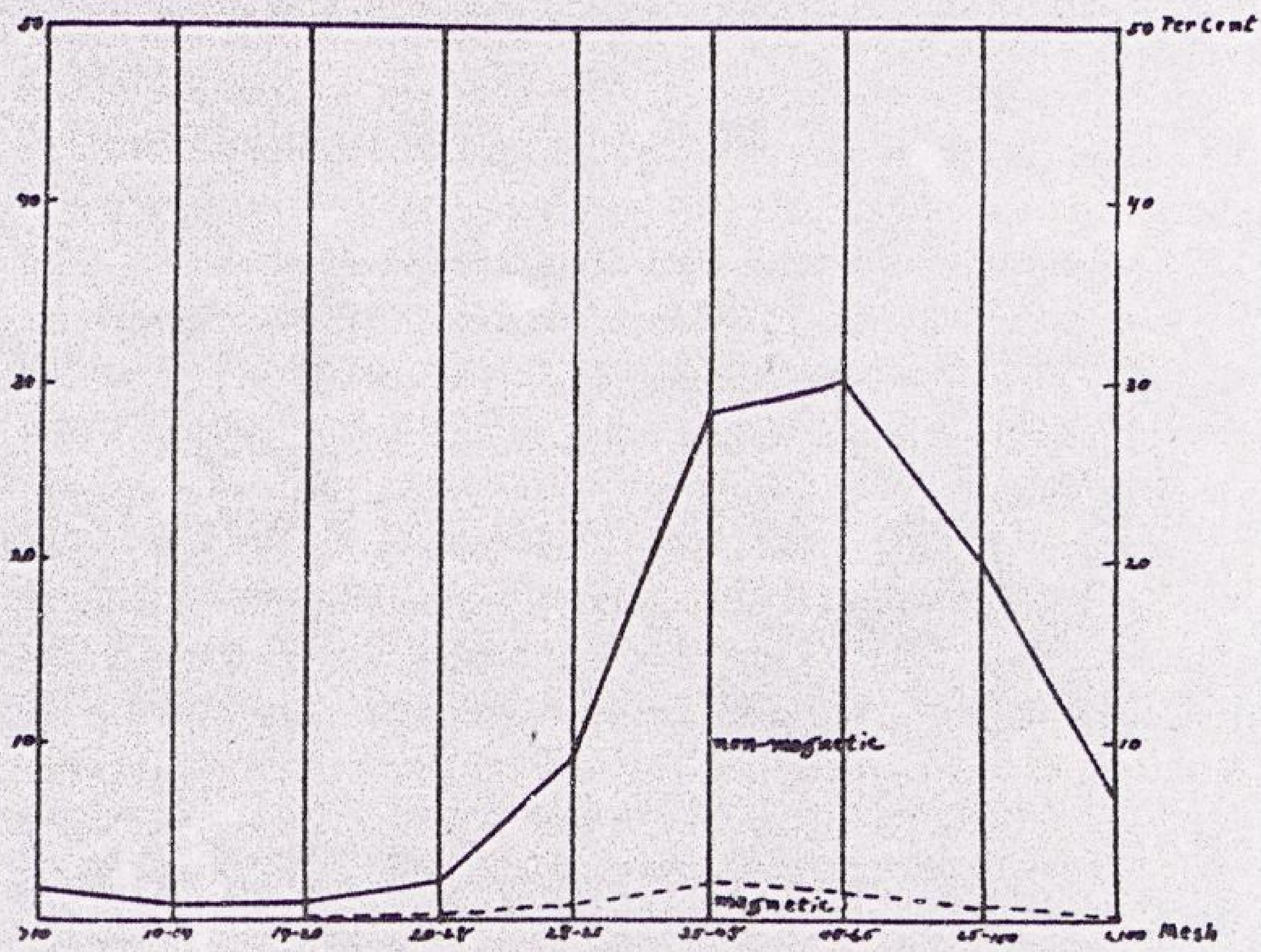


FIG. 6.—Screen analysis of magnetic and non-magnetic portions of sample IV.

ECONOMIC ASPECTS OF CHROME MINING IN MARYLAND

The Maryland chrome mines have lain idle for so many years that they are no longer accessible and but little can be said concerning the deposits that is definite and unquestionably reliable. They appear to have consisted of more or less elongated pockets and nests strung out along a zone of either barren rock or very lean ore and frequently several such zones lay in proximity. The width of the ore bodies was only a few feet, never over 10 feet and usually much less. Horizontally the zones of productive ore were not followed more than a few hundred feet which would indicate the limit of extent in that direction for a workable ore body. Many of the ore bodies were followed down the zone a distance equal to that along the zone. These were probably abandoned because the bottom of workable ore had been reached. Others were not followed to a proportionate depth and are reported to have been abandoned for various reasons other than the exhaustion of the ore body in depth. It may, therefore, be feasible to reopen these mines and with proper equipment work them to greater depth. The origin and geologic relations of the chrome deposits is such that there is no reason to expect them to have a greater extent in depth than they have horizontally so that attempts to work the old mines to greater depth are not certain of success.

A more favorable outlook is presented from the consideration that the chrome deposits represent segregations in the country rock and that those that were found and worked in the past are mainly those that gave sufficient evidence of their existence. The present surface of the serpentine areas is purely fortuitous with respect to the position of the chromite deposits in that rock. Consequently there is every reason to believe and it is probably true that there are many more deposits that have not been discovered than have been worked. The difficulty lies in how to find these deposits. The areas of serpentine rock are large and numerous and there is no way to predict where in this rock the ore bodies lie. It is prudent to assume that their size is of the same order of magnitude as those that have been worked. Underground exploration is expensive as is also core drilling and the chances of happening upon an ore body even if it exists in the area prospected are not large, and the prospective reward of success is limited. The economic outlook for chrome mining in Maryland is not, therefore, over attractive and success is far from assured. One might spend large sums of money in prospecting and find nothing; if successful, the success promises to be only moderate.

Under the stimulation of high prices and the urge of domestic production of necessary minerals during the war, the Choate mine of Soldiers

Delight and the Line Pits in Cecil County were reopened but no large masses of ore were found and the operations were suspended as soon as post-war conditions prevailed. Later on a small amount of ore was produced and some prospecting done at the old Reed mine near Jarrettsville in Harford County but the operations were short-lived.

The new methods of geophysical prospecting afford a means of searching for chromite deposits in the serpentines with better prospects of practical results than were possible in the past. Any one interested in attempting a resumption of chrome mining would do well to try out these methods in searching for new ore bodies.

ECONOMIC ASPECTS OF CHROME SAND WASHING IN MARYLAND

The economic aspects of chrome sand washing in Maryland can be outlined more definitely. The possibilities of production are decidedly limited but at the same time more certain than in the case of chrome mining. There has been an annual demand for about 25 tons of this ore which is exported to Europe for use in setting the colors of paintings on fine porcelain ware, for which purpose the Maryland sand chrome seems to be peculiarly adapated. This demand was easily met. Mr. F. A. Dolfield said that prospecting by the Dorr Company on his Soldiers Delight property showed 2000 tons of sand carrying 20 per cent Cr_2O_3 which with a ratio of concentration of 4 to 1 produced a concentrate with 42 per cent Cr_2O_2. By forcing production as much as 100 or possibly 200 tons of sand chrome might be obtained annually though such a production would lead to the exhaustion of the best localities and ultimately force a much lower production. A number of chrome sand-bearing streams have their supply slowly replenished from year to year and the same places can be worked every few years with satisfactory results. If the production were forced too much and the same places worked annually the yield would soon fall off.

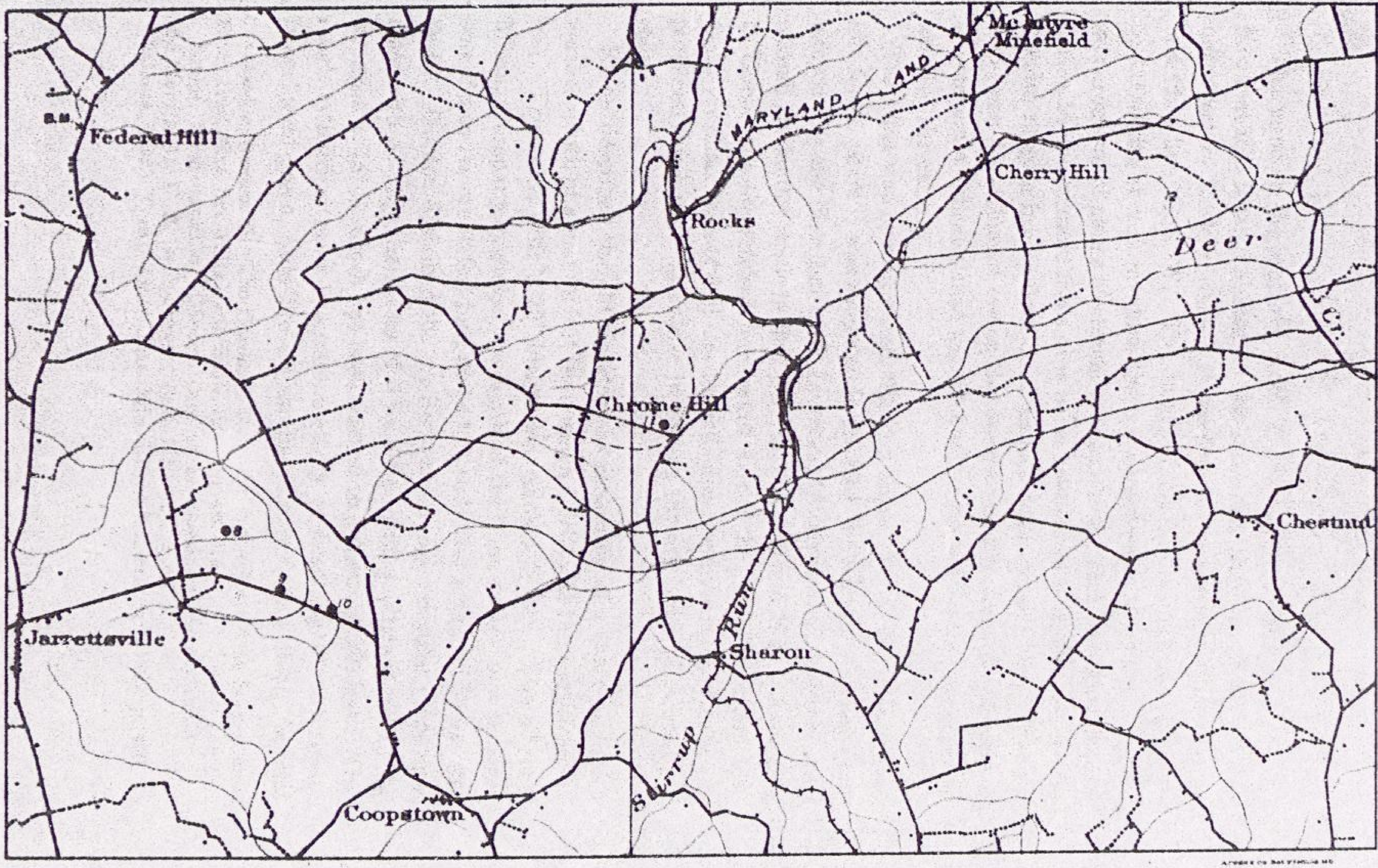
The pre-war prices paid were about $12.00 per ton of concentrate yielded by the sands to the men who dug the sand out of the streams and brought it to the buddles. $3.00 per ton of concentrate to the sand washer, and about $2.00 per ton for hauling to the railroad. The customary royalty paid the owner of the sand was $5.00 per ton. In other words, the cost of production in the past was about $22.00 per ton. The price paid for the sand ore was $30.00 to $35.00 per ton—about twice the price at which the chrome ores sold at the time. The last sales of chrome sand were made early in 1916 when the price had risen to $44.00. Mr. R. A. Triplett, who has washed sand chrome for many years, said he is unable to secure labor at present willing to get out the concentrate at a contract price of $25.00 per ton. Hence the user of sand chrome must be willing to pay a high premium over the price for lump ore. Consequently, both on account of the small quantity that can be produced and the high price it must command, the sand deposits of Maryland can not be looked to as a source of chrome ore for metallurgical use but only as a source for the limited quantities needed for the special purposes to which it has been found to be peculiarly adapted. For these the supply is adequate.

The high cost of producing sand chrome concentrates is due to several causes. An enormous amount of crude sand must be handled to secure a ton of concentrate, it must be handled in a crude way, and it must be handled a number of times. The work must be done largely in water which impedes the efficiency of the worker, and because of the fact that the worker is constantly in water labor avoids it unless the rewards are more attractive than those of other available work.

DESCRIPTION OF DEPOSITS

CECIL COUNTY

In Cecil County rock chrome has been mined at only one locality, the Line Pits, just within the Maryland line, three-quarters of a mile northwest of Rock Springs, though there were several important mines just over the line in Pennsylvania. Sand chrome has been worked at a great many localities in a belt along the State line about a mile or less in width, extending from Conowingo Creek on the west to Lombard on the east.



Map of a portion of Harford County showing serpentine areas and localities at which Chrome Ores have been produced.
Scale, one inch equals one mile

Line Pits (Plate X, 1)[4]

This mine on the property of W. T. West receives its name from the fact that it is located almost on the state line, three-quarters of a mile northwest of Rock Springs. It consists of two shafts about 50 feet apart in a line N. 80° W. The dumps about the openings contain 3,000 to 4,000 tons of rock in which there is considerable chromite. Besides numerous small pieces of chromite, much of the rock has chromite adhering to one or more faces of it or as veinlets cutting through it with a width ranging from a fraction of an inch to an inch or two. There is also some disseminated ore on the dumps but the character of most of the chromite indicates that the ore body consisted for the most part of massive chromite.

The mine was opened about 1828 by Isaac Tyson, Jr. After lying idle for 40 years it was reopened in 1918 by the Chrome Mining Company under the direction of F. Lynwood Garrison of Philadelphia and a small production made in that year, and in 1919 and 1920. According to Glenn[5] the ore pitched northward across the State boundary into Pennsylvania. Knopf and Gordon who described the mine after it was reopened a few years ago agree in stating the ore had a pitch south of east.

Knopf described the old workings as consisting of a shaft sunk to a vertical depth of about 92 feet from which a drift was run southward 75 feet. From this drift a 75° incline was sunk 106 feet. The Chrome Mining Company extended the depth of the mine 40 feet and struck a lens of massive ore 10 feet long and 4 feet wide that averaged 50 per cent Cr_2O_3. Gordon described the ore body as a rough irregular cylindrical mass with average diameters of 5 by 8 feet with a pitch of 60° in the direction S. 75° E. which has been worked to a depth of 250 feet. This rough cylindrical mass is surmounted by a sheathing of williamsite (translucent-green, jade-like serpentine) about a foot thick, beyond

[4] Gordon, Samuel C. The Chromite Deposits of the State Line Serpentines. Proc. Acad. Nat. Sci. Phila., vol. lxxiii, 1921, pp. 449–454.

Knopf, Eleanora Bliss. Chrome Ores of Southeastern Pennsylvania and Maryland. U. S. Geol. Survey, Bull. 725, 1922, p. 96.

[5] Glenn, Wm. Trans. Amer. Inst. Min. Engineers, vol. xxv, 1895, p. 490.

which is the ordinary serpentine. Thick tabular masses of williamsite also formed partings in the chromite and veins of it extended into the serpentine walls. Fractures in the chromite are filled with clinochlore or kämmererite. In the lower levels many veins of magnesite with residual masses of green serpentine cut both the ore body and the serpentine. The chromite forms granular black masses that contain some disseminated williamsite. In thin section it shows fracturing during the period of serpentinization.

Gordon interprets the form and position of the Line Pit deposit as indicating that it was formed later than the surrounding rock but previous to its serpentinization. He suggests that after most of the magma had crystallized to peridotite the pipe-like mass of liquid was injected, further differentiated, and crystallized into enstatite and chromite. Hydrothermal solutions later altered the enstatite to williamsite. This is contrary to the general belief that chromite deposits are magmatic segregations *in situ.*

F. Lynwood Garrison says, in a personal communication, that serpentinization extended only a few feet below the surface and that the ore associated with considerable williamsite was enclosed in peridotite country rock. He also states that at the bottom of the old workings the ore body had pinched to about 2 or 3 feet and that at the end of his extension of the workings it pinched again and a very heavy inflow of water was encountered.

Run west of Rock Springs (Plate X, 2)

Sand chrome is said to have been washed in the run which has its head southwest of Rock Springs and flows westward into Conowingo Creek. The greater part of this run has a broad flat valley floor on which much detrital material has accumulated and the present stream course is to a large extent cut through this. The conditions have been favorable, consequently, for the accumulation of sand chrome. Small accumulations of black sand in riffles were noted at a number of places and a sample collected in the lower course of the stream has been subjected to screen analysis and chemical analysis with the results given on pages 167 to 170 where it is designated as Sample V.

Run east of Rock Springs (Plate X, 3)

A run heading east of Rock Springs and flowing eastward into Octoraro Creek has been the scene of sand chrome washings and was last worked about 30 years ago by Howard Brown. A large part of the course of this stream is swift and the hill slopes on each side steep so that conditions are not very favorable for the accumulation of the fine chrome sands. In about its middle course, however, is a narrow flat more than 100 yards in length that shows evidence of having been thoroughly worked over and the site of the buddle, indicated on the map, is recognizable through traces of the dam above it and from the pile of tailings beside it.

Stone Run north of Rising Sun (Plate X, 4, 5, 6)

The upper course of Stone Run and its tributaries contain numerous broad flats and wide flood plains abundantly covered with detrital material which has been worked off and on in years gone by and which appears to have yielded a considerable amount of sand chrome. The points at which the most recent work has been done and of which considerable evidence still remains are indicated on the map.

On the Stephen J. Reynolds farm (Plate X, 4), three-quarters of a mile west of Rising Sun in April, 1916, Craig Adair and Henry S. Pyle of Wilmington leased a strip along the run from the county road on the east to a short distance below the location of the buddle which is the point shown on the map for this locality. Several months were spent in prospecting but the results were so unfavorable that the lease was surrendered without any shipments being made. A screen analysis and chemical analysis of a sample of the concentrates prepared here is given on pages 167 to 173 where it is described as Sample IV. The abnormally low chrome content of the sample is in harmony with a statement from Mr. Pyle in a letter to the author that "we could not find any deposit of workable size that gave over 8 or 9 per cent chromic oxide in the concentrate."

One mile north of Rising Sun on the Lincoln farm at a fork in the run (Plate X, 5) is an area about 150 feet in diameter showing evidence of having been worked for sand chrome. The last work is said to have been done here about 20 years ago by Joseph P. Cain.

The sands in a flat along the run on the John Stevenson farm (Plate X, 6) 1½ miles northeast of Rising Sun were also worked about 20 years ago by Joseph P. Cain. Thirty-seven tons of concentrates were shipped in the course of about 4 months when operations were suspended on account of the low chrome content of the ore. This locality was again prospected in the spring of 1916 by Adair and Pyle with the same disappointing results that they obtained on the Stevenson farm.

Branch of Northeast Creek, northeast of Calvert (Plate X, 7)

A mile and a quarter northeast of Calvert on the Frank A. Brown farm is a fork of Northeast Creek with broad flat meadows on each side underlain by sands and gravels which are chrome bearing and have been worked in the past. The most productive period is said to have been from 1858 to 1868 and the last work was done about 35 years ago by Joseph P. Cain.

An area of about 3 acres is marked by numerous pits from which the sands were dug. According to John Cain who worked here the pits had a depth of 6 to 7 feet and horizontal dimensions of 10 by 15 feet. In the bottom, 18 inches to 3 feet of chrome-bearing sands and gravels were encountered. After screening the coarse material from this layer it took about ten parts of sand to yield one of concentrate.

HARFORD COUNTY

Rock chrome was worked at two localities in Harford County of which the more important lies about 2 miles northwest of Coopstown. Here were located the Reed mine, which was one of the largest in the State, and the Wilkins mine. Of less importance were openings half a mile east of Chrome Hill. Sand chrome appears to have been worked at a number of localities of which the best known is that to the southeast of Cherry Hill. There was also a concentrating mill near the Wilkins and Reed mines.

Reed mine (Plate XI, 8)

The Reed mine, situated 2 miles northwest of Coopstown and 1 mile northeast of Jarrettsville, was discovered early in the history of the Maryland chrome industry and turned out to be one of the largest producers, being credited with an output of more than 100,000 tons. It seems that the mine was worked at two different periods, for a number of years upon its discovery and again some time after 1860 until it was abandoned about 1880. The property was owned by the Reed family and operated under lease by the Tyson Mining Company. William Glenn[6] gives a somewhat full account of the discovery of the Reed

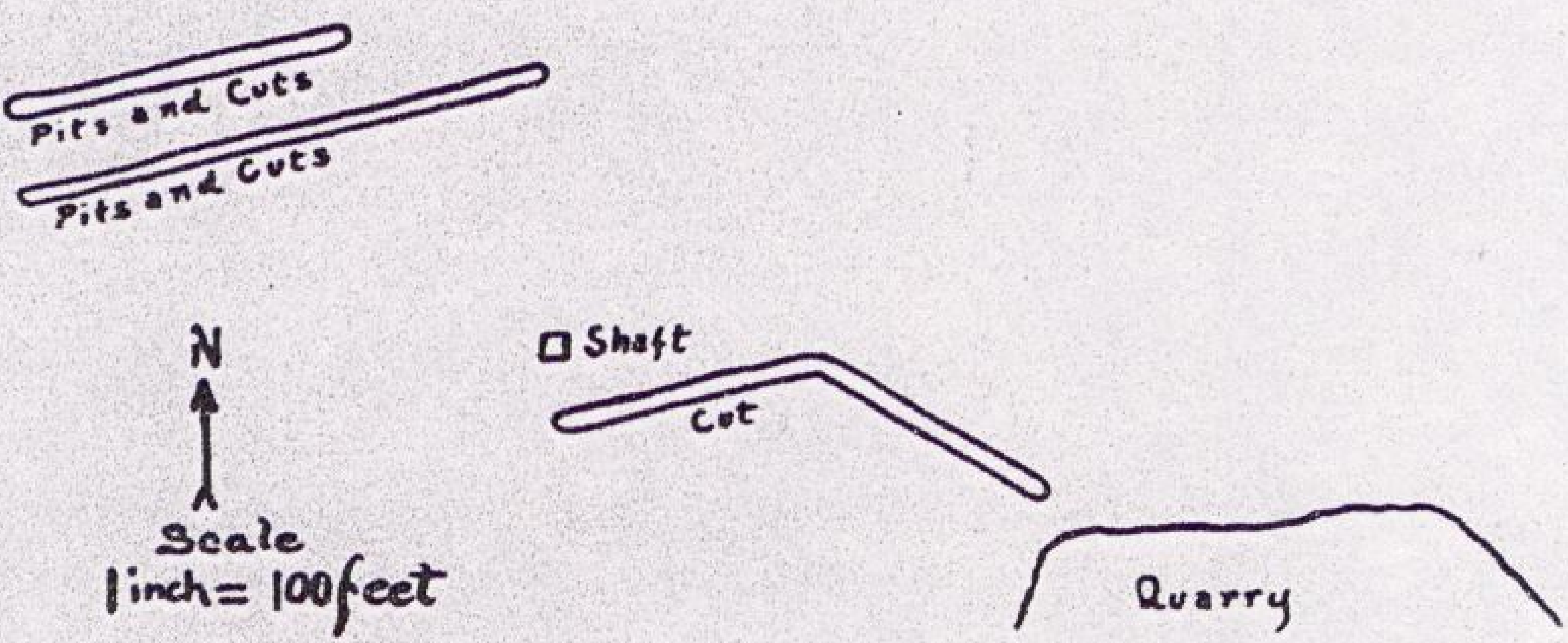


FIG. 7.—Sketch of surface workings of the Reed Mine

mine. He says that in 1827 Isaac Tyson Jr. saw in Belair Market in Baltimore a cart containing a cider barrel held from rolling by some heavy black stones which he recognized to be chromite. The source of the stones was traced to what became the site of the Reed mine near Jarrettsville in Harford County. Within a rude circle a hundred feet in diameter lay nearly 30 tons of such stones on the surface. A shaft was sunk on the site which at the depth of 8 feet encountered a pocket of ore dipping 75° westward. The deposit proved to be 80 feet in length, 25 feet in width, and 4 to 8 feet in thickness. In addition two smaller pockets were found nearby.

[6] Glenn, Wm. Trans. Amer. Inst. Min. Engineers, vol. xxv, 1895, pp. 487–488.

The surface evidence of the operations, in the way of shafts, cuts, and prospect pits, which are unusually extensive, are shown in Figure 7. At the southern end is a stone quarry which has supplied serpentine for road metal. An opening about 6 feet wide and now filled with water to within 15 feet of the top runs from this point for 100 feet in the direction N. 60° W. and thence S. 75° W. for another 100 feet. Twenty feet north of the west end of this opening is a shaft and 100 feet north of the shaft a series of cuts and pits running S. 75° W. for 200 feet. Another series of such openings parallel to the former lies 25 feet to the north of it and has a length of 125 feet. Carroll Pennington says that none of the openings exceed 100 feet in depth.

The mine was very actively worked in the later years of its history, running night and day. The massive chrome ore was shipped in the crude state and the leaner disseminated ore concentrated by Carroll Pennington in his mill three-quarters of a mile to the southeast. The ore was hauled to Whitehall on the Northern Central Railroad for shipment.

The rock on the dump ranges from fresh serpentine to talc in character. Mixed with it is considerable lean disseminated ore in which the chromite grains are about $\frac{1}{25}$ inch in diameter. The quarry at the southeast end of the workings has a face 180 feet long and 15 feet high but shows no evidence of an ore body.

In 1922 the Maryland Chromite Company unwatered and cleaned out the old shaft. A small chrome ore production was reported by the company from 1922 to 1925. Operations were short-lived and the property has been idle for several years.

Wilkins mine (Plate XI, 9)

One-half mile southeast of the Reed mine on the north side of the State Road between Coopstown and Jarrettsville, is a group of 6 pits roughly in a line N. 55° W. that were worked by Wilkins and Street about 1870. Four men were engaged in mining here for about 2 years when the showing became so unfavorable that operations ceased. A mill erected a quarter of a mile east of the mine for the concentration of the ore would indicate that the ore bodies consisted of disseminated rather than massive ore.

Wetherill mill (Plate XI, 10)

The Wetherill mill erected by Wilkins and Street to treat the ore from their mine, which, however, remained in operation for only a short time, was later purchased by Caroll Pennington who concentrated ores for the Tyson Mining Company from the Reed mine. The equipment consisted of 12 stamps by which the ore was crushed to pass through a 12-mesh screen, and circular buddles, and troughs. The stamp pulp was given a first concentration in the circular buddles and a final concentration in troughs against a stream of water. The mill had a capacity of one ton of concentrates per day and Pennington was paid at the rate of $18.00 per ton of concentrate.

Ayres mine (Plate X, 11)

On John Ayres farm, a half mile east of Chrome Hill, is an opening 30 feet long, 4 to 8 feet wide, now full of water. A comparatively large dump corroborates the statement that it reached a depth of 75 feet. The work was done about 1870. Other smaller pits in the vicinity yielded but little ore.

Run southeast of Cherry Hill (Plate XI, 12)

A small tributary of Deer Creek south of the secondary road 1 mile east and southeast of Cherry Hill has yielded considerable sand chrome. About 60 years ago Frank Rigdon employed half a dozen men in operations on this run. Later John P. Grier took out a little ore. Along the course of the stream are a number of little flats where branches unite with the main run, the sands under which have been washed for chrome. The serpentine in this vicinity contains many small grains of chromite averaging under $\frac{1}{25}$ inch in diameter so that the weathering of the rock is constantly liberating grains of ore that finally find their way into the stream. John P. Grier describes the chrome concentrates as consisting of particles about the size of coarse powder grains.

BALTIMORE COUNTY

Baltimore County contains two areas that have been productive of chrome ore. Bare Hills, which lies on the northern edge of the suburb of Mount Washington to the north of Baltimore City, is noteworthy chiefly as the locality at which chrome ores were first discovered in Maryland. Rock chrome was mined from a number of openings but none of the deposits proved to be large. Sand chrome was washed from the streams of this serpentine area. The Soldiers Delight region, about 10 miles northwest of the Bare Hills, has been the most productive area in the State. There were four important chrome mines: the Choate, Weir, Harris, and Calhoun and large quantities of sand chrome were washed from the streams. A concentrating mill treated ores from the Weir and Harris mines. The Choate mine was cleaned out again and produced a small tonnage in 1917 and 1918. Chrome mining had been kept alive in Maryland during the three or four decades preceding the war almost solely through the production of a few tons of sand chrome nearly every year.

Bare Hills (Plate XII, 13–32)

The exact date at which chrome ore was discovered at Bare Hills and at which chrome mining was commenced is somewhat uncertain. H. H. Hayden[7] writing in 1833 says the discovery was made about 1808 or 1810 though later references place the date about 1827. A sketch map of the Bare Hills which Hayden gives has located on it many of the openings now existing and he speaks of the operations there in the past tense and as having been abandoned for some time. Hence it would appear that 1827 is too late and that Hayden's dates may be correct. A number of openings not found on Hayden's map would indicate that work was resumed some time after 1833.

A noteworthy feature of this locality is the great number and wide distribution of the points at which chromite was found, though it is true that most of the occurrences were of insignificant size. But at other localities ore was not found at so many points. Considerable

[7] Hayden, H. H. Description of the Bare Hills near Baltimore. Amer. Jour. Sci., vol. xxiv, 1833, pp. 349–360, map.

Map of portions of Baltimore County showing serpentine areas and localities at which Chrome Ores have been produced.

Scale, one inch equals one mile

sand chrome was also obtained from principal gulches and runs of the area but the work was done so many years ago that only faint traces of it are now discernible and there is no information available regarding it.

On account of the convenient location of the Bare Hills chrome pits they have been the mecca of mineralogists and students from Baltimore until the dumps have been so completely picked over for specimens that it is now difficult to find even a fragment of chromite. Consequently little can be said in description of the ore from present knowledge of material on the ground. Hayden says that large quantities of excellent chrome were obtained and also describes leaner material in which "the veins of chrome are so intimately blended with the gangue, most of which is a very compact indurated talc steatite, that it is almost impossible to separate one from the other and the specimens from the pits are traversed by veins of chrome ½ to 2 inches thick."

At (13) is a trench 12 to 15 feet wide with a maximum depth of 10 feet which runs down the hill slope 50 feet, and 100 feet west of it a smaller opening was made. Two hundred yards to the east, across a fork of the stream, is a group of three pits designated (14), (15), and (16), the westernmost of which appears from the size of the dump to have been the largest. Two hundred yards up this fork on the east side of the hollow is an opening (17), 30 feet by 20 feet, which is now 6 feet deep. Directly over the hill is another small pit (18), and across a hollow from it (19) an abandoned stone quarry where Hayden's map located a chrome opening. At (20) is a trench 50 feet long in the direction S. 40° W. which is 4 to 5 feet wide but now less than 6 feet in depth. At the mouth of this hollow, on its east slope, are three small openings (21), one well up on the nose of the ridge and the other two near the bottom. The largest openings at the Bare Hills area are (22) and (23). The former consist of several pits and a long trench well up on the west slope of the hollow at the base of which an adit was driven into the hill under these workings for 80 feet without making connection with them or encountering ore. The latter consist of an incline, a long cut, and two adits. The incline goes down at an angle of 45° in a southeasterly direction but is now nearly filled with débris. The cut extends from it diagonally down the slope of the hill in a southwesterly direction to the bottom of the hollow from which point a long adit runs back under the higher workings. A second adit, which could not be traversed on account of water, enters from the main run on the north and extends back under the upper workings. Opening (24), near the head of a small gully on the west side of the hollow in which the openings last described lie, is simply a small cut on the dump of which there is some lean disseminated ore. Farther up the same hollow and on the west slope is another cut (25) which is 35 feet long and 4 to 5 feet wide, on the dump of which is much disseminated ore. In the next hollow to the east are two small pits and a trench (26) successively about 100 feet apart from south to north. A small pit and a stone quarry (27) near the top of the ridge across the main stream from the openings hitherto considered show serpentine with sparsely disseminated chromite and there is also a small pit near the nose of the ridge (28). On the south slope of the main run east of the Falls Road is a small pit (29). A pit that from the size of the dump appears to have been deeper than the others on the east side of the road is located at (30). Another pit (31) about 25 feet in diameter and 10 feet deep is on the ridge overlooking Lake Roland. A group of smaller pits on both sides but mainly on the west side of a small hollow (32) cover a larger area than usual and may have also been worked for stone. The rock contains sparsely disseminated chromite.

SOLDIERS DELIGHT

Choate mine (Plate XII, 33)

The Choate mine, located 3 miles west of Owings Mills, was reopened by the Maryland Chrome Corporation in 1917 after having lain idle for 40 years. The property is owned by F. A. Dolfield who was president of the company. Work was started late in the spring of 1917 and all operations ceased upon the declaration of the armistice on November 11, 1918. The work did not get much farther advanced than to clean out the old mine which involved the removal of 2,500 tons of débris. The old mine workings consisted of an incline 165 feet long with a dip of 20° in the direction S. 75° W. from which drifts had been run 80 feet to the south and 40 feet to the north. The method of mining had been to gouge out all the workable ore possible, leaving pillars of ore or rock where necessary.

The edges of the ore body showing in the mine when it was being cleaned out were not over 2 feet thick and for the most part less than 1 foot. Men who formerly worked in the mine described the ore as having been "in and out," that is, rapidly pinching and swelling, often cut out altogether, and never exceeding 4 to 5 feet in thickness. Mr. Dolfield described the ore as occurring in lenses. A lens would pinch down to an inch or two in thickness and then open up into another lens. Eleanora Bliss Knopf[8] described the ore as occurring in irregular pockets that pinched and swelled within a distance of a few inches and says that in places it was concentrated into lenses that range from 18 inches to 4 feet in width.

The ore was hand sorted into lump ore that averaged over 40 per cent Cr_2O_3 and lean ore that was concentrated in a mill equipped with James tables. The composition of three consignments of rock ore and one of concentrates as determined by Penniman and Browne were as follows;[9]

ANALYSES OF CHROME ORE FROM CHOATE MINE

	Rock Ore			Concentrate
Chrome oxide	41.56	43.23	43.59	40.83
Iron oxide	24.96	20.49	12.99	32.48
Silica	6.82	4.44	4.16	2.66

Weir mine (Plate XII, 34)

The Weir mine on the F. A. Warner property lies about 4 miles west of Owings Mills and was the largest of the Soldiers Delight mines. There are two vertical shafts 60 feet apart in a line N. 60° E. Adjoining the second shaft and running in the same direction is a cut over 100 feet long, 15 feet wide, and 6 feet deep; and 30 feet north of the shaft a third shaft nearly completely filled in. About 100 feet northwest of the far

[8] Knopf, Eleanora Bliss. U. S. Geol. Survey Bull. 725, 1922, p. 96.
[9] Personal communication from F. A. Dolfield.

end of the trench is a fourth shaft which continues as a trench 15 feet deep for 40 feet in the direction N. 30° W. and from the far end of which a branch runs for more than 100 feet N. 50° E. The latter is 6 to 8 feet wide and 6 feet deep. The underground workings of this mine are said to have reached a depth of 200 feet and the ore body to have consisted of a series of more or less isolated masses of ore from 2 to 4 feet in width. Associated with the massive ore was much disseminated ore for the concentration of which a mill was built 150 yards northeast of the mine.

Harris mine (Plate XII, 35)

The Harris mine is also located on the F. A. Warner property, a quarter of a mile northeast of the Weir mine, and across the run from it. The surface openings extend for about 200 feet in the direction N. 15° E. and consist of 4 timbered shafts filled with water, the lower ones nearly to the top and the highest to within 30 feet of the top. The wall rock of one of the shafts which at its mouth is enlarged to 25 feet by 8 feet consists of serpentine in which abundant grains of chromite from $\frac{1}{50}$ to $\frac{1}{25}$ inch are disseminated. Fragments of richer chrome occur on the dump. Ore from this mine was also treated at the mill which was located between it and the Weir mine.

Weir and Harris mines mill (Plate XII, 36)

On the north bank of the run separating the Harris and Weir mines was a mill, part of the stone walls of which are standing, that concentrated the leaner ores produced at those mines. The mill was operated by steam power and consisted of crusher and rolls for crushing the ore, and three round buddles and five long buddles for the concentration of it.

Calhoun mine (Plate XII, 37, 38)

The Calhoun mine at the northern edge of the Soldiers Delight serpentine area 1 mile west of Delight has been shut down since about 1880. There were two shafts at this locality. On the east side of the main shaft (37), which is reported to have been worked to a depth of 100 feet, is a ditch over 100 yards long in the direction N. 20, W. in which ore was apparently encountered at only one point N. 45° E. of the shaft. The site of the other shaft (38) is now marked by a large serpentine quarry. There are no evidences of chromite ore in the quarry.

Dolfield buddle (Plate XII, 39)

The sands in the bed of a stream on the F. A. Dolfield property 2½ miles southwest of Owings Mills were washed by William Rose in a buddle built there about 1914 and operated until the spring of 1916. A screen and chemical analysis of a sample of concentrate from this buddle is given on pages 167 to 170 this sample being numbered III. It is the highest in chromic oxide of any of the samples analyzed. The ore was sold to W. C. Lowndes of Baltimore. Mr. Dolfield states that the area was prospected by the Dorr Company in 1917. Twenty pits were dug to bedrock on which there were 6 inches of chrome-bearing sand carrying 20 per cent Cr_2O_3. It was estimated there were 2000 tons of this sand in the flat. A ratio of concentration of 4 to 1 yielded a concentrate of the following composition:

Chromic oxide	42.09
Iron oxide	28.66
Silica	3.30

This is almost identical with the composition of the concentrate from the Dolfield buddle.

Gore buddle (Plate XII, 40)

Jay Gore has a buddle on a stream through his farm 2½ miles west of Owings Mills, the sands of which he worked for a number of years, but has done no work since 1915. He usually worked two or three men a few weeks each year and produced 5 to 6 tons of concentrate which he sold to Pusey Bye of Philadelphia. One year by working his force all summer he got out nearly 15 tons of concentrate. Both the present stream bed and the banks of the stream are worked and the sands are of such a grade that 8 tubs of the screened sand as brought to the buddle after five or six washings are reduced to 1 tub of concentrate. A screen and chemical analysis of a sample of concentrate from this buddle are given on pages 167 to 170 where the sample is described as No. II.

Old Triplett buddle (Plate XII, 41)

The stream between the Harris and Weir mines, 3½ miles west of Owings Mills, was formerly worked by R. A. Triplett for sand chrome. Remains of the dam and buddle, and places along the banks where the sands were worked are still distinguishable.

Triplett buddle (Plate XII, 42)

One-half mile south of the Weir mine on the banks of Chimney Branch on his own property R. A. Triplett had a newer buddle. The conditions here are very favorable for chrome washing. The stream has a broad bed and yet sufficient grade so that not much detrital matter has accumulated. The chromite collects consequently in a fairly concentrated form in the irregularities and depressions in the bed of the stream. Having less protecting cover much of the finer material is carried away and the screen analysis of a sample of Triplett's concentrates shows it coarser than the other samples. Moreover, each year's freshets wash down into the stream from the barren slopes that feed it a new supply of chromite so that it has been possible to work the same places year after year. Triplett was the largest and most regular producer of sand chrome in this region for a number of years. By working a force of six men from July to cold weather he got out as much as 65 tons of concentrate in one season. Since the war he has produced only 12 tons of stream chrome and rewashed the tailings of the Choate mine mill. A screen and chemical analysis of a sample from this buddle are given on pages 167 to 172 the designation of the sample being No. I. The concentrates were formerly sold to the Tyson chrome works and later to W. C. Lowndes of Baltimore.

MONTGOMERY COUNTY

Though there are numerous outcrops of serpentine southwest of Soldiers Delight across Carroll, Howard, and Montgomery counties at only one locality, near Etchison in Montgomery County, does chromite appear to have been found in commercial quantity.

Etchison mine (Plate XIII, 43)

On the farm of Columbus Griffith three-quarters of a mile west of Etchison, chrome ores were mined off and on several times prior to the Civil War and hauled to Woodbine for shipment. There appears to have been three openings. The largest and only accessible one shows no evidences of chrome ore. It consists of a pit 30 feet in diameter and 15 feet deep from which a gallery runs with a steep down grade for 50 feet N. 20° W. and then turns N. 70° E. for 30 feet. The country rock is a soft talcost schist with the direction N. 70° W. 30° N. A second opening 80 feet distant in the direction N. 35° E., and a third 50 feet N. 75° E. of the second are now completely filled up but the small dumps about them contain serpentine in which there are metallic particles but no pieces of massive chromite could be found. The indications are that not much ore was produced here.

MANGANESE ORES IN MARYLAND

INTRODUCTORY

Manganese, an important metal of modern industry, exists in the United States in quantities inadequate to the demand. For many years prior to the war the United States produced less than 1 per cent of its high-grade manganese consumption. Under abnormal conditions of the war, as a result of special encouragement, the domestic production was stimulated to the point of meeting 35 per cent of our manganese consumption. Under post-war conditions, despite a protective tariff, manganese production has decreased to 11 per cent of consumption. The possibilities of domestic manganese deposits is consequently a subject that has received much attention and the question arises what can Maryland contribute toward a domestic manganese production.

MANGANESE ORE LOCALITIES IN MARYLAND

The localities at which the occurrence of manganese ores is mentioned are not numerous. Ducatel and Alexander in 1835 mentioned several localities at which manganese ores occur but not in sufficient quantities to be workable. In the western part of the State they give Bear Creek, a tributary of the Youghiogheny River, and Keysers Ridge 5 miles south of the National Road as localities at which ores of good quality occur. Farther east they cite the occurrence of manganese ore associated with copper near New Market and a formation of mangenese ore near Mechanicsville, now Olney, in Montgomery County. P. T. Tyson, in 1862, mentioned the occurrence of a manganese deposit near Brookville in Montgomery County which had been worked some years earlier, and J. D. Weeks in 1894 referred to the Brookville occurrence and to a deposit that had been worked on the Potomac River near Harpers Ferry. In 1911 the author described the occurrence of some manganese ore in association with iron ore near Mount Airy and the occurrence of from 2 to 4 per cent manganese in some of the limonites of Bachman Valley and Catoctin Mountain.[10] Only two of these localities are reported to have produced manganese ores, namely, the deposit near Brookville in Montgomery County and that near Dargan, on the Potomac River in Washington County, both of which are now idle.

DESCRIPTION OF PRODUCTIVE LOCALITIES

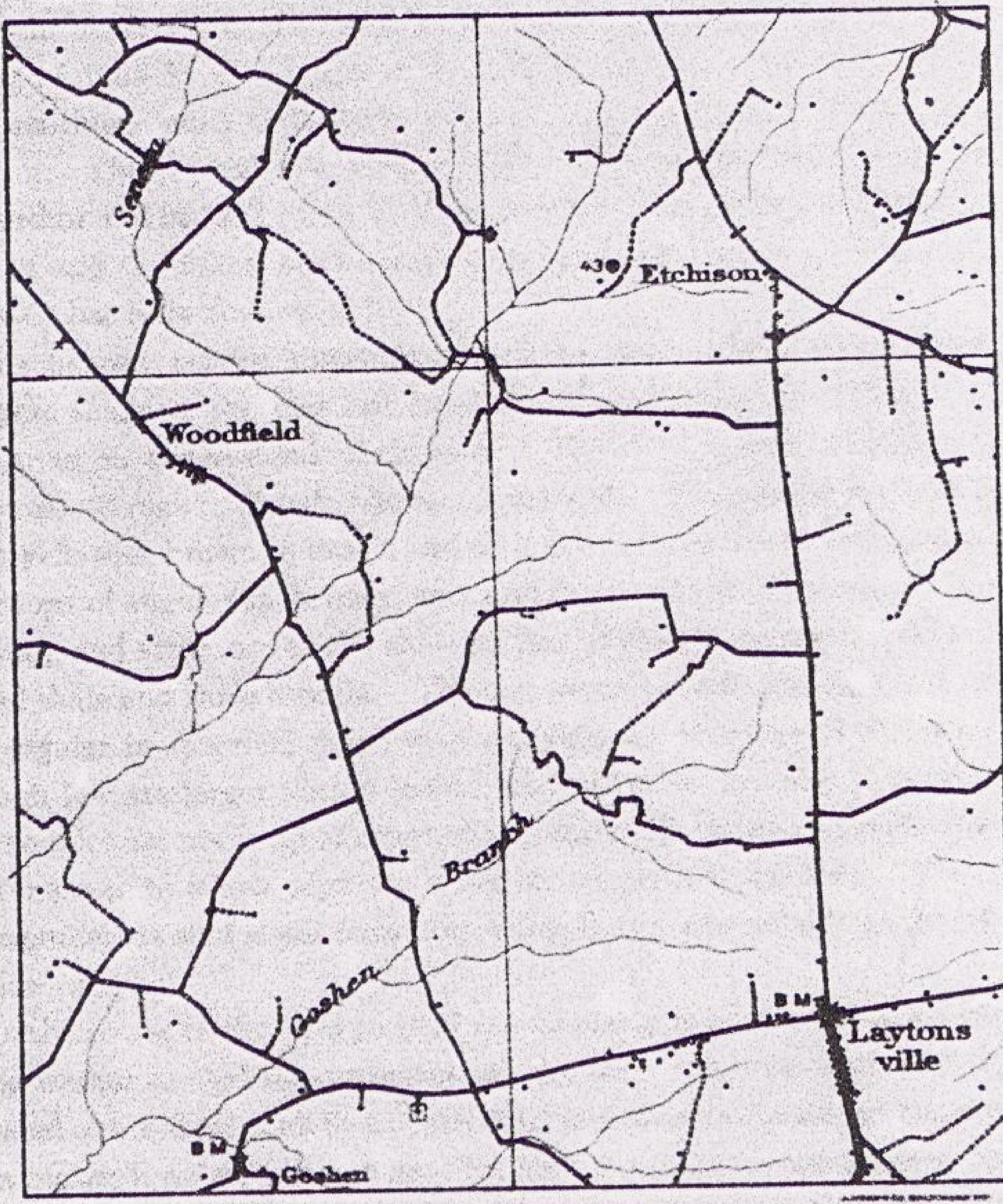
Brookville mine

P. T. Tyson on page 68 of his report as State Agricultural Chemist in 1862 mentions the occurrence of a manganese deposit 1½ miles west of Brookville in Montgomery County. It was prospected some time before 1860 and the mining not proving profitable was soon abandoned. At the time of Tyson's visit the old opening was already so filled in that there was nothing to be seen. In 1910 the author was able to discover no evidence of it nor any one in the neighborhood having knowledge of its exact location. As Mechanicsville was less than 2 miles south of Brookville this may also be the locality referred to by Ducatel and Alexander as near Mechanicsville.

Dargan mine

The Dargan mine is situated on the north bank of the Potomac River and on the north side of the Chesapeake and Ohio Canal, 3 miles north of Harpers Ferry and 1 mile southwest of Dargan. The mine was

[10] The Iron Ores of Maryland. Md. Geol. Survey, vol. ix, 1911, pp. 123–327.



Map of a portion of Montgomery County showing locality at which Chrome Ores were mined.

Scale, one inch equals one mile

opened in 1876 by Wells and Davis who obtained both hard and soft manganese ore which was shipped on the Chesapeake and Ohio Canal. The openings extended below the level of the canal and a flooding of the workings caused a suspension of operations. About 1898 the mine was again opened by a Mr. McIntosh who sunk a 23-foot shaft about 100 feet from the canal. Work had only been carried on about a month when the shaft was flooded and the property again abandoned. In the spring of 1908 E. R. Cooper of Baltimore resumed operations which were continued until 1910 by the Potomac Refining Company organized by him. The deposit was visited while the work was under way by the author and in 1912 by D. F. Hewett of the United States Geological Survey and the following description is based on data then obtained. No work has been done since 1910.

The deposit occurs along an overthrust fault plane whereby the Harpers shale on the east has been thrust up against the Tomstown limestone on the west side of the fault. The ores are found in a zone of decomposed rock or clay that lies along the fault. This clay is variegated light-yellowish-brown to brown and pink in color, contains numerous impressions of angular shale fragments, and frequently shows distinctly the bedding and structure of the shale so that it clearly represents decomposed shale and shale breccia. The ores occur as hard slag-like nodules of irregular to spherical shape with a maximum diameter of 20 inches, though few are larger than 6 inches, embedded in the clay. Most of the nodules are made up of alternating concentric layers of psilomelane and manganite which separate when struck with a hammer. Brown manganiferous wad is not found but irregular patches of soft pyrolusite replace clay.

In the course of the 1908 to 1910 operations pumps were installed and a log washer erected for concentrating the ore. The old openings were cleaned out, a shaft sunk to a depth of 60 feet close to the limestone, and at a higher level an adit run east through a pocket of manganese ore and thence N. 12° E. for 150 feet through pink manganiferous clay. The operations yielded about 60 tons of good-grade lump ore and 90 tons of low-grade washed ore. The ratio of crude ore to washed ore is not known but is very high. The analysis of a sample of the ore collected by J. S. Grasty is:

Manganese	22.59%
Silica	26.58
Iron	2.73
Phosphorus	0.37
Sulphur	0.004

The work done on this deposit has been confined to a zone about 50 feet wide immediately east of the limestone, though the zone of decomposed shale has a width in places of over 150 feet. The same geologic conditions were found in a tunnel cutting the fault zone about 3,800 feet north of the mine and the presence of a small amount of manganese ore determined. There are also scattered nodules on the surface between the two points. These facts suggest the possibility of a considerable horizontal extension of the manganese ore along the fault. On the other hand, from physiographic considerations Hewett concludes that the bottom of the Dargan mine represents a depth 150 feet greater than that of the Virginia mines of similar geologic position at the time of ore formation and consequently suggests that the poor showing thus far encountered in this deposit may be because it represents the lower limit of ore deposition. The available information concerning the possibilities of the deposit is, therefore, somewhat uncertain and additional prospecting would be required to prove its real character.

ECONOMIC ASPECTS OF MANGANESE MINING IN MARYLAND

According to data in hand only one locality in Maryland offers any prospects of being capable of furnishing manganese ores. The work thus far done there has yielded results of an inconclusive nature. It has hardly been sufficiently thorough or systematic to justify a condemnation of the deposit as unworkable. On the other hand, it has given no indication of the existence of a large body of workable manganese ore. All that can be said is that the deposit is worthy the attention of any one willing to take a long chance in the development of a manganese property.

PART III

THE SERPENTINES OF HARFORD COUNTY, MARYLAND

BY

ALBERT JOHANNSEN

THE SERPENTINES OF HARFORD COUNTY

INTRODUCTION

Location of Area

There is a narrow region extending through Maryland and through Pennsylvania, New Jersey, and Delaware on the north; and through Virginia, North Carolina, South Carolina, Georgia, and into Alabama on the south, throughout which are numerous disconnected areas of serpentine and talc rocks. The general distribution is shown on Plate I, but owing to the small scale of the map many minor areas had of necessity to be omitted. The geology of much of this region has never been thoroughly mapped and it has been impossible to obtain data for more than a general platting of these areas, especially to the south.

The Piedmont Plateau

All of these serpentine and talc bodies lie in the region known as the Piedmont Plateau. This is a region of folded, crumpled, highly metamorphosed, and crystalline rocks extending from New York to Alabama. A similar district occurs to the northward and extends through Rhode Island, Connecticut, eastern Massachusetts, southeastern New Hampshire, and along the coast of Maine. The southern area widens southward until it is 300 miles broad in North Carolina. South of this it is not so well defined and gradually disappears beneath the Coastal Plain of Alabama. To the east the boundary is well marked throughout the greater portion of its extent. Resting upon the upturned edges of the hard, compact, crystalline rocks of the Piedmont Plateau are the loosely consolidated, horizontal beds of clay, sand, and gravel of the Coastal Plain. These Mesozoic and Cenozoic deposits, with their comparatively low dip, have been much less eroded than the older rocks of the Piedmont, and the physical features, which have been formed to a great extent by the drainage, stand in great contrast with the topography of the latter. Throughout its entire extent the eastern boundary corresponds closely to what is known as the "fall line." North of the Roanoke River in Virginia this line is near the head of the tidal estuaries. At Trenton, New Jersey, the falls are several miles above the southern boundary of the Philadelphia gneiss. Above Havre de Grace, on the Susquehanna, the falls are about the same distance above the head of the tidal estuary. The falls of the Potomac and the end of the Piedmont are several miles northwest of the city of Washington.

South of the Roanoke, the Coastal Plain sediments end above tidal level and the boundary of the Piedmont swings to the west and ends beneath the Mesozoic and Cenozoic rocks of Alabama. Throughout the region south of Virginia the boundary is, therefore, less clearly defined, and the sediments scantily cover an intermediate zone of varying width, making the establishment of a clearly defined line impossible. Though the fall line at the north is not often a sharply defined scarp and the deposits of the Potomac and Pleistocene sometimes overlap the boundary, yet the physiographic contrast and the petrographic difference in the rocks make the division a sharp one.

The western boundary of the region is not so well marked petrographically, but the broken, rounded hills stand out in strong contrast with the quartzite crest of the Blue Ridge. The rocks, highly metamorphosed in the eastern part of the Piedmont region, gradually become less so and pass into the less contorted and unaltered Paleozoic rocks of the Appalachian zone. South of Virginia the western or northwestern boundary is more clearly marked by what is known as the "Cartersville Fault".[1] This is an overthrust fault with an overlapping in some places of as much as 11 miles. West of this fault the rocks are unaltered Paleozoic sediments, and the overlying metamorphic rocks form a nearly continuous line of bluffs of from one hundred to three feet in height.

[1] Hayes, C. Willard. "The Overthrust Faults of the Southern Appalachians." Bull. Geol. Soc. Amer., 1890, v. II, p. 147.

THE ROCKS OF THE REGION

All of the rocks which occur in the Piedmont area are highly metamorphosed and crystalline, and extend with a general northeast-southwest strike across the plateau. The major portion of the rocks are mica-gneisses and phyllites into which have been intruded granites, gabbros, peridotites, and pyroxenites. The gneisses and phyllites are considered, for the most part, as sedimentary rocks in which the original character and bedding have been obliterated by subsequent metamorphism due to earth-movements, the intrusion of other rocks, and the action of underground waters. It is not at all improbable that with the original sedimentary rocks were associated igneous and eruptive rocks. It is, in fact, more than probable that this was so; but whatever the character of the original rocks, their former characters have been so changed that we can only say that some, at least, were sedimentary. Since the mineral constituents of the sedimentary rocks were derived originally from igneous rocks, one can easily see that when highly metamorphosed, it must be impossible to determine their origin.

The groups of rocks which are of greatest importance in this region are the gneisses, phyllites, granites, quartzites, gabbros, diorites, peridotites, pyroxenes, and limestones. Of these the gneisses and phyllites are the ones most widely distributed.

THE GNEISS

This rock varies greatly in character in different parts of the area and even in areas not far removed from one another. It ranges in color from a white to dark-gray or black, and in texture from very coarse and friable to very compact, homogeneous, almost pure quartz rock. At times it consists of feldspar and quartz with but little mica, and again it shows but little besides mica or hornblende. In many places the rock is so massive that even in quite large pieces it is impossible to see the parallel arrangement of the constituents; in others, there is an exceedingly fine parallel arrangement of the minerals. Very often this banding becomes exceedingly fine, and its crumplings, twistings, and foldings show that the rock has been subjected to repeated dynamic action.

THE PHYLLITE

These rocks are intermediate in character between the slates and the gneisses. They are essentially fine-grained mica-schists. The chief mineral is generally mica having its flakes parallel with the cleavage or schistosity of the rock. Associated with this is quartz, which, with the mica, forms the chief part of the rock. In many places garnets are very abundant in the rock, often forming as much as one-third of the bulk. Tourmalines are also very abundant in the quartz in many localities.

THE GRANITE

The granites in general are of medium fine-grained texture and are usually compact and homogeneous. In composition they vary somewhat, some carrying biotite, muscovite, hornblende, epidote, allanite, or zircon. The "granite" of Port Deposit, really a monzonite, is somewhat banded and consists of orthoclase, oligoclase, mica, and quartz. The Ellicott City granite is distinguished by the presence of large Carlsbad twins of orthoclase.

The granites are both older and younger than the other eruptive rocks with which they are associated. Their eruptive origin is clearly shown by their diverging apophyses, by the inclusions of the rocks through which they penetrated, and by the crumpling and contact-metamorphisms of the neighboring rocks.

THE QUARTZITES

A small portion only of this area consists of quartzites. It consists of quartz and muscovite in thin layers. In the micaceous layers are many fragments of stretched tourmaline, indicating a movement after the crystals had been formed.

THE GABBRO

This rock consists of hypersthene, diallage, bytownite, and magnetite, with some hornblende and apatite. It is generally of fine grain, massive, and very dark in color. The rock varies in texture as well as mineralogical composition. When the ferro-magnesian constituent is principally an orthrombic pyroxene the rock becomes a norite. In many places the rock has been metamorphosed and passes into a schistose rock—the meta-gabbro. When the pyroxene is replaced by hornblende the rock becomes a gabbro-diorite.

THE DIORITE

The diorites closely resemble the granites in appearance, differing in the predominance of a plagioclase feldspar over the orthoclase. They always contain hornblende and generally also biotite. Quartz may or may not be present. Diorites are of much less importance in Maryland than either the gabbro or granite, and are much less widely distributed.

THE LIMESTONE

The limestones consist of marbles, limestone breccias, and impure limestones. The marbles vary in texture from a fine-grained dolomitic marble to a coarse-grained rock with but little magneisa. They are often accompanied by tremolite, muscovite, phlogopite, tourmaline, scapolite, quartz, pyrite, and rutile. All of these occur in layers, corresponding to the bedding. In Carroll and Frederick counties a mottled red and white marble known to the trade as "Potomac marble" or "Calico rock" is found. It consists of subangular fragments of limestone, quartz, slate, granite, and porphyry in a red ferruginous cement. It may have originated as talus slopes which were later cemented.

THE PERIDOTITES AND PYROXENITES

These are the youngest of the eruptive rocks in the region. They consist of the basic end of the gabbro magma. The peridotites consist of olivine and pyroxene, with more or less magnetite; the pyroxenite, of bronzite and diallage. Both of these rocks are generally much altered. The pyroxene, when it occurs alone, passes into secondary hornblende, and this in turn to talc; tremolite and chlorite being usually associated in the talc beds. The peridotites, consisting of olivene with pyroxene, usually alter to serpentine; the serpentine rocks generally containing secondary hornblende formed from the diallage. Neither of these rocks cover large areas but usually occur in small lenses and stringers. North of the Carolinas the rocks are generally altered; farther south they are very much less so changed.

The sequence of the intruded rocks as given by Dr. F. Bascom for Cecil County[2] is as follows, the granites being considered by her as first intruded in the area which she describes: Granite, Meta-rhyolite, Gabbro, Pyroxenite, Peridotite.

THE SERPENTINE AREA

The region of the serpentine stands out prominently in this area of crystalline rocks. The landscape in general is characterized by great diversity of aspect; by rounded hills with U-shaped valleys between—a topography caused by long continued erosion upon the various kinds of rock forming the plateau. The hills are deeply covered with soil and along the roadside large trees make pleasant shade. In the serpentine areas, however, the trees are stunted and the fact that he is walking or driving over a serpentine area is brought forcibly to the notice of a traveller during the summer by the intense heat of the sun which beats down through a growth of stunted oaks, scrub pines, and mountain laurel upon the heated soil, through which everywhere project boulders of the country rock. These areas are known throughout the country as the serpentine "barrens." Wild, uncultivated, almost unsettled, they stand in great contrast to the surrounding rich and prosperous country. The sterility of the soil may be explained in several ways. Owing to the nature of the rock it decomposes very slowly and the products of decomposition may be wached away nearly as fast as they are formed. Consisting, as it does, of silica, magnesia and iron oxides it lacks the lime and potash necessary for the nutrition of plants. It may may be, as suggested by Dr. Loew[3] of the Department of Agriculture, that the preponderance of magnesia over lime may be detrimental to

[2] Bascom, F. "The Geology of the Crystalline Rocks of Cecil County." Md. Geol. Survey, Cecil County, 1902, p. 110.

[3] Loew, Oscar. "Physiological Rôle of Mineral Nutrients." Bull. No. 18, Div. of Vegetable Physiology and Pathology, U. S. Dept. Agri., 1899, p. 42.

plant life owing to the fact that the capacity for food assimilation by the plant may be altered by the substitution of magnesia for lime in the cells.

The color of the soil varies although it is generally of a deep-red when of some thickness. In the shallower portions it is of a lighter color, even yellow or yellowish-green, and from this ranging through all shades of red to an exceedingly dark-red color due to the iron oxides. The soil generally is not more than 6 or 8 inches in depth and even that is attained usually only in the interstices of the broken and fractured rocks. It is quite possible that the slight depth and the consequent inability to retain moisture, may account in large measure for the unproductiveness of the soil.

THE DISTRIBUTION OF THE SERPENTINE OF THE PIEDMONT

Before taking up the study of the serpentine areas of Harford County it will be necessary to see what relations they bear to the serpentine areas found elsewhere in the Piedmont. Following a summary of the distribution of the serpentine north and south of Maryland, will be given a general discussion of the Maryland serpentines. There has been much confusion caused by the fact that both the mineral and the rock are known by the same name. The origin of serpentine has long been in dispute and in order to take up the study of this area it will not be out of place to give a resumé of the various theories proposed. Since serpentine may originate from the alteration of different minerals, it is not improbable that the different serpentines of this area have originated from different rocks. In working up the literature of the serpentines of the Piedmont belt it was found that different writers have traced the origin of the various localities to different original rocks. Since the serpentines of Maryland are apparently of the same general nature as those of other parts of the Piedmont area, if it is true that these have originated from different rocks, it will be necessary to examine the Maryland serpentines and see if they too may be ascribed to the alteration of more than one kind of rock.

AREAS NORTH OF MARYLAND

STATEN ISLAND

The serpentines forming the main range of hills on Staten Island[4] extends from New Brighton to a little west of Richmond, a distance of 8 miles. The serpentine body must be of considerable thickness for in a well near Stapleton[5] it was encountered at a depth of 50 feet below the surface underneath a covering of drift. The boring extends through 150 feet of serpentine without passing through it. In this area the color of the rock varies from a light-green to nearly black and the texture from compact to earthy. There have been various theories expressed as to its origin. Dr. N. L. Britton[6] in 1881 said that he considered the theory that it was derived from a highly magnesian limestone as the one most in accordance with the facts observed. In a later paper[7] the same author says that he now regards them as derived both from limestones and "hornblende, or rather tremolite," strata. There is no proof, he says, of its being a metamorphosed igneous rock. Newberry[8] regarded it as a pseudomorphic condition of a hornblende slate; Julien,[9] that it is derived from a hornblende schist as it contains fragments of altered amphibole. Britton says that this rock differs from the Baltimore serpentine described by Williams, in that there are no olivine fragments and that there is evidence that it was derived from stratified rocks since the strikes and dips are approximately parallel to the neighboring gneiss which the serpentine overlies. The limestones occurring near this area are parallel to it, or nearly so.

NEW JERSEY

Serpentine occurs in several places in New Jersey. Just north of Hoboken[10] it outcrops along the river bank and rises to a height of from

[4] Merrill, George P. Ann. Rept. Smithson. Inst., 1886, pt. 2, p. 367.
[5] Trans. N. Y. Acad. Sci., 1881, vol. i, p. 56.
[6] Britton, N. L. "On the Geology of Richmond Co., New York." Annals of the N. Y. Acad. Sci., 1881, vol. ii, p. 166.
[7] Trans. N. Y. Acad. Sci., 1886, vol. vi, p. 12.
[8] Newberry, J. S., Trans. N. Y. Acad. Sci., 1881, vol. i, p. 57.
[9] Julien, A. A., Ibid.
[10] Cook, George H. Geology of New Jersey, 1868, pp. 325–326.

40 to 50 feet above tide at Castle Point. The outcrop is not more than half a mile in length along the river and from 200 to 300 feet wide, covering an area of about 30 acres. From Castle Point the outcrop descends rapidly both to the north and to the south and is soon covered by the surficial deposits. That it extends considerably farther south is known, for it was found near the end of the Long Dock, Jersey City, at a depth of 179 feet. It is probable that this is part of the same formation which is seen in Staten Island and which extends along the western border of the gneiss from one place to the other. At Hoboken it rests upon the gneiss rocks which outcrop farther south.[11] The serpentine here contains chromic iron in small grains.

At Montville,[12] in Morris County, occurs a deep-green and oil-yellow, often translucent serpentine associated with a massive and coarsely crystalline dolomite. It occurs principally in nodules of a few inches[13] up to 1 or 2 feet in diameter, or as a thin coating on boulders up to 8 or 10 feet in diameter. Merrill says in conclusion[14]: "The Montville serpentine is a highly hydrous variety, approaching retinalite in composition, and was derived by a process of metasomatosis from a mineral of the pyroxene group with the optical and chemical properties of diopside. This change has been accompanied by a considerable increase in bulk, and in most cases the production of beautiful slickensided surfaces, and a platy structure due to pressure. The excess of lime has recrystallized chiefly as granular calcite of a light bluish tinge, and also in fibrous forms . . . .

No free silica in the form of chalcedonic veins, such as are an almost universal accompaniment of altered beds of dunite, have been found. It is inferred that sufficient magnesia must have been furnished from other sources to convert the whole into serpentine, or that further search will bring to light secondary silicate minerals. . . . ."

[11] Russell, I. C. "On the Geology of Hudson Co., N. J." Annals of N. Y. Acad. Sci., 1882, vol. ii, pp. 30, 31.

[12] Merrill, George P. "Building and Ornamental Stones in the U. S. National Museum." Rept. Smithson. Inst., 1886, pt. 2, p. 366.

[13] Merrill, George P. "On the Serpentines of Montville, New Jersey." Proc. U. S. Nat. Mus., 1888, vol. xi, p. 105.

[14] Merrill, George P. Ibid., p. 110.

Serpentine occurs also at Split Rock, in Morris County; at Franklin, in Sussex County; at Phillipsburg and Jenny Jump Mountain, in Warren County; and at Wenoque, in Passaic County.[15]

DELAWARE

In Delaware[16] a limited body of serpentine occurs 6 miles northwest of Wilmington, and a similar vein near where the Brandywine River enters the state. Traversing the first area is a vein of pegmatite from which much pure feldspar has been obtained. The ridge has a length of about 1 mile and a width of from one-third to one-half mile.

PENNSYLVANIA

In Pennsylvania the serpentine areas have been well mapped and there are numerous references to them in the reports of the Geological Survey. They occur in the counties of Northampton, Montgomery, Delaware, Chester, and Lancaster, all in the southeastern part of the state.

Northampton County

In Northampton County, just north of Easton, there is a ridge of hornblendic gneiss with a maximum elevation of 700 feet above tide and with a general strike of N. 60° E. This gneiss is very dense and has distinct bedding planes with a dip of from 40 to 60 degrees to the southwest. Interstratified with the gneiss are bands of calcite and dolomite of from 5 to 30 feet in thickness. In some places tremolite, phlogopite, and occasionally pyroxene, occur in such quantity as to nearly or entirely replace the carbonates, leaving almost a pure tremolite rock. Professor F. B. Peck[17] says of them: "The explanation of the occurrence here of beds of tremolite would seem to be simple. In the first place the post-Algonkian dolomites are more or less siliceous. . . . .

"Immediately below them come beds of carbonates which are usually

[15] Geology of New Jersely, Final Rept., 1889, vol. ii, pt. 1, p. 18.
[16] Booth, James C. Mem. Geol. Survey Del., 1841, pp. 13; 34–35.
[17] Peck, F. B. "Preliminary Notes on the Occurrence of Serpentine and Talc at Easton, Pennsylvania." Annals N. Y. Acad. Sci., 1901, vol. xiii, p. 420.

highly dolomitic. . . . . Underlying these in turn are the pre-cambrian gneisses which with their included quartz lenses and granite intrusions could furnish free quartz enough by infiltration to transform the beds of carbonates over into silicates of lime and magnesia. . . . . This process of transformation was doubtless greatly facilitated by dynamical forces resulting from faulting, as well appear later. . . . ." Farther on (p. 423) he says: "The serpentines and talcs *are all of them associated with a system of faults* (the italics are mine) which follows the trend of the ridge. Within a distance of two miles north and two miles south of Easton there are four distinct thrust faults. . . . .

"The first of these faults extends along the northwestern side of Marble Mountain and Chestnut Hill and constitutes the boundary line between the pre-cambrian and the post-Algonkian." Branching off from this is another fault which runs along the southeastern slope of Chestnut Hill. "It is along this branch fault . . . . that all the talc and serpentine deposits or the region, with one exception, occur. . . ." Even this exception is described as occurring along another fault.

Continuing, Professor Peck says: "All of the rocks involved in the faulting are so sheared, stretched, and profoundly altered as often to be recognized with difficulty. . . . . The hornblende alters for the most part to serpentine, in fact the richly hornblendic granites seem to furnish one source of serpentine. The calcite-dolomite beds shear to a slaty, foliated, talcose mass. . . . . *Phlogopite*, (again italics are mine) which is locally developed in large quantities in connection with these beds, sometimes in huge crystals a foot in diameter but usually in rather finely granular masses, alters quite uniformly to serpentine and *constitute the chief source of that mineral in the Easton quarries.* Huge masses of it weighing many tons are removed from time to time, consisting quite wholly of phlogopite mica in different stages of alteration to serpentine. . . . . (William's) quarry has been excavated in a nearly pure tremolite rock which lies in heavy beds nearly 50 feet thick and dipping south under granite. . . . . Evidently this rock has been faltered [faulted] into its present position. . . . . The shearing to which it has been subjected has partially altered the tremolite to talc along the shearing planes. . . . . Scattered through this finely crystalline, sometimes massive white tremolite rock, are seams and irregular aggregations of what was originally phlogopite or pyroxene, now altered thoroughly to a beautiful apple-green serpentine. . . . ."

Merrill,[18] writing of the same area, compares the serpentine with that of Montville New Jersey, and suggests that the association of the serpentine with the white tremolite rock indicates its genetic relationship. He does not discuss the origin of the tremolite, but says that there is a gradual transition of the white tremolite to a rock composed of serpentine, tremolite, and calcite, sometimes within a distance of a few inches. As serpentinization continues the tremolite is broken up into fibrous aggregates cut through by the serpentine with but little regard to the cleavage lines.

Montgomery County

In Montgomery County[19] are several lines of serpentine outcrops a couple of miles south of the town of Conshohocken, and extending from Bryn Mawr to Chestnut Hill. As mapped by the Pennsylvania Survey there are some 18 areas, the longest of which is about a mile in length and from 400 to 500 feet in width. Bascom[20] says of the Chestnut Hill area of Montgomery County, that the serpentine was derived from olivine and not from a dolomite or an enstatite rock. The dark-green crystals which are often twinned, are speudomorphs after olivine. This serpentine lies wholly within the mica-schists southeast of the precambrian gneiss.

In the Lafayette belt[21] in a quarry is an enstatite-like rock which appears to be the rock that is here altered to serpentine, for one bed can be seen to be enstatite below and serpentine above. The country rock of Montgomery County is micaceous schist and gneiss. In Lower

[18] Merrill, George P. "Notes on the Serpentine Rocks from near Easton, Pennsylvania." Proc. U. S. Nat. Mus., 1889, vol. xii, p. 599.

[19] Second Geol. Survey Pa., Rept. X, 1885, p. lxxxi; Rept. C6, 1881, p. 26.

[20] Bascom, F. Proc. Cad. Nat. Sci. Phila., 1896, p. 219.

[21] Second Geol. Survey Pa., Ann. Rept. for 1886, pt. 4, p. 1608.

Marion township the bounding rock of a steatite belt is distinctly garnetiferous mica schist to the north.[22]

Rogers[23] says of the origin of the magnesia of the soapstone which extends east from the Wissahickon on the brow of Chestnut Hill across the Schuylkill to Mill Creek beyond Merion Square: "Viewing the steatite as a stratified rock of the mica-slate group, we may reasonably regard it as having been metamorphosed to its present composition and structure, by infusion of magnesian matter from the dyke of intrusive Serpentine which everywhere adjoins it."

Delaware County

In Delaware County[24] a serpentine belt extends entirely across the county. There are mapped some 65 or 70 areas by the Second Geological Survey, the majority of which are not more than a quarter of a mile in length; the longest area being about 2¼ miles. The serpentine occurring in the central part of the county, extending from about 9 miles from Rockdale to Darby Creek, has been quarried for building material. The outcrops are all approximately parallel and are in what is called by Hall of the Pennsylvania Survey, the "Chestnut Hill schist area," and, according to him, apparently belong to the upper part of that series. He says of it[25]: "The Delaware County deposits demonstrate the fact, that the serpentine areas are shallow synclinal basins, many of them saucer-shaped. . . . .

"I think that there is no question that the steatite belongs to the same horizon as the serpentine. . . . ." All the serpentine through this region (Delaware and Montgomery counties) belongs to the same geological horizon, "but it is safe to assume that the serpentines are one of the most recent deposits."

[22] Second Geol. Survey Pa., Ann. Rept. for 1886, pt. 4, p. 1607.
[23] Rogers, Henry D. Geology of Pennsylvania, 1858, vol. i, pp. 71–72.
[24] Second Geol. Survey Pa., Atlas X, 1885, p. xlvii.
[25] Second Geol. Survey Pa., Rept. C5, 1885, p. 13.

An analysis of the serpentine from Mineral Hills gives:[26]

Moisture expelled at 110°	2.10%
Loss on ignition	12.78
Silicic acid	44.18
Alumina	tr.
Ferrous oxide	1.64
Magnesia	39.37
	100.07

Associated with the serpentine of Delaware County are beds of impure limestone, pure kaolin, and corundum. Fine crystals[27] of corundum weighing several hundred pounds have been found[28] in several places. The corundum occurs with the feldspar of which extensive mines have been worked in the western part of the county.

T. C. Hopkins,[29] in a paper read before the American Association for the Advancement of Science at the Boston meeting, on "Some Feldspar in Serpentine from Southeastern Pennsylvania," said that the feldspar of this district occurs in veins or dykes, often attaining a thickness of 20 to 25 feet. The feldspar varies from white to pink, and appears to be entirely orthoclase. In Chester County the mines are also near the corundum mines.

Chester County

The largest veins of serpentine in Pennsylvania are found in Chester County. There are some 24 or 25 areas, all of which seem to occur on the south side of the hydro-mica slate belt and the feldspathic micaceous gneiss belt.[30]

"Whatever may be the age of the rocks of this region," says Frazer[31] in speaking of the gneiss belt, "they were originally sediments of mud, sand, and gravel, for they are everywhere more or less distinctly strati-

[26] Second Geol. Survey Pa., Rept. C5, 1885, p. 120.
[27] Ibid, Rept. C4, p. 37.
[28] Ibid., Rept. X, p. xlvii.
[29] Hopkins, T. C. Amer. Geol., 1898, vol. xxii, p. 256.
[30] Second Geol. Survey Pa., Rept. C4, 1883, p. 62.
[31] Ibid., p. 37.

fied. . . . . Even were we sure of the relationship of the limestones and serpentines to the schists and gneisses, they would not be quite available as key-rocks, because they seem to be of more or less local origin; and even where they appear to underlie the surface in continuous lines or belts, they are only occasionally visible in or above the soil."

Of the soapstone he says: (p. 52) "The soapstone (steatite) strata on the Schuylkill are only mica slate beds with the mica wholly replaced by talc. . . . . "

The second area in size is the one south of Paoli. This has a length of about 6 miles. Of this Rogers[32] says: "Its course is W. about 25° S., coincident nearly with that of the strike of the gneiss and talcose slate which border it for the greater part of its length. . . . . Beyond Maris's Grist Mill its total breadth is nearly 2000 feet . . . . north-east of East Goshen Friends' Meeting-house . . . . a breadth of no more than 400 or 500 feet . . . . . Throughout its entire range, this serpentine appears chiefly as a stratified rock, and in its widest central portion we may distinctly perceive that it has a synclinal or indulated structure. It is, indeed, rather an impure talcose slate, largely impregnated with serpentinous matter, than a zone of genuine intrusive serpentine. . . . ."

The eastern end of this zone of serpentine is bordered both south and north by the talcose-slate formation, in which it seems to lie as a folded synclinal trough; but from the vicinity of Maris's Grist Mill to its western termination, its southern margin is in contact with a massive hornblendic gneiss, its northern touching in some places upon ordinary talcose slate; but in others, especially towards the western end, upon quartzose and garnetiferous micaceous gneissoid rock. . . . .

Along the northern edge, or a little outside of the northern margin of this line of serpentine, trap-rock occurs in greater or less abundance, and apparently as a succession of narrow elongated dykes. . . . . "

An analysis by S. B. Sparkler[33] of a specimen from East Goshen shows the following:

[32] Rogers, Henry D. Geology of Pennsylvania, 1858, vol. i, p. 188.
[33] Amer. Jour. Sci., (2), vol. xlii, 1866, p. 272.

SiO_2	32.89%
Al_2O_3	—
Fe_2O_3	—
FeO	1.38
CaO	—
MgO	40.48
MnO	—
H_2O	13.45
	99.20

The specific gravity is given as 2.72.

Along the boundary line between Pennsylvania and Maryland and extending from the center of the southern part of Chester County along the southern part of Lancaster County southward into Cecil County, Maryland, and thence across the Susquehanna River into Harford County, is the tract known as the "State Line serpentine." Its length is about 17 miles from Elk Creek to the Susquehanna. It has a mean width of about 1 mile. The Pennsylvania Survey[34] says that the southern margin is in contact with the black hornblende gneiss, but the serpentine is apparently without conformity of dip on the Susquehanna; the rock to the south is a talcose slate.

On the north throughout its entire length the bounding rock is the talcose slate of the Primal series. "Much trap rock presents itself just west of the Little Elk along the southern edge of this range of serpentine, and dykes of that material occur within and adjacent to the belt, especially throughout its southern half, and apparently along its whole course."

In the same report, in speaking of the chrome ore which occurs with this serpentine body, the statement is made that the chrome ore occurs in the serpentine as true ore veins, cutting through it with considerable regularity. For some time the State Line serpentine was the source of most of the chromium in the United States.

The serpentine of this region is regarded by most of the writers as of two kinds. In speaking of the serpentine near Morgan Corners, Rogers says:[35] "The belt of serpentine comprises both true injected or

[34] Second Geol. Survey Pa., Rept. C4, 1883, p. 91.

[35] Rogers, Henry D. Geology of Pennsylvania, vol. i, 1858, p. 163.

igneous serpentine, and *serpentinous steatitic talc-slate*." Again in speaking of the West Chester Barrens: (p. 169) "[These] exposures of serpentine and steatite occur so nearly in one line, and this is so probably a line of dislocation connected with the synclinal fold of the older strata, that we can hardly doubt that these outcrops derive their existence from one chain of injections of true serpentine mineral along the southern margin of the talcose Primal slates."

Throughout his article Rogers makes particular mention of the fact that there are two kinds of serpentine, "stratified serpentinous talc-slate" and "injected or infused true igneous serpentine."

Theodore D. Rand[36] in 1896 before the Academy of Natural Sciences of Philadelphia, said that he regarded the serpentine of southeastern Pennsylvania as belonging to all least two groups, "one bordering the ancient gneiss; the other, which he believes to be much more recent, occurring in the mica schist and gneisses.

"The former are altered igneous rocks, either pyroxenic or crysolitic, the chief material being enstatite, found often but slightly altered; the latter of more doubtful and perhaps varied origin. . . . .

"The bright yellow serpentine from Easttown Township, Chester Co., is probably altered chrysolite chiefly, while that from Fritz Island, near Reading, is an altered dolomite. That from Brinton's Quarry, near West Chester, contains bronzite, not entirely changed.

"The Radnor serpentine is chiefly an altered enstatite but . . shows, also, a change from asbestos into serpentine. . . . ."

Persifor Frazer[37] summing up the various theories of the origin of the serpentine of this region, says:

"Were these [serpentine exposured] ranged in more than one line the task of explaining their appearance at the surface would be much easier. But a *single line* of them necessarily places them either at the top or at the bottom of the talc-mica schist formation; Mr. Hall choosing the former, Mr. Rogers the latter alternative.

"The case is complicated by the fact that the outcrops along this one

[36] Proc. Acad. Nat. Sci. Phila., 1896, p. 219.
[37] Second Geol. Survey Pa., Rept. C4, 1883, p. 81.

line are sometimes serpentine, and sometimes limestone. It looks as if the serpentine might be a subsequent modification of the limestone; or else, that one and the same magnesian sediment was heavily charged with carbonate of lime in some places, and was a non-calcareous silicious mud in others.

"It would of course be possible for the two species of rocks to have no connection . . . . if they were sporadic deposits at very nearly but not quite the same geological horizon; . . . .

"If Mr. Hall's structure be accepted, if the talc-mica belt be Hudson river slate, then this serpentine limestone range would represent the Upper Siliurian calcareous deposits.

"If Mr. Rogers' structure be accepted, if the talc-mica belt be primal slates passing northward underneath the Potsdam sandstone, and Valley limestone, then the serpentine range can have nothing to do with the Valley limestone formation."

Corundum has been found in many plaees in Chester County. Colonel Joseph Willcox[38] says of it:

"Many large lumps were formerly lying on the surface of the ground, and vain efforts were made to drill holes in them for the purpose of blasting them. A final disposition was made of them by digging holes near them, in which they were buried deeply enough to cause no interference with the plow." In 1848 a lump weighing more than 5200 pounds was sent to Liverpool. In 1866 John Leslie dug up about five tons which he sold for $60 per ton, but soon after the price advanced to 50 cents per pound. In 1872 a mass weighing about 200 tons was found on the margin of the serpentine bed against a wall of gneiss rock on the north side. Associated with it were margarite, damourite, and lesleyite; in other places associated with tourmaline, albite, and spinel.

On page 351 of the same volume Persifor Frazer says: "It is evident that the *corundum* . . . . is a metamorphosed part of the gneiss composed more exclusively of alumina than the rest."

[38] Second Geol. Survey Pa., Rept. C4, 1883, p. 349.

Lancaster County

The State Line serpentine area continues westward into Lancaster County. The rock has been penetrated to a depth of 700 feet in the chrome mines without passing through it. At several places in this belt titaniferous iron ore has been mined. Roger[39] says: "A careful examination of these . . . . belts of serpentine near the State line of Lancaster County cannot fail to convince any observant geologist that the material, ordinarily termed serpentine, as presented in these barrens, comprehends both a stratified and a unstratified rock. Pure serpentine is here found only in the form of dykes intruded through a stratified serpentinous talcose rock, evidently a metamorphic clay-slate—the mica and talc-slate formation of the Susquehanna. The stratified serpentinous rock seems to have been impregnated with the magnesian minerals during the intrusion of these veins of igneous serpentine. The evidences in support of this view are abundant in the ravines which intersect the barrens north of the village of New Texas. The genuine serpentine rock is itself a material of quite diversified aspect, some of it being of a dark-green color, and very tough; other varieties less dense and heavy, and much more easily fractured, and of a pale or yellowish green. This latter kind usually abounds in contact with the chromiferous iron-ore at Wood's Mine and the other chrome localities. . . . ."

Besides this State Line area there is but one more of any size in Lancaster County. This is situated to the northwest of the former and is about 5 miles in length. The outcrop is of an irregular shape, the two ends run nearly north and south and are connected by an east and west area.

AREAS SOUTH OF MARYLAND

VIRGINIA

Information on the serpentine of Virginia is meager. In Rogers' report[40] he says that in Albemarle County there is a tough, somewhat

[39] Rogers, Henry D. Geology of Pennsylvania, 1858, vol. i, pp. 171, 172.
[40] Rogers, W. B. Reprint of the Geology of the Virginias, 1884, pp. 296–297.

soft rock of a bluish-gray color occurring between two ranges of sandstone. This rock is steatitic and is associated with talcose and other strata. It is uniform in texture and capable of being worked. From Albemarle County it runs southwest, increasing in width and becoming more serpentinous. In Nelson County it occurs west of Ligons and the greater part of it is serpentine. On the same line it occurs in Amherst County at the base of Buffalo Ridge as a narrow belt and contains copper ore. Farther south, near Lynchburg, it crosses the James River but here contains but little serpentine. Continuing southwestward there is soapstone in Franklin County but still farther south these talcose rocks thin away.

In Fluvana and Louisa counties (Idem., p. 463) soapstone, unmingled with serpentine, extends with variable width nearly in the direction of the county line between Mechanicsville, and Newark. In Fairfax County both soapstone and serpentine occur, but the principal rock is serpentine. Between Difficult Creek and, Still House Branch both occur and here also chrome ore is associated with it.

NORTH CAROLINA

South of Virginia the olivine rocks are less serpentinized. In North Carolina the prevailing type is dunite and the rocks have been subjected to alteration in but few places.[41] Associated with these rocks in North Carolina, South Carolina, Georgia, and Alabama is corundum and chromite. These magnesian rocks extend over a wider area in North Carolina than in any of the other states of the Piedmont belt. The rock, in numerous disconnected outcrops, is spread over an area 40 miles wide. With the exception of a small area in Clay County, there is no serpentine south of Waynesville. It is rather remarkable that the region south of Waynesville is thickly dotted with small peridotite areas while north of the village the areas are rather scattered and few, yet among all these southern areas none is serpentinized. In Buncomb, Madison, and Yancey counties the granular rock is largely

[41] Lewis, J. V. "Corundum and the Basic Magnesium Rocks of Western North Carolina." Bull. 11, N. C. Geol. Survey, 1896, p. 33.

changed to serpentine, and the microscope shows that it is altered olivine rock. Magnetite and chromite are associated with it. In a serpentine found on Ivy River in Madison County, there remains a large percentage of unaltered olivine "in some cases visible to the naked eye."[42] Most of the serpentine is similar in appearance to that of Maryland and Pennsylvania. Pratt gives as a proof of the igneous origin of the peridotite the fact that at Webster, Jackson County, "a large block of gneiss is completely enclosed by the peridotites in such a manner as could only be attributed to the intrusion of the latter in a molten condition."[43]

SOUTH CAROLINA

The reports on the geology of South Carolina that have been examined are all of them of old date and I have been unable to find reference to any recent work. The latest map that I have seen is that published by the Department of Agriculture in 1883 and on which are shown areas of soapstone in Kershaw, Fairfield, and Richland counties, all of them a short distance north of Columbia; and in Laurens, Pickens, and Spartenburg counties in the extreme western portion of the state. Tuomey[44] in his report for 1848 speaks of "talcose-slates" as composed chiefly of talc and quartz and sometimes of talc and feldspar; but these can hardly be classed with serpentines or soapstones. Associated with the talc-slates are mica-slates. These are found in passing (p. 74) "by insensible degrees, into talcose-slates, by the substitution of talc for mica; when both minerals are found in the same rock it is called talco-micaceous slate. This and the talcose slates are confined to that portion of the state known as the gold region, and to the belt in York and Spartanburg that contains the magnetite iron ores. The finest specimens of talcose slate are found near Cherokee Ford, associated with the ores of that locality, and at Hale's mine, in Kershaw. In Lancaster it passes into talco-micaceous slate, which is the gold bearing rock of the district."

Farther on (p. 106) he says: "A strip of talco-micaceous slates of the

[42] Pratt, Joseph Hyde. "The Occurrence, Origin and Chemical Composition of Chromite." Amer. Inst. Min. Eng., Trans., 1899, vol. xxix, p. 20.

[43] Pratt, Joseph Hyde. Idem., p. 31.

[44] Tuomey, M. Rept. on the Geology of S. C., 1848, p. 9.

gold formation, crosses the north-west corner of the (Edgefield) District on the Savannah. . . . .

"Near the Newberry line (Newberry District) and midway between the Saluda and Broad River, is an elevation . . . . principally composed of mica and talcose slates. . . . . Near the mill the slates . . . rise up on the side of the mountain, being pushed into a position nearly vertical—the bedding planes so straight and even as to present smooth surfaces where the rock is split, and often so hard as to offer inducements for opening a quarry for flagging stones for pavements. . . . ."

A few miles from Chester is a bed of soapstone which has been slightly worked. Lieber[45] speaks also of the talcose slate. He says: "The talcose slate . . . . embraces several disconnected bodies, which are mostly separated from one another by granitic rocks. . . . . It stretches between the granite of the Waxhaws and the granitic and syenitic dyke of Taxehaw over the main portion of Lancaster, from which district it passes into Chester, terminating about two miles east of the Charlotte and South Carolina Railroad. . . . . Here it touches the gneiss of West Chester, while to the north and south it is bounded by mica slate, the result apparently of a contact metamorphosis.

"A metalliferous country rock the talcose slate occupies, with us, a most prominent position, and in reference to gold, at least as far as I have been able to observe, it stands highest in the scale. . . . ."

"Soapstone shows itself in some parts of York and Chester. The large dykes are usually impure, and often form a species of porphyry in which the imbedded crystals are hornblende. When the grain of it is fine it is termed a talcose of chloritic trap. At the Nation Ford of the Catawba in York, and immediately north of Chesterville, soapstone of a fine quality is quarried." (p. 36)

GEORGIA

In Georgia all the corundum deposits occur in veins intersecting the peridotites and their alterations,[46] but no perfect serpentine has as yet

[45] Lieber, Oscar M. Report on the Survey of South Carolina, 1856, p. 22.
[46] King, Francis P. Bull. 2, Ga. Geol. Survey, 1894, p. 75 et seq.

been found in any part of Georgia although there are some partially serpentinized chrysolites. These basic magnesian rocks in this state are usually small areas stretching across "like a string of beads with here and there a missing member" as described by King. Most of these eruptive rocks are west of the Chattahoochee River and near the semi-crystalline boundary, in which, however, none occurs. King calls these rocks the youngest of the Algonkian crystallines (p. 71).

ALABAMA

In Alabama asbestos has been found in Coosa and Tallapoosa counties near the corundum mines. Corundum, associated with peridotites, has been found near Dudleysville, Tallapoosa County, and near Bradford in Coosa County.[47] Talcose rocks, and beds of hornblende and soapstone occur on the Tallapoosa River near the falls.[48]

AREAS IN MARYLAND

The serpentines in Maryland were early known because of the association with them of the chrome ores, which for a long time formed the principal source of chrome in the world. Chrome was first discovered in America at the Bare Hills, north of Baltimore, on the property of Isaac Tyson. Tyson's son soon started in to manufacture chrome yellow from this material. In the same year he recognized, in a stone which was used to support a cider barrel in Belair market, a valuable piece of the ore. This led to the purchase by him of considerable areas in Harford County, near Jarrettsville, where this fragment had been obtained. The opening of the mines here showed so great an abundance of the material that it was found more profitable to work than at the Bare Hills, consequently the latter workings were abandoned. Tracing the occurrence of chrome by its association with serpentine, Tyson in 1833, discovered the deposit on the Wood farm in Cecil County and at once purchased the property. This proved to be the richest chrome deposit ever found in America, and was worked with great success until

[47] Smith, Eugene A. Outline of the Geology of Alabama. 1878, p. 19.
[48] Smith, Eugene A. Bull. 3, Geol. Survey Ala., 1892, p. 84.

about 1881, with the exception of from 1868 to 1873. Chrome ore had been discovered in Asia Minor in 1848, and early in the eighties it was found that the foreign product could be imported cheaper than the domestic product could be mined, consequently the Maryland workings were abandoned.

The areas of serpentine and soapstone stretch across Maryland in a series of lenticular masses similar to those of Pennsylvania, and occur in Cecil, Harford, Baltimore, Carroll, Howard, and Montgomery counties. All of these rocks are plainly of secondary origin, being derived from the non-feldspathic magnesian rocks—peridotites and pyroxenites. In general the direction of these lenses is that of the strike of the neighboring gneisses and phyllites. The dip, where it can be made out, varies from 40 degrees to nearly vertical.

CECIL COUNTY

Ducatel,[49] in his report for 1837, speaks of the occurrence of a good quality of soapstone on the west branch of the Northeast River. The material was quarried for stepping stones. At New Leeds and on the County line between the Octorara and Conowingo, asbestos and talc are mentioned as occurring, being used in the manufacture of "stone points," a substitute for metallic pigments made by grinding up the soft and light-colored varieties in whale oil. He also mentions the use of asbestos as a lining for fire-proof chests and speaks of the occurrence of chrome ores in the county.

F. Bascom[50] writes as follows: "For five-eights of a mile from the northern limit of the gabbroic material to Bald Friar, the Susquehanna cuts through a belt of soft and sometimes soapy greenstones.

"These greenstones represent various phases in the metamorphism of non-feldspathic igneous rocks. This belt widens to the northward and, with a width on the Mason and Dixon Line of three and one-eighth miles, passes, north of Rock Springs into Pennsylvania, where it trends

[49] Ducatel, J. T. Ann. Rept. Geologist of Md., 1837, p. 15.

[50] Bascom, F. "The Geology of the Crystalline Rocks of Cecil County." Md. Geol. Survey, Cecil Co., 1902, p. 93 et seq.

to the east and sweeps southward into Cecil County at four points between Rock Springs and Fair View. The last exposure is some sixteen and a half miles east of the Susquehanna river. The two more easterly of these occurrences are disconnected at the surface from the main mass by gabbro.

"The greater portion of this ultrabasic material has undergone complete alteration to serpentine. So thorough is the transformation throughout the mass of the formation that the original characters of the rock may only be determined by microscopic study.

"At scattered localities along the southern periphery of the serpentines, gradations into only partially altered pyroxenites and peridotites may be observed in the field. Such passage into well-recognized pyroxenites and peridotites is also exhibited in the dykes . . . . and in the lens-shaped included masses. . . . . The serpentine is most varied in color and general appearance. It ranges in tint from a light buff, or a light yellowish green, to a rich, deep emerald or a dark blue green.

"Where the serpentine possesses a soft earthy texture, the colors are usually light in tint. Where it is compact and massive there is a deepening of the green tones, while a schistose or fibrous character is associated with a greyish green shade, which is due to the development of either talc, asbestos or tremolite.

"The rock possesses no original structural planes, but exhibits more than one system of secondary planes produced by pressure acting upon a massive rock. The master-joints are nearly vertical and strike northeast and southwest. The joint faces are often slicken-sided.

"The metamorphism of the original ferromagnesian silicates (pyroxene, amphibole and olivine) into the hydrous magnesian silicate, serpentine, is accompanied by the liberation of iron oxides and silica, in the form of hematite or limonite and quartz or opal, or a yellow limonitic jasper or chalcedony.

"The ground is strewn with these rusty yellow silicious iron-stones, which exhibit more or less of a honey-comb structure due to a finally complete removal of the magnesian silicate.

"Serpentine is always accompanied and is sometimes completely replaced by a final alteration product talc (steatite, soapstone). Soapstones are therefore also of frequent occurrence in serpentine areas.

"With the serpentines are also associated amphibole schists containing asbestos, tremolite, anthophyllite, actinolite or chlorite, and representing the metamorphism of pyroxenites. All these associated types, the original peridotites and pyroxenites, the serpentines representing one phase of metamorphism, the amphiboles representing another phase of metamorphism, the soapstones and the iron-stones representing an extreme phase of alteration, are considered a geological unit and mapped as a single formation. . . . .

"The main serpentine belt is locally known as "the barrens" and strikingly merits that name. At the border of the serpentine belt the aspect of the country alters abruptly. One leaves behind a prosperous and pleasing agricultural region and enters a wild and desolate district supporting a scanty vegetation. . . .

"The comparative sterility of the soil may be due to its thinness and inability to hold water rather than to its chemical composition. . . . .

"In the serpentine as in the mica-gneiss there are phematite veins. Some of these are of considerable size and have been opened for the feldspar.

"The veins usually, but not always, strike northeast-southwest.

"There are a number of abandoned openings for feldspar in the region of Goat Hill. . . . . Three-eights of a mile east of Rock Springs, are two feldspar openings in a vein some six to eight feet wide, which have been abandoned for three years. . . . . The serpentine bordering the vein has altered to talc. . . . .

"About one and a half miles east from Rock Springs, on the edge of the serpentine is the Taylor feldspar and flint quarry. This vein strikes northeast-southwest and has considerable width. . . . .

"Magnesia has also been mined in the serpentine, but only in small quantities. . . . . On the roads from Conowingo to Rock Springs and from Conowingo to Pilot, there are pits in the serpentine made in search of gold ore . . . . with the expectation of finding the rocks richly auriferous. The results did not meet their expectations. . . . ."

An analysis is given (p. 133) of a pyroxenite of the variety websterite.

SiO_2	53.21	RECALCULATION.	
Al_2O_3	1.94	Hypersthene	43.72
Fe_2O_3	1.44	Diallage	55.97
FeO	7.92	Misc	.79
MgO	20.78		
CaO	13.12		100.48
Na_2O	.11		
K_2O	.07		
H_2O+	.87		
H_2O-	.14		
CO_2	.10		
TiO_2	.26		
ZrO_2	trace		
P_2O_5	"		
Cl., F	undet.		
FeS_2	.03 (0.02 S.)		
Cr_2O_3	.20		
NiO, Co O	.03		
MnO	.22		
BaO	none		
SrO	"		
Li_2O	trace		
V_2O_3	.03		
Total	100.47		

Analysis made by W. F. Hillebrand, of the United States Geological Survey.
Amer. Geol., vol. xxviii, 1901, p. 159.

Bascom says further (p. 134): "Massive serpentines more generally disclose a peridotitic origin, but even the earthy serpentines show remnants of original olivine. The fibrous serpentines exhibit remnants of tremolite and other fibrous amphiboles by means of which their origin can be traced by pyroxenites.

"Serpentine possesses a more uniform appearance under the microscope than in the hand specimen. Faintly green, transparent sections, showing in polarized light a confusedly fibrous character and mesh structure, with olivinic cores and an occasional crystal of pyroxene or tremolite, are a common type of earthy or massive serpentine. . . . ."

"A preponderance of tremolite, anthophyllite or smaragdite characterizes the fibrous serpentines. Tremolites may still show a central area or core of pyroxene.

"Talc is a common secondary product both in the fibrous and massive serpentines. It may completely replace both serpentine and amphibole, converting the rock into a soapstone or a steatite-schist. . . . .

"The change of talc to the fibrous amphiboles is accompanied by the separation of calcite or dolomite which fills the interstices of the talc. . . . .

"The origin of serpentine and soapstone from pyroxenites and peridotites is a well recognized fact, and the occurrence of serpentines with such a genesis . . . . has been described."

HARFORD COUNTY

J. T. Ducatel,[51] in 1838, speaks of the occurrence of the chrome ores associated with the serpentine in the vicinity of Coop Town and "Mine Old Field," and near Dublin. "This *Chrome ore*" he says, "is always found imbedded in a rock, called the *Serpentine*, which latter also contains a variety of *Magnesian minerals*. . . . . Associated again with these minerals, there are varieties of *Asbestos*, that within a few years have come to be extensively used in the manufacture of what are called *Stone paints*. . . . . "

Tyson,[52] in 1862, speaks of the occurrence of chrome ore in Harford County, the working of the pits near Cooptown, and their abandonment for the Cecil County deposits. Associated with the serpentine here he speaks of copper: "Near the northern edge of the serpentine formation north of Cooptown some traces of copper ore, in the form of carbonate of copper, were observed some thirty-five years since. The openings at that point, however, gave no encouragement to those by whom it was explored. . . . . "

Genth[53] in a report on the serpentine of Broad Creek said: "Immediately adjoining and under the talcose rocks, and from them separated

[51] Ducatel, J. T. Ann. Rept. of the Geologist of Md., 1838, p. 5.

[52] Tyson, Philip T. Second Rept. of St. Agricul. Chemist, 1862, p. 65.

[53] Genth, F. A. "Geol. Rept. of the Maryland "Verde Antique" Marble, and Other Minerals on the lands of the Havre Iron Co., in Harford County, Md." 1875, p. 4.

in most cases by seams of chlorite or chlorite-slate, lies a very large bed of green serpentine, presenting, as observed alongside of Broad Creek, a thickness of about 500 feet, and under this a bed of black mottled serpentine of about 800 feet in thickness, and, frequently imbedded in the latter, masses of the above-mentioned green serpentine, increasing in quantity in a north-westerly direction. This immense bed of serpentine in these two varieties rests upon chloritic slates, frequently containing octahedral crystals of magnetite, and talc slates, and below these again occurs another, but smaller, bed of green serpentine of 180 feet in thickness, which, like the other, is underlain by chloritic and talcose slates, and, where Broad Creek makes a westerly turn, followed by a third bed of green serpentine. . . . .

"The 'outcrop' of the first or upper bed of green serpentine of about 500 feet in thickness can be traced by its outcrop almost the whole distance between the upper ford on Broak Creek, and over the hill in a north-easterly direction to the ravine on Broad Creek, a distance of, about 1800 feet; it also crosses Broad Creek in a south-westerly direction, but it has not been ascertained how far it extends.

"The outcrop of the second bed of green serpentine was measured on top of the hill between the horse-shoe of Broad Creek to be about 180 feet, and it is very conspicuous on the west side of Broad Creek; but as neither this, nor the third, are in the least developed, and as their exploration cannot offer any advantages, nothing more need be stated, but that they exist and show throughout the same character. . . . .

"From the present developments, the relation of the magnesian rocks on this property, in their alternate beds of talcose and chlorotic slates and serpentine, to that of the micaceous strata cannot be ascertained with certainty, but they do not appear to be comformable in their stratification and dip, and while the latter have an average strike of about N. 40° E., with a dip of about 30 to 40° toward the south-east, the whole body of magnesian rocks seem to form a large lenticular mass in the micaceous strata, having the same general direction, but an average strike of N. 69° E., with a south-easterly dip of about 75°. . . . .

"This green serpentine . . . . is a variety of massive serpentine somewhat resembling Williamsite, and shows sometimes a slightly slaty structure. It occurs in various shades of green, from pale leek-green to a deep blackish green, and from a small admixture of magnetic iron, more or less clouded; rarely with thin veins of dolomite passing through the mass. It is translucent to transparent; it is exceedingly tough, and its hardness is considerably greater than that of marble. . .

"The analysis of a deep green translucent variety gave the following result:

Silicic acid	40.06
Alumina	1.37
Chromic oxide	0.20
Niccolous "	0.71
Ferrous "	3.43
Manganous "	0.09
Magnesia	39.02
Magnetic iron	3.02
Water	12.10
	100.00

Hardness 4.00 Specific gravity 2.668

Its green color is due to the oxides of chromium, nickel and iron present

". . . . A black mottled serpentine underlies the green, forming a bed of about 800 feet in thickness. . . . . It weathers more readily than the green, changing into a white rock spotted with black. . . . . The analysis shows it to be a variety of serpentine, like the green, with an admixture of a larger percentage of magnetic iron. It contains:

Silicic acid	40.39
Alumina	1.01
Chromic oxide	trace
Niccolous "	0.23
Ferrous "	0.97
Manganous "	trace
Magnesia	38.32
Magnetic iron	6.22
Water	12.86
	100.00

Hardness 4.00 Specific gravity 2.669"

Merrill[54] gives an analysis of the gray-brown soil into which the green serpentine weathers as follows;

Silica	60.17
Iron oxides	10.40
Alumina	14.81
Magnesia	7.23

This is quite a contrast with the fresh rock which carries nearly 40 per cent of magnesia, and less than one-half of one per cent of alumina.

This Broad Creek quarry is the principal serpentine quarry in Maryland, and the rock produced here is of exceptional beauty. Slabs of large size have been sawn out and polished. The color varies from a rich emerald green mottled with darker patches and streaks to a deep blue-black. The variety is sometimes called precious serpentine although it is hardly transparent enough to be true precious serpentine. The product of the quarry was called "verde antique" although it was not such. Extensive preparations were made for developing the quarry in 1880 but these were not entirely successful. The stone is extremely hard and the expense of working the material and getting it from the quarry is great. A great deal of the stone, has, however, been put upon the market, and it has been used in the interior decoration of buildings in New York, Philadelphia, Washington, Wilmington, St. Augustine, and elsewhere. At the present time the quarry is not in operation and when visited during the summers of 1901 and 1902 it has apparently been abandoned.

Another quarry in Harford County which has placed stone upon the market is the one near Cambria. Samples from this quarry formed a considerable part of the building stone exhibit made by the State of Maryland at the expositions at Buffalo and Charleston in 1901 and 1902.

BALTIMORE COUNTY

The discovery of chrome ore in the serpentines of the Bare Hills north of Baltimore has already been mentioned. Ducatel in his

[54] Merrill, George P. "Rocks, Rock-Weathering and Soils." 18, p. 226.

early reports speaks of this chrome and in 1860 Tyson[55] says of it that "it seems to have been forced in as an intrusive rock in isolated masses of limited areas. . . . . It is slowly acted on by atmospheric agents, and furnishes a barren soil wherever it is the nearest rock to the surface." In the Appendix to the same report (p. 15) he says of the region to the north of Baltimore, that "the district called the Bare Hills, because of its sterility, owing to the large quantity of magnesia in the soil." In 1862[56] he mentions the Soldier's Delight area. "From eight to ten miles west by north from the Barehills is another formation of serpentine called Soldier's Delight. . . . . The only minerals of industrial value it contains are chrome ore and a magnesian mineral; the latter having been used for the manufacture of epsom salts.

"The chrome ore here is similar to that at the Barehills, and continues to be mined to some extent, but operations have not been extensively carried on within either of those formations since they were commenced in Harford County, about thirty years since. . . . ."

The first petrographical study of the Baltimore serpentine was published in 1886 by G. H. Williams[57] in an article on the Gabbros and Associated Hornblende Rocks Occurring in the Neighborhood of Baltimore. In this paper he clearly showed the secondary origin of the serpentines, tracing the origin to the basic non-feldspathic rocks with which they are so often associated. He says: "The olivine-bearing rocks of the Baltimore region exhibit a most interesting and instructive series of alterations, the study of which has satisfactorily established the fact that masses of a similar character were the original form of a varied group of magnesian rocks common throughout the district. . . . "Generally speaking, the olivine of these rocks changes to serpentine and magnetite; the pyroxene, whether bronzite or diallage, alters at first to a light-green or colorless hornblende, having the composition of actinolite or of tremolite. This hornblende in turn is frequently transformed into

[55] Tyson, Philip T. First Rept. St. Agricul. Chemist, 1860, p. 24.

[56] Tyson, Philip. Second Rept., 1862, p. 65.

[57] Williams, George Huntington. "The Gabbros and Associated Hornblende Rocks Occurring in the Neighborhood of Baltimore, Maryland." Bull, 28, U. S. Geol. Survey, 1886, pp. 56–59.

talc, accompanied by the separation of the calcium in the form of the carbonate. . . . .

"All of these changes may often be very perfectly and satisfactorily traced out in a single rock-mass of small dimensions. Moreover, wherever any of the original minerals remain, they seem to be, for rocks of this class, in all cases the same. No other process of alteration could be discovered in the peridotites within the area examined; and hence it would appear quite justifiable to assume a similar origin for all such serpentine and talcose rocks as are identical with undeniable alteration products of olivine rocks, even though they may not themselves contain any remnants of their original constituents. . . . . The alteration of olivine to serpentine . . . . is . . . . too well known to need further mention. . . . . Whether the less common alteration of this mineral to hornblende . . . . also takes place in our rocks is not certain. Most of the serpentines contain considerable amphibole but no instance has yet been observed where it could not be traced with more probability to the pyroxene than to the olivine.

"In case the olivine is the only constituent which has undergone alteration, a bronzite or diallage serpentine results, in which crystals of pyroxene are porphyritically scattered through the serpentine groundmass. . . . . The alteration of the pyroxene of the olivine rocks seems to be at first always to some form of hornblende. Sections of many comparatively little altered specimens show under the microscope a tendency to develop colorless hornblende needles and fibers in the bronzite and diallage crystals . . . . This change may be continued until no vestige of the pyroxene remains. In connection with the alteration of the olivine it gives rise to hornblendic (tremolite) serpentines, which are by far the most abundant of the magnesian rocks of Baltimore County. To them belong the serpentines of the Bare Hills, some seven miles north of the city. . . . . In sections of these serpentines unmistakable traces of diallage may sometimes be discovered, although, as a rule, colorless hornblende needles and serpentine are the only silicate minerals which are present. Rocks identical in all respects with the Bare Hills serpentines have a widespread distribution in and around the gabbro area. They are especially abundant about its edge. . . . . In many of these exposures the gradual transition to the little-altered olivine rock may be traced, both macroscopically and microscopically, with great clearness.

"Similar conditions prevail towards the western side of the area as we approach the valley of the Patapsco River. At the western edge of the bridge at Hollofields, an interesting magnesian rock occurs, in which the original constituents, olivine and pyroxene, were arranged in parallel bands. This structure is still perfectly preserved in the alternating layers of nearly black serpentine and silvery white hornblende. . . . .

"The large area of serpentine farther to the northeast, known as Soldiers' Delight, appears to be of the same nature as that at the Bare Hills. Similar rocks also occur along the southern limit of the gabbro area in the valley of the Patapsco near Ilchester.

"In many specimens of these magnesian rocks a peculiar glistening mineral is largely developed which imparts a light silvery-green lustre to a freshly fractured surface. . . . . (Microscopical and chemical tests) clearly indicate that it is talc.

"This alteration of hornblende to talc in olivine rocks was first described by Tschermak, who regarded the presence of olivine as a necessary condition of the change. . . . . Tremolite passes into talc, accompanied by a change of calcium silicate to calcium carbonate. . . .

"It seems probable that the asbestos deposits of Baltimore County . . . . may likewise be the results of the alteration of original pyroxene masses."

In addition to these areas there are several long, narrow lenses of talc and serpentine near Whitehall in the northern part of the County. Of these the only one of economic importance is that on Burns' place on the creek west of the village. Here the serpentine is hard and compact. It has been quarried to some extent, although the opening was primarily made to ascertain the quality of the rock.

CARROLL COUNTY

Tyson[58] speaks of the occurrence of chrome ores in the body of serpentine which stretches from near New Lisbon through Howard County toward the Potomac River. The area has not been further studied.

HOWARD COUNTY

The area just mentioned extends nearly through Howard County in a southwesterly direction, to within a short distance of Tridelphia. The area is about 15 miles in length and is midway between Sykesville and Woodstock.

MONTGOMERY COUNTY

Ducatel[59] in 1857, says the argillites of the Patuxent on the northeast boundary of the County pass into steatites and soapstones, followed by serpentine between Etchinson's Mills and Tridelphia. The principal mineral resources of the County occur with the serpentine.

"The tract referred to appears to be confined to the Western side of the Seneka and extends from the dividing ridge between the head waters of the Seneka and those of the Patuxent in a southern direction nearly down to the Potomac. . . . . The mineral contained within it is usually designated as the chrome ore. . . . . Wherever the serpentine rocks occur the soil is found to be poor, supporting a stinted growth of oaks and pines, and seldom adapted to any profitable cultivation. . . . That there is a great abundance of chrome iron-ore in Montgomery County there can be no doubt. . . . ."

GENERAL SUMMARY

Summarizing the foregoing, it is seen that there exists in the Piedmont Plateau a region in which the rocks are serpentine or serpentine-like, and talc. The rocks to the south of Maryland are much less serpentinized than those to the north and are generally peridotites of the dunite

[58] Tyson, Philip T. Second Rept. of Agricul. Chemist, 1862, p. 68.
[59] Ducatel, J. T. Ann. Rept. of the Geol. of Md., 1837, p. 20.

type. The area underlain by these rocks is in general bare and uncultivated, or covered with a tangled scrub owing to the sterility of the soil, which is due to the large amount of magnesia contained in it and also to the fact that the rocks decompose slowly and the products of decomposition are washed away nearly as fast as they are formed.

On Staten Island there is a body of serpentine covering an area of some 13½ square miles. The rock here is regarded by Britton as derived from limestones and tremolite strata, and he found no proof of its being a metamorphosed igneous rock. Julien, on the contrary, regards it as derived from a hornblende schist. No olivine materials occur here and the rock lies nearly parallel to the neighboring gneisses and limestones.

In New Jersey there are several outcrops of serpentine. Merrill regards the Montville se ntine as derived by metsomatic processes from pyroxene, and since no free silica in the form of chalcedony is found, as is almost universal when the serpentine is formed from dunite, he thinks that there must have been sufficient magnesia furnished from other sources to change the whole into serpentine.

In Pennsylvania there are many serpentine exposures extending across the southeastern portion of the state, in Northampton, Montgomery, Delaware, Chester, and Lancaster counties. Peck regards the Northampton County serpentine, which he says always occurs along fault lines, as due to the alteration of hornblende and phlogopite. The tremolite with which it is associated he thinks is due to the alteration of silicates of lime and magnesia. The dolomitic beds underlain by gneisses have furnished the magnesia and silica and lime. Merrill suggests that the association of the serpentine with the tremolite rock indicates its genetic relationship, for there is a gradual transition of tremolite to a rock composed of tremolite, serpentine, and calcite.

Rogers regards the steatite of the Chestnut Hill area in Montgomery County near Philadelphia, as having been metamorphosed to its present condition by the infusion of magnesian matter from the dike of intrusive serpentine which everywhere adjoins it. This area is regarded by Miss Bascom as derived from an olivine rock and not from a dolomite or an enstatite rock. The serpentine of the Lafayette belt in the same county is regarded by the Second Pennsylvania Survey as derived from an enstatite rock.

Charles E. Hall of the Pennsylvania Survey said of the areas in Delaware County, that they demonstrate the fact that the serpentine areas are shallow synclinal basins; that the steatite belongs to the same geological horizon as the serpentine; and that both are of the most recent formations there.

Frazer says of the Chester County soapstone strata that they are only mica slate beds with the mica wholly replaced by talc. Of the Paoli belt Rogers says that it is rather an impure talcose slate largely impregnated with serpentinous matter, than a zone of genuine intrusive serpentine. He speaks of the western end of it as being bordered both north and south by the talcose slate formation. Of the State Line serpentine he says that it comprises both true injected serpentine and serpentinous steatitic talc-slate. He dwells upon the fact that there are two kinds of serpentine here, one stratified talc-slate and the other the true igneous serpentine. Rand, in 1896, also regarded the serpentines here as of two kinds; one derived from altered igneous rocks, either pyroxenic or chrysolitic; and the other of doubtful, and perhaps varied, origin—that from Fritz Island being altered dolomite.

Rogers says of the Lancaster County serpentines, as he said of the areas in Chester County, that there are two kinds of serpentine; a stratified and unstratified one, one from dikes, and the other from impregnations by serpentinous matter.

In North Carolina the olivine rocks have suffered less alteration and the rock is chiefly dunite, but wherever the serpentine occurs it can easily be seen that it is derived from the olivine rocks. The peridotite is clearly of a later age than the gneiss, for blocks of the latter are enclosed in it.

Farther south, in Georgia, there are peridotites but no perfect serpentines, although the peridotites are in some few cases slightly altered to serpentine.

In Maryland the serpentine occurs in the counties of Cecil, Harford, Baltimore, Carroll, Howard, and Montgomery. The rock has been quarried for building purposes in Harford and Baltimore counties but is principally as the rock containing chrome ore that the serpentine has been worked. Chrome ore has been found in all of the counties named but it has been worked chiefly in Baltimore, Harford, and Cecil counties.

Bascom regards the serpentine of Cecil County as altered peridotites and pyroxenites, the more common origin being the peridotite and says that in different localities gradations may be traced from completely altered to only partially altered peridotites and pyroxenites. The serpentine is always accompanied and is sometimes completely replaced by a final product of alteration—talc. Feldspar and flint are associated with the rock in various localities.

In Harford County occur the largest quarries from which serpentine has been taken for building and decorative purposes, those at Cambria and Broad Creek being the largest. At the Broad Creek quarry occur two kinds of serpentine, a green and a black, the latter containing more magnetic iron.

In Baltimore County there are numerous areas, the principal ones being those at the Bare Hills and Soldiers' Delight. The serpentines are here chiefly derived from the olivine rocks. By far the most abundant of the magnesian rocks of the county are hornblende serpentines derived from pyroxene-olivine rocks. Where the olivine solely has been altered bronzite or diallage serpentine results. Hornblende is frequently altered to talc in these rocks with the separation of calcium carbonate.

In Carroll, Howard, and Montgomery counties are areas of serpentine which have, however, only been examined with reference to the chrome ores.

It is thus seen that in the region of serpentines extending from New York to Georgia, which in all probability are similar, the origin has been variously explained. Rogers dwells upon the fact that there occur here two kinds—an injection and a replacement serpentine—and this is also noted by Rand. That limestone or dolomite is the original mother rock of the Fritz Island serpentine is held by Rand and a similar view is held by Britton for a part of the Staten Island rock. Hornblendic rocks have altered to serpentine in Staten Island (Julien), and in Northampton County, Pennsylvania (Peck). Merrill regards the Montville, N. J., serpentines as derived from pyroxene. The serpentines regarded as derived from olivine rocks and which include the greater part of the rocks studied, are those of Chestnut Hill, Pa., and Cecil County, Md. (Bascom); part of the State Line serpentines (Rand); the Bare Hills and Soldiers' Delight area (Williams); and those of North Carolina (Pratt). The soapstone and serpentines are generally held to be of the same age and a geologic unit. Hall believed them to have been deposited in shallow synclinal basins; Frazer and Rogers thought that the soapstone bodies were formed by replacement or infusion of magnesian matter; Bascom and Williams that the talc is a final stage of alteration of the serpentine.

HISTORICAL

It is probable that the λιθος ὀφιτης of Dioskorides and the *Ophites* of Pliny were applied to serpentine. The name ὄφις may have been given to it on account of the spotted appearance, like that of a snake, or it may be that it was given on account of the use made of the mineral as an antidote for the bite of snakes as mentioned by Dioskorides. Later the name was translated into Latin (*Serpens*, creeping, as a serpent) as *Serpentaria* by Agricola in 1546 (*De natura fossilium*); Serpentina by Boetius de Boot; *Marmor Serpentinum* by Wallerius in 1747 (Mineralogie); *Serpentin* by Cronstedt in 1758 (Mineralogie, p. 76) Emmerling in 1793 (Mineralogie, p. 384) used it as a family name in the Talc order. Haüy in 1822 in his Mineralogy speaks of the serpentine also as a species of the genus talc.

In 1810 Leopold von Buch,[60] observing the frequent association of the serpentine with gabbro, suggested that it might be an extremely fine-grained gabbro in which it was impossible to recognize the individual minerals, or a gabbro containing a large proportion of talc.

In 1823 Haidinger,[61] opposing von Buch's views, claimed that serpen-

[60] v. Buch, L. Berlin Magazin d. naturf. Freunde, Bd. IV, pp. 142, 148.
[61] Haidinger, W. K., Gilb. Ann., 1823, Bd. LXXV, p. 385.

tine was a distinct mineral with a definite crystalline form which he described in the serpentine from Snarum, in Norway, but in 1831 Breithaupt[62] declared that Haidinger's forms belonged to olivine. He speaks of other forms which are not like olivine and he thus early supposed that serpentine takes the forms of pyroxene and amphibole as well as of olivine. Assuming this he says that the process is perhaps applicable to large serpentine masses which may, therefore, be nothing else than altered hornblende or diorite strata.

Following this there were numerous discussions on the origin of the Snarum crystals in which Scheerer, Herrmann, Tamnau, Naumann, and Blum took part, and the question was only settled in 1851 by Quenstedt and G. Rose[63] who showed that the "crystals" consisted of 30 per cent of serpentine and 70 per cent of olivine, and that the inner cores of the crystals were still composed of the latter mineral. Rose concluded that all the crystals which had been called serpentine were simply pseudomorphs after olivine, hornblende, augite, diallage, chrondrodite, spinel, and mica, as had already been shown by other investigators, and that serpentine itself did not crystallize. He also said that wherever and in however large masses serpentine occurs, it is never primary but has been built up by later replacement processes. This idea was extended by many later observations. In 1854 Briethaupt[64] described a gabbro in which the augite was at times entirely altered to serpentine, as were also some of the feldspars. In other places eclogite appeared to be changed to serpentine. Hochstetter[65] in 1854 observed in the serpentine of the Granulitgebeite of Bohemia indications that it was originally a hornblende rock, although later observations of von Camerlander[66] indicate that it was derived from an olivine-augite rock. About this time G. Bischof pointed out that serpentine belongs to the last alteration product of minerals and that it seldom undergoes further change.

[62] Breithaupt, Aug., Schcrigg. N. Jahrb. Chem. u. Phys., 1831, Bd. III, p. 282.

[63] Rose, G. Zeitschrift der Deutschen geologischen Gesellschaft, Bd. III, 1851, p. 108.

[64] Breithaupt, Aug. Neues Jahrn., 1854, p. 181.

[65] Hochstetter, F. von. Jahrb. geol. Reich. Anst. Wien, 1854, p. 1.

[66] von Camerlander, Carl. Zur Geologie des Granulitgebeites von Prachatitz. Jahrb. k-k. Geol. Reich., Bd. XXXVII, 1887, p. 124.

In 1860 T. Sterry Hunt[67] assigned an aqueous origin to the Canadian serpentines, chlorites and steatites and said that they were formed by reactions between the soluble silicates of calcium and alkalies from decaying rocks and the magnesian salts from natural waters. He still held this view in 1886.[68]

Up to this time there had been no rocks known composed entirely of olivine, but in the early sixties they were described from numerous localities. Sandberger said in 1866[69] that serpentine which contains pyrope, bronzite, chrome-diopside, or picotite must have originated from olivine rocks, since only in these rocks do such minerals occur as original constituents. He found the rocks near Tringenstein to be from one-quarter to one-sixth fresh olivine.

In 1867 Tschermak[70] published a paper confirming the results of Sandberger. Up to this time it was generally supposed that almost any kind of rock could be altered into serpentine, since it was found in the field that transitions could be traced from many rocks to serpentine. Tschermak showed that there might occur a considerable variation in the mineralogical composition of any rock mass, and that an olivine-bearing rock with no feldspar might pass gradually into a feldspar-rich and olivine-poor rock. If in a such mass the olivine became altered to serpentine, a transition might be traced in the field from a feldspatic rock without olivine to a serpentine, yet this does not show a serpentinization of a feldspar rock.

The work of Sandberger and Tschermak produced a reaction against the earlier views and for a time it was thought that serpentine could only be produced from olivine rocks. In 1869, however, J. Roth[71] showed by chemical equations that this view was too narrow and that all alumina-free or alumina-poor magnesian silicates might alter into

[67] Hunt, T. Sterry. Canadian Naturalist, June 1860; Amer. Jour. Sci. (2), vol. xxxii, 1861, p. 286.

[68] Hunt, T. Sterry. Mineral Physiology and Physiography, 1886, p. 501.

[69] Sandberger, F. Ueber Olivinefels und die in demselben vorkommenden Mineralien. Neues Jahrb. B., 1886, p. 392.

[70] Tschermak, Gustav. Sitz. Wein. Akad., 1867, Bd. LVI, p. 283.

[71] Roth, J. Uber den Serpentin und dis genetischen Beziehungen desselben. Abhandl. Berlin Akad., 1869, p. 329.

serpentine. According to his view, therefore, olivine, augite, diallage, hornblende, enstatite, and bronzite might form serpentine.

In 1871 Drasch,[72] by chemical and microscopical studies, divided serpentines into two classes—the true serpentine and the "serpentine-like" rocks. In both of these the chemical composition showed them to have the same composition but the microscope revealed that the former showed the typical mesh structure of rocks derived from olivine, while the latter do not possess this structure and were derived from diallage. (This mineral was later shown to be augite.)[73] This latter rock often shows a flaky structure, and in an example which the author mentions, is the serpentine from the Windisch Matrey in northern Tyrol, which is interstratified with a calcareous mica-schist. The rock is often cut by veins of calcite, asbestos, and chrysotile.

An analysis of the rock is given as follows:

SiO_2	41.57
Al_2O_3	0.67
Fe_2O_3	2.63
FeO	5.31
CaO	1.22
MgO	36.66
CO_2	0.51
Loss	11.88
	100.45

This analysis is that of a serpentine, but it differs from a true serpentine in that it is not acted upon by hydrochloric acid.

In spite of all these determinations Doelter[74] continued to maintain that it was still undetermined whether serpentine was ever derived from any other mineral than olivine, and he regarded descriptions of pseudomorphs after any other mineral as doubtful.

[72] Drasch, Richard von. Ueber Serpentine und serpentin ähnliche gestein. Tschermak's Mineralogische Mittheilungen, 1871, pp. 1–12.

[73] Hussak, Eugen. Ueber einige alpine Serpentin. Tscher. Min. Mitt., Bd. V, 1883, p. 61.

[74] Doelter, C. Ueber das Muttergestein der bömischen Pyropen. Tscher, Min. Mitt., 1873, pp. 13–18.

In 1875 Weigand[75] showed in the serpentines from the Vosges Mountains, that amphibole and bronzite might also be altered to serpentine, confirming the statement made some forty years earlier by Breithaupt, and by Hochstetter twenty years before. Of the serpentines of the Vosges those of Bonhomme and Starkenbach are plainly derived from olivine, showing under the microscope the characteristic mesh structure, but that of the Rauenthal is quite different. It occurs in a gneiss series in which there are hornblende members. By an increase in the hornblende the rocks pass into an amphibole and it is with the latter rock that the serpentine occurs. From the margin of the serpentinized areas inward there is a gradual increase in the amount of serpentine until the rock is wholly a serpentine although differing from normal olivine serpentines in often having a schistose structure. Under the microscope the mesh-structure is absent, but the characteristic cleavage lines of hornblende show that the original mineral was a hornblende.

An analysis of this rock shows:

	Rauenthal serpentine	Adjacent amphibole
SiO	37.706	46.407
Al_2O_3	0.201	6.727
Fe_2O_3	10.428	4.649
FeO	—	2.107
CaO	1.677	10.642
MgO	36.602	26.252
H_2O	13.386	3.584
	100.000	100.368

This is the composition of a serpentine with much iron oxide. Weigand concludes that the serpentine was produced from the alteration of a hornblende rock and that in the change calcium oxide was removed and the alumina of the original hornblende was united with some of the magnesia to form a chlorite which is always associated with the serpentine.

[75] Weigand, Brunu. Die Serpentine der Vogesen. Tscher. Min. Mitt., 1875, pp. 183–206.

In 1883 Hussak[76] examined the rocks of the Windisch Matrey which Drasch had described 12 years before. Near Sprechenstein are lenticular masses of serpentine, talc, and magnesite which are associated with serpentinous schists and which have the same strike as the phyllites with which they occur. The green schistose variety was found to be composed chiefly of antigorite scales, with grains of magnetite and colorless augite between them. Some chlorite and staurolite occurs with it. The massive variety was found to be a normal serpentine derived from olivine.

In 1877 Bonney[77] described the Lizard serpentines and showed that they were altered olivine rocks of the Lherzolite type. The field relations of these rocks show that they are intrusive.

In 1883 Schulze[78] showed another example of the alteration of amphibole to serpentine at Erbendorf in the Oberfalz where an olivine-grammatite rock was altered, the alumina of the grammatite passing into chlorote as in the case described by Weigand.

In 1888 Merrill[79] showed that in the Montville, N. J. and in Essex County, N. Y., serpentine was produced by the alteration of a pyroxene.

In 1889 Vecker [80] described a serpentine from the southern California which he says is derived from sandstone and that augite, hornblende, quartz, feldspar, and apatite have become altered to serpentine.

Bonney[81] in 1891 published a table showing the minerals contained in the serpentines of the Lizard District, and which is as follows:

[76] Hussak, Eugen. Ueber einige alpine Serpentine. Tscher. Min. P. Mitt. Neue folge, Bd. V, 1883, p. 61.

[77] Bonney, T. G. On the Serpentine and Associated Rocks of the Lizard District. Q. J. G. S., 1877, vol. xxxiii, pp. 884–924.

[78] Schulze, George. Die Serpentin von Erbendorf in der bayerischen Oberpfalz. Zeits. deutsch. geol. Gesell., Bd. XXXV, 1883, pp. 433–460.

[79] Merrill, George P. "On the Serpentine of Montville, N. J. Proc. U. S. Nat. Museum, 1888, pp. 105–111; ibid. 1889, pp. 595–600.

[80] Becker, George F. Quicksilver Deposits of the Pacific Slope. 8th Ann. Rept. U. S. Geol. Survey, 1889, Pt. ii, p. 970.

[81] Bonney, T. G. "Crystalline Rocks of The Lizard District." Q. J. G. S., 1891, vol. xlvii, p. 467.

Localities	Olivine	Enstatite	Augite	Hornblende	Chlorite	Iron Oxides	Spinellides	Remarks
Balk Quarry					?	•	?	Red
Cadgwith	•			•		•	•	Red
Quarry north of same		•		•		•	•	Red
Enys Head, near	•	•	?	•	?	•	•	Black
Kennack Cove		•				•	•	Black calcite or magnetite in veins
Carn Spernic	•	•	•		?	•	•	Red
" "		•				•	?	Red
Lankidden Cove		•				•	?	Greenish-purple
Coverack	•	•	•			•	•	Red
"	•	•	•			•	•	Red
"		?				•	•	Dark, much disseminated opacite affected by contact
Polkerris		?				•	•	Reddish
Perthalla					?	•	•	Greenish-purple
"		?		•	•	•		" "
"					•	•		" "
"		?		•	?	•		Same but colors more separated
"				•	•	•		Same, colors in bands
Goonhilly Downs Quarry	•	•	•	•		•	•	Streaky-reddish; a brown hornblende
Helston-Lizard Road	?	?	?	•		•	•	Darl; much white horn-blende, a little brown
Mullion Cove	•			•		•	•	Nearly black; much white horn-blende
Lower Predannack Quarry	•	?		•	•	•	•	Reddish; much white hornblende
Ogo-dour Cove						•	•	Black, streaky; much chrysotile
Georges Cove	•	•		•		•	•	Striped and light greenish-gray
Gew Graze	•	?	•	•		•	•	Reddish; a little brown hornblende
The Riil	•	•	•	•	?	•		Dark, white spots; feldspar or chloritoid (?)
Lawarnick Pit	•	•		•	•	•		Rather dark
Kynanee Cove		•				•	•	Striped reddish-brown
" "						•		Red, compact
Holestrow						•		Greenish-gray, veined with steatitic minerals
Pentreath Beach						•		Calcite or magnesite veins

The minerals which occur are starred.

THE MINERAL SERPENTINE

Serpentine occurs both as a mineral and as a rock and is in composition a hydrous magnesian silicate with the formula $H_4Mg_3Si_2O9$, or $3MgO \cdot 2SiO_2 \cdot 2H_2O$. In percentages the composition is silica 44.8, magnesia 42.0, and water 12.9 for the pure mineral. Often a small part of the magnesium is replaced by iron, and nickel and chromium are often present in small amounts. The mineral is soluble in hydrochloric acid with the separation of gelatinous silica.

Megascopically, it is a compact, dirty-green to black mineral with a splintery fracture and a greasy or pearly to waxy luster. The color of the rock depends upon the amount of pure serpentine present, and upon the amount of magnetite and chromite, the pure serpentine being of an oil-green color but, with much finely divided magnetite, approaching black. Chlorite gives it a dirty-green color. By the local alteration of the magnetite to iron oxide and hydroxide, the color of the rock becomes dark-brown to blood-red.

The mineral is often megascopically of a fibrous structure, sometimes it is schistose and is often interlaced with talc or chlorite. Sometimes these threads are separable but often they are not. The hardness varies from 2.5 to 5.5, depending upon the variety. The cleavage is parallel to 010 and is sometimes distinct.

VARIETIES

MASSIVE VARIETIES

1. *Noble or precious serpentine.*—A translucent variety with a rich oil-green color; sometimes quite dark. Hardness from 2.5 to 3.0.

2. *Common serpentine.*—Subtranslucent and generally dark in color. Hardness owing to impurities sometimes as high as 4.0.

3. *Bowenite.*—(Dana, Mineralogy, 1850, p. 265). A very fine-grained and massive variety. It has a hardness of from 5.0 to 6.0 and varies in color from greenish-white to apple-green. It was named by Dana and is the mineral which Bowen (Amer. Jour. Sci., 1822, vol. V, p. 346) described as Nephrite. Smith and Brush (Amer. Jour. Sci., 1853, vol. XV, p. 212) showed by chemical analyses that it is a variety of serpentine.

4. *Retinalite.*—(Thomson, Mineraolgy, 1836, vol. I, p. 201) (ῥητίνη resin + λίθος stone). A honey-yellow to light oil-green variety with a waxy or resinous luster.

5. *Schweizerite.*—(Jour. pr. Chem. 1844, vol. XXXII, p. 378). Named after the chemist Schweizer who analyzed it. A very compact, greenish-yellow or pale yellowish-green serpentine with a waxy to dull luster and

with a greasy feel, from the Findel glacier at Zermatt and from the Fee glacier in Wallis. It has a splintery or shallow conchoidal fracture. Merz (Natur. Ges. Zurich, 1861, Heft 4.) says it is simply a compact serpentine.

6. *Vochauserite.*—(Kenngott, Uebers. min. Forsch. 1856–57, p. 71). An amorphous, dark-brown or greenish-black serpentine somewhat translucent; from Monzoni in the Tyrol. Named for Johannes Vorhauser.

7. *Williamsite.*—(Shepard, Amer. Jour. Sci., vol. VI, 1848, p. 249). An apple-green serpentine from Texas, Pennsylvania. Found by Williams and named for him by Shepard.

LAMELLAR VARIETIES

8. *Antigorite.*—(Schweizer, Pog. An. vol. XLIX, 1840, p. 595). Thin, lamellar in structure, separable into translucent folia. Feels smooth but not greasy. Hardness of 2.5. First found in the Antigorio Valley in Piedmont, Italy.

9. *Warmolite.*—(Nuttall, Amer. Jour. Sci., vol. IV, 1822, p. 19). A thin foliated serpentine first found at Hoboken, N. J. So called from μαρμαίρω glistening, and λιθος stone.

10. *Thermophyllite.*—(Nordenskiold, Beskrif. Fin. Min. 1855, p. 160; Phil. Mag. vol. XVI, 1858, p. 263). From λ heat, and λ leaf; so called on account of the swelling and foliation under the blowpipe. A bluish-green lamellar serpentine.

FIBROUS VARIETIES

11. *Chrysotile.*—(Kobell, Jour. pr. Chem., vol. XXX, 1843, p. 469). Delicately fibrous; the fibers usually flexible and easily separated. Luster, silky. Color, white and yellowish to green. Name from ρυσὸς gold, and τιλαι threads. Often in seams in serpentine and always at right angles to the walls. This variety includes the silky Amianthus, and is often in marketable quantities as asbestos.

12. *Pictolite.*—(Hausmann, v. Moll's Efemerid. Berg und Huttenkunde., 1808 IV. Lfg. iii, p. 401). Named from a variety found by

Hausmann in the Taberg, Sweden, alternating with layers of gypsum and magnesia; πικρός bitter, and λιθος stone, on account of its magnesia content. Later Hausmann applied the name to fibrous serpentine with fibers sometimes, and sometimes not, easily seperable. Fracture splintery. Color usually green and generally dark. The fibers as seen under the microscope are often radial.

13. *Baltimorite.*—(Thomson, Phil., Mag., vol. XXII, 1843, p. 191). A picrolite from Bare Hills near Baltimore.

14. *Hydrophite.*—(Svanberg, Pogg, Ann., vol. LI, 1839, p. 525). A compact to fibrous variety from Taberg, in Sweden, with a high percentage of water content. Occurs with much magnetite.

15. *Jenkinsite.*—(Shepard, Amer. Jour. Sci., vol. XIII, 1852, p. 392). Named after J. Jenkins of Monroe, N. Y. A fibrous, pale-green crust on compact magnetite found in Orange County, N. Y. Smith and Brush (Amer. Jour. Sci., vol. XVI, 1853, p. 369) gave similar analyses to this and Hydrophite.

16. *Metaxite.*—(Brithaup, Scherige N. J. Chem. Phys., vol. III, 1853, p. 276). From μέταξα raw silk. A feeble silky lustrous translucent serpentine occuring in white crystalline limestone in Saxony. Hardness from 3.5 to 4.0. Fusible before blowpipe. Under the microscope the fibers are often divergent.

MICROSCOPICAL CHARACTERISTICS

Under the microscope serpentine appears to be made up principally of fine fibers, thin prisms, or thin laminated plates. When the fibers are parallel they generally show that the axis of least ease of vibration is in the direction of the fibers, and bisects the optic axes. In flakes and laths the dispersion is $\rho > v$, therefore positive. At times in a felty aggregate the optical characters counterbalance, and the mineral may appear isotrophic. According to Tschermak, fibrous serpentine has the axis of least ease of vibration at right angles to the direction of the fibers, and the greater parallel to them, and has a large optic angle. Many varieties, however, have positive character and show interference figures in sections cut at right angles to the fibers.

The extinction is parallel to the fibers and the mineral shows a faint pleochroism, $\mathfrak{a}$ and $\mathfrak{b}$ paler green than $\mathfrak{c}$. The double refraction is weak and the interference colors are therefore low; $\gamma - a = 0.013$. The index of refraction is low, being about the same as Canada balsam, therefore the relief is low. The plane of the optic axes is parallel to the longer direction of the prismatic cleavage; thus in chrysotile $c = \mathfrak{c}$, $b = \mathfrak{a}$, $a = \mathfrak{b}$. The mineral is biaxial with a variable angle which is often large; $2E = 16°$ to $98°$, depending upon the percentage of iron present.

SERPENTINE PSEUDOMORPHS AFTER OTHER MINERALS

Serpentine never occurs in original crystals but always as pseudomorphs after other minerals. Among these the following have been described:

Augite	Merrill	Easton, Pa.
Apatite	Dana	Tilly Foster Mine
Biotite	Dana	" " "
Bronzite	Rosenbusch	Baste, Harz.
Brucite	Dana	Tilly Foster Mine
Calcite	Dana	" " "
Chlorite	Dana	" " "
Chondrodite	Dana	" " "
Chromite	Heddle	
Chrysolite	(See Olivine)	
Diallage	Becke	Neokhori
Diopside	Merrill	Montville, N. J.
Dolomite	Rand	Chester Co., Pa.
Enstatite	Wadsworth	Melbourne
Feldspar	Becker	California
Garnet	Blum	Schwarzenburg
Hornblende	Dana	Tilly Foster Mine
Macacolite	(See Diopside)	
Monticellite	v. Rath	Monzoni
Olivine	Rose	Snarum, Sweden
Phlogopite	Peck	Easton, Pa.
Ripidolite	Dana	Tilly Foster Mine
Spinel	Blum	Warwick, N. Y.
Staurolite	Rand	Mill Creek, Pa.
Tremolite	Merrill	Easton, Pa.
Quartz	Becker	California

THE ROCK SERPENTINE

Serpentine often forms entire rock masses and is generally quite compact and massive, although at times it is schistose and thinly laminated. The color varies from green to yellow or brownish-red, and often shows clouds and streaks on account of the magnetite or chromite occurring in it. The hardness is generally low but it varies with the other minerals contained in it. The rock is composed primarily of mineral serpentine but it generally also contains fragments of the minerals from which this was derived such as olivine, bronzite, diallage, diopside, and hornblende. Chlorite is often present in large quantities and gives the rock a dirty-green color. Magnetite and chromite are generally present and in the Ural Mountains serpentine is the mother rock of platinum. Brucite, talc, picrolite, and other hydro-silicates occur in fractures and cracks, and opal intersects it in all directions, at times increasing the hardness very materially.

Chemically the composition is about that of the mineral serpentine, but variations occur which are due to difference in its origin. The amount of water varies, as does the specific gravity and the CaO content. Cr_2O_3 is seldom lacking in the rock, although it is often present in small amounts.

The majority of the serpentines are derived from the olivine rocks and under the microscope the appearance depends upon the original rock from which it was formed. It is often possible, when the change has not gone too far, to recognize from the fragments remaining, the original minerals from which the rock was formed.

THE ALTERATION OF OLIVINE TO SERPENTINE

The thin sections under the microscope show, when the rock has been derived from olivine and the process of alteration has not gone too far, a peculiar structure which has been called the "mesh-structure." The original crystal of olivine is first altered to serpentine along the fracture lines; the iron contained in the olivine is changed to magnetite and most of it is deposited along these primary cracks. As the serpentinization progresses the increase in bulk of the mineral forces the cracks still farther apart and so permits the more rapid serpentinization of the remainder. (*See fig. 8—1.*) According to the degree to which this is continued, the mineral shows under the microscope an irregular net work of ore particles; the irregularity of the cracks due to the fact that the olivine possesses no good cleavage. The first-formed fibers of serpentine are arranged along these cracks perpendicular to the edges. In the enclosed spaces may remain fragments of the unchanged olivine, or the entire space may be filled with serpentinized material; here, however, the structure is seldom fibrous but is rather platy. These spores, too, seldom contain ore, or if they do, it is in a very much divided

1 2 3

FIG. 8.—Textures of serpentine formed by the alteration of 1. olivine, 2. amphibole, and 3. pyroxene.

state. The color of this central filling, if of serpentine, is paler and between crossed Nicols, shows very much darker. It may even at times appear entirely isotropic, or at least very dimly lighted.

THE ALTERATION OF AMPHIBOLE TO SERPENTINE

Serpentine derived from amphibole shows what Weigand[32] called the "Gitteroder Fensterstructure." In this structure the characteristic 124° cleavage of the amphibole remains and along these cleavage lines the first formed fibers of serpentine stand out at right angles. In the spaces between the cleavage cracks the original mineral remains, or it is entirely replaced by entangled masses of fibrous serpentine showing dark between crossed Nicols, as in the case of olivine. The first formed

[32] Weigand, Bruno. Die Serpentine der Vogesen. Tscher. Min. Mitt., 1875, p. 198.

fibers usually polarize in brilliant yellows in a slide of the usual thickness. In the pinacoidal section the cleavage of the hornblende is right-angled, and is not in this case characteristic, for the vertical sections of bronzite show similar right angled cleavage lines; therefore only sections parallel to the 010 face or at least faces approaching this are characteristic. The net-work of ore inclusions are usually lacking in the hornblende serpentines; all the particles being usually concentrated in larger, isolated masses.

THE ALTERATION OF PYROXENE TO SERPENTINE

Since the cleavages of pyroxene are at right angles, it may be seen that the serpentine derived from these show a "Balkenstructure." In this there is a right-angled net-work in which parallel beams or bars are arranged at right angles to the long axes of single beams. (*See fig. 8—3.*) These straight fibers show pleochrosim of yellowish-green to pale blue-green. In the pyroxenite-serpentines the absence of picotite is noticeable. This beam structure was first described by von Drasch in 1871 in the serpentines of Windisch Matrey, but at that time it was not traced back to pyroxene. Hussak[83] first recognized its meaning in 1883.

THE MORE IMPORTANT ROCKS FROM WHICH SERPENTINE IS DERIVED

Olivine-rich rocks: Pyroxene rocks carrying olivine as Lherzolites, pikrites, bronzite-olivine rocks; amphibole-bearing rocks.

Olivine-bearing hornblende rocks:

Pure amphibole (actinolite, tremolite) rocks.

Olivine-bearing pyroxene (enstatite, bronzite, augite, and diallage) rocks.

The view held by T. Sterry Hunt and the older Canadian geologists that serpentine is an original sedimentary rock is no longer considered tenable.

[83] Hussak. Eugen. Ueber einige alpine Serpentine. Tscher. Min. Pet. Mitt., vol. v, 1883, p. 65.

SERPENTINIZATION

PHYSICAL CHANGES

A comparison of serpentines and the rocks from which they were derived, shows that there has been a great change megascopically as well as microscopically. The change as seen under the microscope has already been described in the preceding chapter. Megascopically there is seen to be a change from a crystalline rock to one that is aphanitic and compact. From a rock composed of several essential minerals, a rock is formed consisting of only one. The rock, originally massive, unbroken and unfractured, is now shattered, full of joints, fractures, seams, and veins. Many of these joints show slicken-sides and others may be filled with opal or calcite. Often too, crystals of magnetite are scattered throughout the rock. The original rock was subject to alteration. The serpentine is relatively stable and, although itself a soft rock, is yet able to withstand weathering much better than the original rock.

CHEMICAL CHANGES

If we compare analyses of olivine and serpentine we have apparently a simple change. Teall[34] gives the following analyses by Holland:

	Olivine from snarum	Serpentine derived from it	Theoretic composition of serpentine
SiO_2	41.32	42.72	43.48
Al_2O_3	0.28	0.06	
FeO	2.39	2.25	
CrO	0.05	tr.	
MgO	54.69	42.52	43.48
H_2O	0.20	13.39	13.04

The change is not, however, as simple as it appears. In the analyses we see a slight loss of magnesia and an increase of water. Hunt[35]

[34] Teall, J. J. H. British Petrography, 1888, p. 105.
[35] Hunt, T. Sterry. Mineral Physiology and Physiography, 1886, p. 506.

has shown that in the alteration of olivine to serpentine there must be an increase in bulk of 33 per cent owing to hydration. In the formation of the serpentine rocks we know that there has not been such an increase. It is true that the serpentine is everywhere broken up by fractures and joints and veins cut the rock in every direction, but on examining the rock under the microscope we see that the original minerals, even though entirely altered to serpentine, show no great distortion. The uniform polarization of the particles shows that there has been no very great disturbance. The particles may have become separated to a slight extent, but they have not been crushed and sheared as they would have been had the original rock increased in bulk as much as 33 per cent. The rock itself, it is true, shows many slickensides, indicating movements, yet often this appearance of a slickenside may not be due to a movement. Lemberg[86] has shown that there is often a luster in hornblende rocks not only upon the smooth surface, as there would be in slickensides, but often occurring on rough surfaces and sometimes in a rock containing feldspar and hornblende in which case the hornblende shows the gloss but the feldspar does not. This gloss he ascribes not to movement, but to an infinitesimally thin coating of a hydroscu-magnesian silicate. In some cases, therefore, there may have been no great sliding in the serpentine mass although the formation of the magnesian silicate took place in cleavage cracks due to fracture in the original minerals.

Taking the theoretical composition of serpentine—$H_4Mg_3Si_2O_9$, or $3MgO \cdot 2SiO_2 \cdot 2H_2O$, we find two molecules of water. Experiment has shown that one of these may be driven off at a temperature of 100°C., and the other only on raising the mineral to a much higher temperature.

The low alumina content of serpentine is an indication of the fact that only alumina-free or alumina-poor silicates are capable of producing serpentine; for, as J. Roth pointed out,[87] in ordinary weathering agents,

[86] Lemberg, J. Ueber die Contactbildung bei Predazzo. Zeits. deutsch. geol. Gesell., Bd. XXIV, 1872, p. 262.

[87] Roth, Justis. Ueber den Serpentin und die genetischen Beziehungen desselben. Abh. k. Akad. Wiss. Berlin, 1869, p. 329.

water, carbonic acid, and oxygen, are incapable of removing alumina. In serpentine, besides hydration there is a subtraction of MgO and FeO, and probably also of SiO_2. Now magnesium-hydroxide, as well as magnesia, is practically insoluble in pure water, but B. Müller found by experimenting with carbonated water upon powdered olivine, that a part of the SiO_2 and MgO and most of the FeO went into solution, and that the composition of the part remaining was similar to serpentine with the exception of the water content.

Since, therefore, serpentine can only be produced from a non-aluminous mineral Roth proceeded to consider the different minerals capable of producing it. These are: olivine, the orthohombic pyroxenes, diallage and non-aluminous hornblende and augite. The process of serpentinization begins by the oxidation of the iron and the taking up of H_2O from water containing free oxygen. Since there must be no increase in bulk some of the bases must be removed. Calcium, if present, as well as some of the magnesium, would easily be removed as carbonates. Taking five molecules of an iron-free olivine, Mg_2SiO_4 or $2mgO \cdot siO_2$, we have:

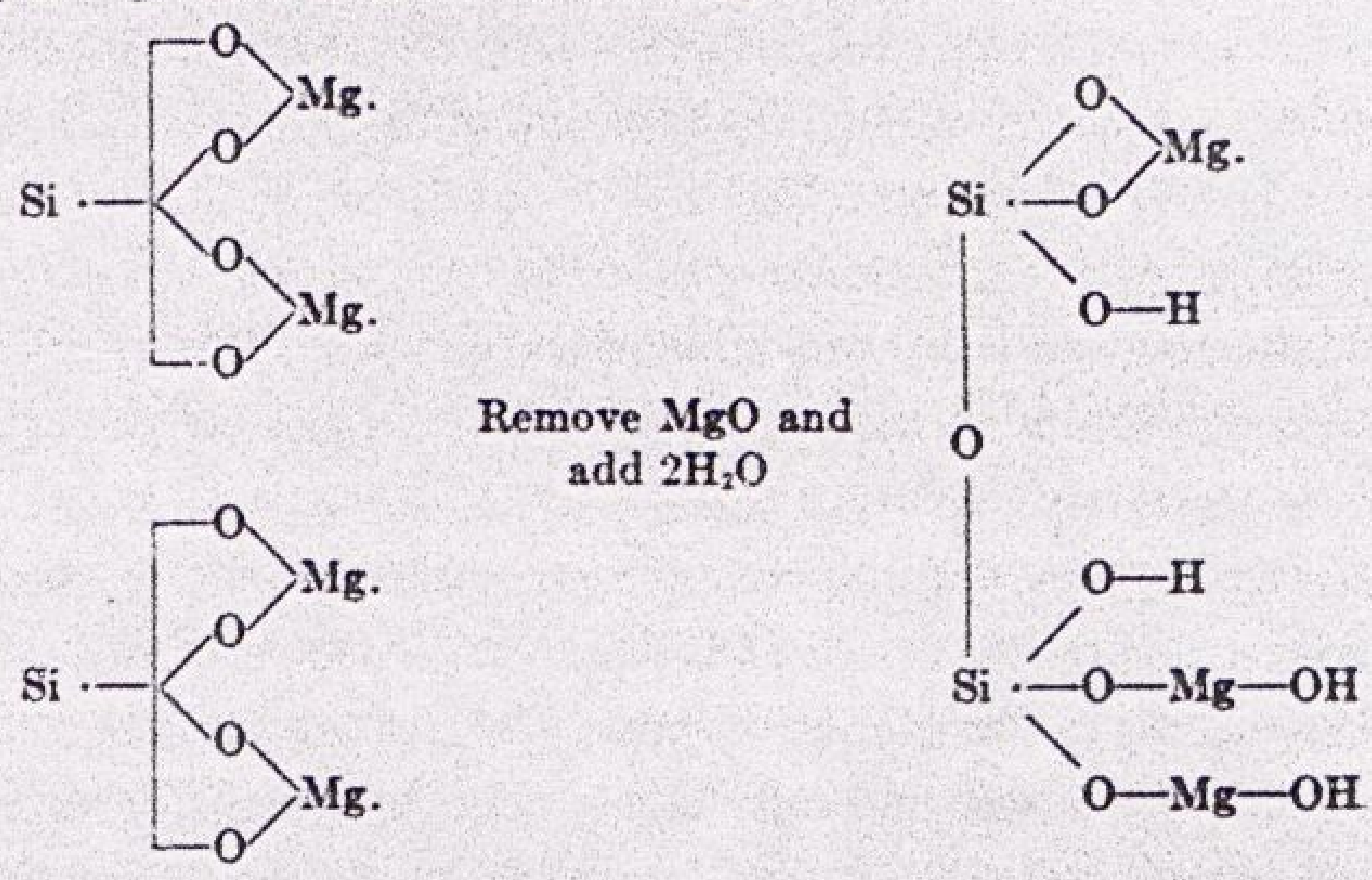
$$\begin{array}{rl} \text{Five olivine} = & 10\ MgO \cdot 5\ SiO_2 \quad \text{and subtracting} \\ & \underline{4\ MgO \cdot \ \ SiO_2} \\ & 6\ MgO \cdot 4\ SiO_2 \end{array}$$

Adding 4 molecules of H_2O we have 2 molecules of serpentine; 2 $(3\ MgO \cdot 2SiO_2 \cdot 2H_2O)$.

Supposing that the 4 $MgO \cdot SiO_2$ as given above is removed by carbonated water we have;

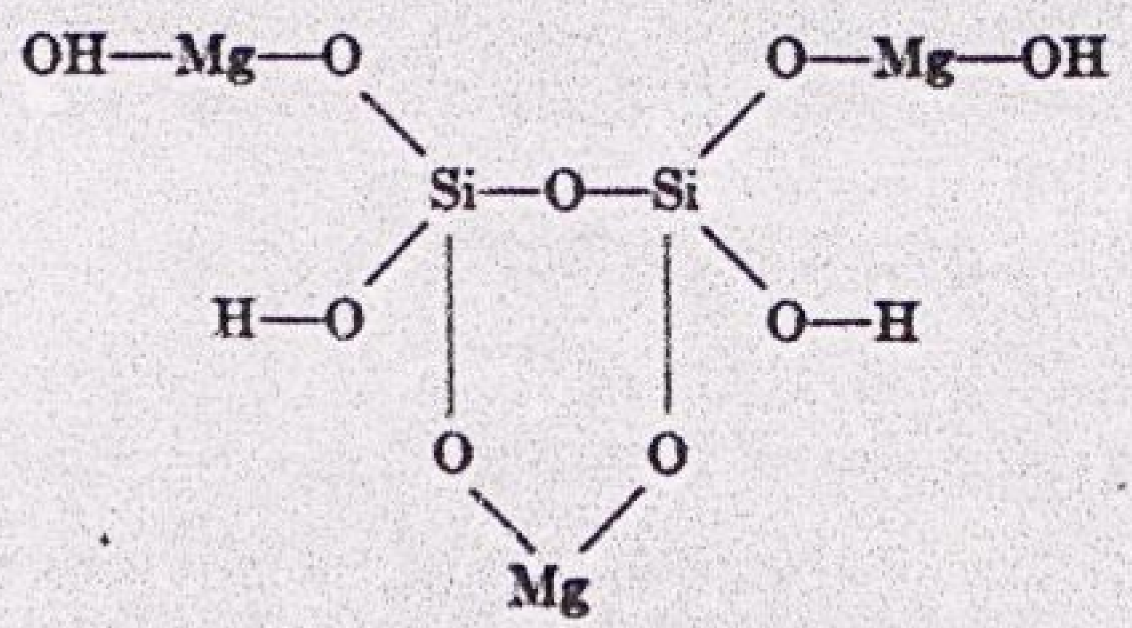
$2\ (4MgO \cdot SiO_2) + 2H_2O + 5CO_2 + 3MgO \cdot 2SiO_2 \cdot 2h_2O + 5MgCO_3$, or serpentine plus magnesite, thus explaining the frequent occurrence of carbonates with the serpentine. The calcium reaction is similar.

Brayns[88] gives a formula as follows;



OLIVINE SERPENTINE

At least two molecules of olivine are necessary to produce one of serpentine. The iron which occurs with the olivine separates out as magnetite and the magnesia forms the carbonate magnesite. Brauns prefers the unsymmetrical serpentine formula rather than Tschermak's symmetrical one:



because it explains an experiment recently performed by Clark and Schneider, who repeated an old experiment of Daubrée, whereby on heating serpentine to the melting point and driving off the water it was found to separate into enstatite and olivine.

$$3MgO \cdot 2SiO_2 = MgO \cdot SiO_2 + 2MgO \cdot SiO_2 + 2H_2O$$

SERPENTINE ENSTATITE OLIVINE

[88] Brauns, E. Betrachtungen ueber die chemische Zusammensetzung Mineralien der Serpentin-, Chlorit-, und Glimmer-gruppen. Neues Jahrb. B.. I. 1894, pp. 217, 242.

In the case of the serpentinization of a non-aluminous lime-magnesia-iron pyroxene from Sala, Sweden, Roth gives the following analyses:

	I	II	III	IV	V
SiO_2	54.86	59.66	63.33	56.16	48.77
CaO	23.57	11.55	5.18	0.88	
MgO	16.49	22.28	26.31	33.96	48.88
FeO	4.44	5.44	4.36	7.74	
MnO			0.82		
Al_2O_3	0.21	0.47		1.26	2.35
	99.57	100.00	100.00	100.00	100.00

I. Fresh pyroxene (Rose). II Altered pyroxene with 8.12% water (Rose). III. Altered pyroxene with 5.52% water (Rose). IV. Altered pyroxene with 9.83% water (Svanberg). V. Serpentine with 12.33% water (Lynchnell).

In these analyses it is seen that to produce the change from the pyroxene to serpentine a large amount of SiO_2 and CaO must have been removed, or that some of the MgO has been added, both possibilities suggested by Roth.

Merrill[59] gives the following analyses of a white pyroxene from Montville, New Jersey (I) and the serpentine derived from it (II).

	I	II
SiO_2	54.215	42.38
MgO	19.82	42.14
CaO	24.71	—
Al_2O_3	0.59	0.07
Fe_2O_3	0.20	0.97
FeO	0.27	0.17
H_2O	0.14	14.20
	99.945	98.85

The formation of magnesite and calcite from the products removed from the original rock in the process of serpentinization is well authenti-

[59] Merrill, George P. Rocks, Rock-Weathering and Soils, p. 114.

cated, but that serpentine is produced from limestone and dolomites is not established. Serpentine, it is true, often occurs associated with dolomite and limestone, and since certain of them are very rich in silicates, as melacolite and tremolite, it is quite probable that the serpentine has been derived from them in the ordinary way, leaving the limestone itself unaltered. The deposition of serpentine as such without alteration in the primordial sea, as suggested by T. Sterry Hunt, is not considered to have taken place. At the present time no geologist holds that view.

Feldspar may alter to serpentine but the process is not a simple one. Bishof[90] gives the following reactions:

A silicate of lime may be decomposed by magnesium sulphate or chloridewith the for mation of magnesium silicate and calcium sulphate or chloride.

Aluminium silicate is decomposed by magnesium sulphate or chloride with the formation of magnesium silicate and aluminium sulphate or chloride (p. 69).

Calcium silicate and magnesium bicarbonate form magnesium silicate and calcium bicarbonate (v.i, p. 13).

Potassium silicate and magnesium bicarbonate form magnesium silicate and potassium carbonate (v.ii, p. 69).

C. H. Smyth, Jr.[91] gives the following formulae for the alteration of enstatite and tremolite into talc:

$$\underset{\text{ENSTATITE}}{4\,Mg\,Si_2O_3} + H_2O + CO = \underset{\text{TALC}}{H_2\,Mg_3\,Si_4O_{12}} + Mg\,CO_3$$

$$\underset{\text{TREMOLITE}}{Ca\,Mg_3\,Si_4O_{12}} + H_2O + CO_2 = \underset{\text{TALC}}{H_2\,Mg_3\,Si_4O_{12}}\,Ca\,CO_3$$

DETAILED STUDIES OF THE SERPENTINE AREAS OF HARFORD COUNTY

The serpentines of Harford County had, up to the present time (1903), been mapped only in a preliminary way, and to the rocks had been

[90] Bischof, Gustav. Chemical and Physical Geology. English Ed., vol. ii, pp. 66, 67.

[91] Smyth, C. H. Jr. School of Mines Quarterly, vol. xvii, No. 4, 1896, p. 339.

assigned an origin similar to that of the serpentine of the rest of Maryland, that is, from the serpentinization of peridotites and pyroxenites, principally peridotites. The present work was done to fully determine the extent and areal distribution of the areas, the mode of occurrence of the serpentines, the rocks from which they were derived, and the processes of metamorphism through which they had passed to their present state of serpentinization.

The studies are based principally upon the work done by the author during the field seasons of 1901 and 1902 during which time all the areas were examined in detail, 299 specimens were collected evenly distributed over the areas, and 27 thin sections were prepared for microscopic study. Besides this material the author has had access to the specimens collected by Professor George H. Williams, the field notes of his preliminary work, and 20 slides for the microscope prepared by him.

The author's investigations and studies in the field show that there are about 25 serpentine areas in Harford County. These vary in length from a few hundred feet to 14 miles, and in width from less than a hundred feet to a mile. The areas which are fully described below, are as follows: 1. Deep Creek area, 2. Broad Creek area, 3. The Glades area, 4. Bald Hill—Scarboro—Deer Creek area, 5. Between Bald Hill and Castleton areas, 6. Castleton area, 7. Macton area, 8. Two small dikes north of Macton, 9. Soapstone knoll, 10. Mill Green area, 11. Ady area, 12. Cherry Hill area, 13. Chrome Hill area, 14. Coopstown-Jarrettsville area, 15. Cardiff area, 16. Pylesville-Clermont Mills area, 17. Federal Hill area, 18. Little Deer Creek area, 19. Carsins area, 20. Hickory area, 21. Area south of Hickory, 22. Area south of area 21, 23–24. Two areas north of Gibson, 25. Belair area, 26. Wimbledon area, 27. Fallston area, 28. Small area between 26 and 27.

The location of all these areas is shown on the accompanying map, and the numbers marked upon the map are the numbers of the specimens which are described in the following pages.

Area 1. Deep Creek.—This area is a very narrow one on Deep Creek about a mile and a quarter west of Flintville and about a half mile north of Broad Creek. The serpentine is exposed in the creek from a couple of hundred feet north of the house on its east bank to a point opposite the house. The length of the area could not be determined for it is everywhere, except where cut by the creek, covered by the soil derived from the crinkled mica schist which borders it to the north and south. The area is probably not more than 500 or 600 feet in length.

Area 2. Broad Creek.—This is a lens-shaped area about one and three-eighths of a mile in width at the widest portion. To the north of this area is a crinkled mica schist somewhat chloritized (327 and 374).[92] To the south and separating it from Area 3 is a mica schist (331). The general direction of the area is northeast and southwest, approximately on the direction of the strike of the surrounding mica schist. From the relationship of the mica schists at the north to those at the south the mass appears to be either included in them or else intruded after the mica schists had been deposited. It is from this area that the greatest amount of material has been quarried for decorative and building purposes. On the southern border on Broad Creek, about at the middle of the area, are the Broad Creek "Verde Antique" quarries.

When visited by the author in 1901 and 1902 the quarry and saw mill appeared to have been abandoned. Most of the machinery had been removed and the buildings were in poor condition. The general nature of the "barrens" may be seen from the photograph in Plate XV taken just to the north of the quarries. Everywhere the serpentine outcrops through the soil, and the vegetation is scanty. The serpentine in this area varies from a beautiful dark-green to a rock that is nearly black. Surrounding the area on every side is a border of talcose rocks and beyond these there is a chloritic schist, grading into the mica schist and appearing as though the mica had been replaced by chlorite, the magnesium for which may have leached from the intruded magnesian rocks.

The specimens from this area are as follows:

328.—From the north boundary at the east end of the area. A dark-green chlorotic rock containing crystals of magnetite. The rock is soft, being easily scratched with the thumb nail.

[92] The numbers in parentheses throughout the following pages refer to specimen numbers.

329.—South of the preceding on the road. An almost white soapstone, flaky in places. It contains a few crystals of magnetite.

330.—A compact, dark-green, typical serpentine from the same road. This was taken from a boulder at the roadside which may possibly have been brought here as road ballast. No other rock outcrops here.

332.—From the Broad Creek quarries. A compact, medium-green serpentine and typical of the area.

*333a.[93]—From the south boundary on the road to the southwest. A compact white to very light-green talcose rock with a vein of fibrous talc running through it. It contains numerous cavities from which crystals of magnetite have rusted out.

Under the microscope the rock is seen to consist of a mass of talc fibers and plates. In the vein the fibers are arranged in parallel position and extend from the two sides of the fracture, meeting in the center. The main mass of the rock is compact talc unstained by iron oxide although the vein filling was considerably stained. The ore grains and crystals are magnetite, often showing octahedral cleavage fragments.

333b.—Similar to the preceding.

*333c.—A green chlorite, nearly pure ripidolite. Under the microscope the section shows typical radiation or fan-shaped bunches of rods and plates of chlorite. Some of the plates are nearly isotropic. The fibrous plates are slightly pleochroic; pale-yellow to green. Uniaxial or nearly so. Chlorite. A very few magnetite crystals occur in the slide.

375.—From the south boundary at the western end, near lane. A chlorite schist.

*63B.[94]—From the Broad Creek quarries. A typical serpentine. Under the microscope the slide shows a typical pale polarizing serpentine. It contains an unusual amount of carbonate, possibly two-thirds of the slide.

*64B.—Same locality as preceding. A pale-green serpentine mottled with black. Not as homogeneous as the usual rock.

[93] Sections have been made from the specimens marked (*).

[94] Series B is a collection of crystalline rocks and accompanying microscopical sections from Maryland, Virginia, etc., collected by the late Professor Williams for the U. S. Geological Survey between 1887 and 1894.

Under the microscope it is like 63B but with less carbonate and with coarser fibers of serpentine. There is much ore scattered through the rock in crystals and very minute grains.

65B.—Same locality as 63B. Light-green, much slickensided serpentine.

Under the microscope it is seen to be nearly pure serpentine with very little ore. The ore that does occur is in large pieces and around these the serpentine fibers stand out at right angles in a peculiar manner.

*66B.—Chlorite rock from Deep Run, north of the boundary of Area 2. Under the microscope a typical chlorite with some magnetite. Very similar to 52B and 53B of Area 8. q. v.

The area ends about 800 or 900 feet west of the lane extending south. Adjoining the area on all sides is a chloritized schist, shown by (328), (375), and (327) farther north which is less chloritized and more schistose. Thus we have a compact serpentine body surrounded by a talc border, beyond which is a rim of chlorite schist and beyond that a crinkled mica schist.

Area 8. The Glades.—On the north boundary at the center is (334) a decomposed gneiss, and (335) a dark compact gneiss, less decomposed and consisting of quartz, mica, and feldspar. South of this is (336) a serpentine-like rock, somewhat decomposed. This continues along the road in a red clay soil where it is mingled with fragments of a mica schist. At the south boundary of the area there is a crinkled mica schist with quartz lamellae (377). This specimen was taken from the south boundary of the area about one mile east of the western end. The lens is about 2 miles in length and a half a mile wide in the widest portion. The general character of the rock is serpentinous, but throughout the area there is no compact and typical serpentine. The rock is well exposed in numerous places throughout the region but everywhere it presents the same serpentine-like characters. In the midst of the area along the creek is a quarry opening from which at some time quartz has been quarried. This association of quartz in large veins with the serpentine is not at all uncommon and occurs with most of the areas in the county. At the eastern end the serpentine-like rock extends nearly to Broad Creek and ends on the south side of the creek. There is, however, a distinct area of gneiss extending to the north of the area and separating it from the Broad Creek serpentine. The entire area is overgrown with briers, laurel, scrub oak, and even much large timber and walking through this region is very difficult. There seems to be very little reason in the name which has been given to it—"The Glades"—for little of it has been cleared, especially in the eastern end. At the western end the location of the boundaries is not easy for the rock being very schistose when broken up by weathering and when decomposed very much resembles mica schist that is chloritized.

The specimens from the area are as follows:

1311.—Near McNabb's saw and grist mill, 1½ miles southeast of Macton. A chloritized and schistose rock. Much iron stained and full of rusty cavities. It is decomposed and looks like a serpentinized gabbro.

*69B.—At the corner near stamp's house. A massive, serpentine-like rock occurring in place in the road. A few feet from the road, near the house in a well, however, the rock is chloritized gneiss. The specimen is an actinolite-chlorite rock.

Under the microscope the rock shows its composition to be principally fibrous hornblende and chlorite. It contains magnetite and a little quartz. Professor Williams remarked of the slide that it "looks like the mother rock of many serpentines and is itself an alteration product, possibly of a pyroxene."

*71B.—In front of the next house east of the preceding. A hornblende-epidote rock. A green actinolite rock with apparent remnants of former feldspar.

Under the microscope the rock shows that it was probably formerly a gabbro. The pyroxene is now wholly changed to hornblende and the feldspar is epidote. A transition between a gabbro and a serpentine.

Area 4. Bald Hill—Scarboro—Deer Creek.—This is by far the largest area in Harford County. It extends from the Susquehanna River to a mile west of Chrome Hill, a distance of 13½ or 14 miles. The area is a continuation of what is known in Cecil County as the "State Line

Serpentine." The strip in Harford County is about a mile broad on the average, and maintains this width for the greater part of its length. At the western end, south of Chrome Hill, the area narrows down to a quarter of a mile and the direction changes from a northeast-southwesterly one to northwest. Here too the strike of the bordering gneiss and mica schist changes to the same direction and the rule that the serpentine masses follow closely the strike of the surrounding rock, is not departed from. In the eastern part of the area the rock is a compact serpentine as is also a narrow strip running along the northern boundary nearly to Deer Creek. This compact rock is shown in specimens (316), (317), (318), (319), (353), (378), (554), and (532). The western half of the area is for the most part a chloritic rock, 627 being a good example. About a mile west of Scarboro in the midst of the serpentine-like rock there is a dike of granite (75B) and (557).

All along the northern boundary the rock is a mica schist. To the south, at the east end from the river to a mile west of Dublin, the rock bounding the serpentine is a gabbro; then for a mile west it is granite; and the remainder of the distance it is a very schistose gneiss. becoming like a mica schist at the extreme western end. Toward the western end the determination of the rock to the south was often difficult on account of the great decomposition and disintegration that has taken place, in most places forming a deep covering of sandy micaceous soil.

A verbal description of the locations where the following specimens were obtained would be extremely long and confusing. To obviate this the specimen numbers have been marked upon the map, Plate XVI, at the localities where they were obtained.

The specimens are as follows:

315.—A schistose green serpentine.

316.—A medium-green, compact serpentine. Compact and contains fibrous serpentine in the cracks. There is very little magnetite and no talc.

317.—A very compact, medium, dark-green typical serpentine. The last two are from Bald Hill on the road about a half mile west of the Susquehanna River. 58B, 61B, and 62B are from the same locality.

318.—A compact, medium-green serpentine containing some magnetite.

*319.—A compact, somewhat granular, light-green serpentine of uniform color. It shows some fibrous serpentine in the cracks. There are a very few magnetite crystals.

Under the microscope the rock consists almost wholly of pale polarizing serpentine in carnation petal-like blades. In these the magnetite occurs in large crystals, few in number. There are remnants of a mineral which is slightly pleochroic, from pale-yellowish to greenish, with an extinction of about 22°. The mineral shows parallel cleavage or parallel fibers which are full of elongated, cylindrical, opaque inclusions of ore. At right angles to these fibers is shown a parting. The polarization colors are high. The mineral is diallage. In some of these diallage fragments there is a change around the borders to pleochroic hornblende, showing the beginning of the alteration of a pyroxene to amphibole. There is no indication of the presence of olivine or of there ever having been any in the rock. The appearance of the slide is an altered pyroxene.

320.—A mica schist with thin laminations of quartz and mica.

337.—A decomposed, dark-green rock. Contains ore particles and a green serpentine-like mineral.

338.—A gabbro.

*344.—A light-green, somewhat iron-stained rock which at first sight granular but is seen to be made up of fine fibers. The rock contains some magnetite. This specimen was collected from the road running south from Flintville and is about a half mile south of the flint mill on the north boundary of Area 4.

Under the microscope the rock appears to be a fibrous hornblende rock. Cf. (61B and 62B). The fibers are parallel, have a high index of refraction, a slight pleochroism, and an extinction of about 15°. At right angles to the cleavage there is a definite parting. The individuals are never terminated and are a pale green in plane polarized light. The mineral is probably actinolite. There are also remnants of a more compact amphibole, showing high blue and green interference colors, and full of ore inclusions. In several fragments the rhombohedral cleavage of the amphibole is seen. There are a few large magnetite crystals and a little talc.

348.—A dark-green, almost black rock. Appears to be made up of serpentine and hornblende.

349.—Decomposed rock. Pale-green with rusty spots. Contains quartz and serpentine or chlorite.

350.—Serpentinized gabbro? Consists of quartz, a green mineral, and probably feldspar.

351.—Compact and somewhat schistose rock. Contains quartz, a green mineral, ore, and perhaps feldspar. Gabbro?

352.—Similar to last. The decomposed rim shows what appears to be decomposed feldspar.

353.—Serpentine or a siliceous talc. Quite hard and consisting of a pale-green fibrous mineral. Some magnetite.

354.—A fibrous vein in a compact serpentinized rock.

378.—Compact, medium-green serpentine. Somewhat inseparable blades. This is from near the fork in the road a mile and a half north of Dublin.

379.—Similar to the last but full of ore particles which make the specimen look darker than it really is. There are many pits where the ore is weathered out.

*380.—A dark-blue rock, quite soft, showing pearly white where crushed by the hammer. The rock is made up of fibers and crystals of what appears to be pyroxene.

Under the microscope the slide shows that the rock is almost entirely made up of talc, retaining the form of fibrous hornblende. There are fragments of a mineral which is slightly pleochroic and shows the rhomboidal cleavage of amphibole. One fragment of a mineral with slight pleochroism, medium-double refraction, extinction 15° to 16°, fibrous and showing partings across the fibers. It contains numerous inclusions of ore. The color is slightly greenish and the fibers are unterminated. Actinolite. There are a few patches of a gray polarizing serpentine and there is considerable magnetite. The rock has every appearance of having been changed to talc from an actinolite-hornblende rock. It was probably originally pyroxene and the whole appearance of the slide indicates this. The rock in general appearance resembles slide 344 except that this one is altered farther and is now almost wholly talc.

381.—Decomposed yellowish-brown serpentine. Contains ore particles, many of them rusted out.

382.—Pale-green rock consisting of a fibrous hornblende probably. Somewhat decomposed and has a hardness of about 3.

383.—Dark-green to black rock consisting of quartz, feldspar, and a green mineral. Surface pitted like a weathered gabbro. This is a gabbro south of the area from northeast of Dublin.

384.—A soft, rusty, chloritic rock from a half mile north of Dublin.

*385.—Megascopically a compact, dark-green serpentine showing slickensides in the cracks. Very slightly schistose. Contains a few crystals of magnetite.

Under the microscope almost pure serpentine fibers with very little magnetite and some carbonate. The serpentine fibers are very fine.

386.—A mile and a half northwest of Dublin and north of Area 4. A chlorite schist consisting of layers of quartz and chlorite.

531.—On the north boundary of the serpentine along Deer Creek, 240 feet south of the second bridge. A compact, medium-green, typical serpentine.

546.—Gneiss. North of Scarboro.

547.—Rusty decomposed fibrous rock. Probably a serpentine or a talc rock. This specimen was taken 50 feet north of the school at the triangle in the roads north of Scarboro.

*548.—Three-fourths of a mile west of Scarboro on the road west and just west of the second lane leading north. The rock is in place all along here. It is a light-green, compact serpentine. Part of the rock seems to be in flakes or scales.

Under the microscope almost pure serpentine. The slide is pale-green in planepolarized light and shows but very little ore. Polarizes in blues and yellows. There is a very little talc.

553.—A chlorite schist. Between this area and the Ady area.

554.—A light-green serpentine from the north boundary of the area, one-fourth of a mile south of Ady. Hardness about 3. Another specimen from the same locality is very much decomposed.

555.—A very soft, rusty talc rock. Contains cavities from which magnetite has rusted out. The rock is finely fibrous.

556.—A very dark-green chloritic rock. Possibly an altered gneiss.

559.—Pegmatite.

611.—Schistose, thinly laminated rock with quartz and rusty chlorite.

612.—Similar to last with ore rusted out.

613.—Indistinctly laminated. Mica, a green mineral, and quartz; probably also feldspar. Somewhat decomposed. Gneiss?

614.—Laminated, pale-green to white talc rock. Silvery white.

616.—Gneiss. Thin bedded, mica-quartz-feldspar rock.

617.—Green pyroxene, rusty quartz, feldspar, and probably mica.

621.—Rusty-green, rather coarse-grained rock, with light spots of decomposed feldspar. Some magnetite and serpentine. Probably a gabbro with serpentined hornblende.

622.—Three hundred and eighty feet south of the second-class road leading west, south of Aad. A soft, pearly-white talc rock. Many rusty cavities.

627.—Chloritic schist with ore particles.

629.—Dirty, dark-green rock similar to 627 but not so schistose.

630.—Paler than 629, but probably the same rock.

631.—Dark-green, somewhat schistose chloritic rock, quite hard. Contains many rusty cavities.

632.—Similar to last but shows feldspar in elongated lenses.

633.—Similar but more feldspar. Gabbro?

634.—Similar with finer feldspar.

635.—Similar but less even than 634 of feldspar.

636.—Similar, schistose; parallel pyroxenes and elongated quartzes.

650.—Gneiss? Between Chrome Hill and Sharon, north of the serpentine of Area 4.

651.—Chloritic schist. Rusty cavities and a dark-green mineral. The rock is quite soft.

652.—Gabbro? Quartz, green pyroxene and feldspar.

653.—Thin laminated chloritic schist.

654.—Rusty laminated chloritic schist.

667.—Schistose chloritic rock with layers of quartz or feldspar. Shining green.

668.—Dark-green chlorite schist with magnetite crystals.

814.—Crinkled mica schist, nearly "bran" gneiss.

*815.—A mile southwest of Chrome Hill at the western end of Area 4. A light-green serpentine. Much slickensided. Shows much iron ore on slickensides which is a yellowish-green. Very much large magnetite.

Under the microscope. Almost pure serpentine fibers. A pure serpentine is unusual at this end of the area. It is possible that this is separated from the main area for there is a strip of micaceous sandy soil 400 feet wide separating this from the main boundary. Under the microscope there are some remnants of a mineral which appear dark-brown and remain so when polarized. Non-pleochroic. The magnetite in the slide is in large crystals.

834.—Laminated, wavy chloritic schist with rusty cavities.

835.—Laminated chlorite schist with magnetite.

836.—Crinkled talc schist. Rusty and silvery-white. Harder than talc schist usually is.

*45B.—Compact serpentine. One and a quarter miles west of Chrome Hill and one-third of a mile south of the contact.

Under the microscope the slide is seen to consist of pure serpentine fibers with grains of magnetite and dolomite and some talc.

*58B.—Serpentine from the Dublin Pike 2 miles northeast of Dublin. Under the microscope the slide consists of typical serpentine in rather coarse blades and fibers. Some of the serpentine appears nearly isotropic. There are patches of compact ore but no fine dust.

*61B.—From Bald Hill, east end of the area. Fibrous hornblende rock. Under the microscope rock composed entirely of interlacing individuals of finely fibrous green hornblende. Appears as though it were pyralite after pyroxenite. Very little chlorite. Cf. 74B.

*62B.—Locality same as last. Fibrous hornblende rock. Under the microscope like the preceding but more serpentinized especially in the *centers* of the hornblende crystals. The hornblende looks still more as if it were secondary after pyroxene.

*72B.—North edge of the area on the road from Macton to the Dublin Pike. Granular serpentine. Under the microscope. A felty mass of talc and fibrous serpentine.

*74B.—Fibrous hornblende rock from one mile southwest of Scarboro in the creek west of the cross road. Under the microscope exactly like 61B but fresher and coarser. Contains a few magnetite crystals.

75B.—A granite dike.

76B.—Locality same as 74B and 75B. Hornblende-epidote rock. Cf. 71B of Area 3. Exactly like specimen 71 but fresher. Dr. Williams said of this specimen that "it shows still more distinctly its gabbro origin." The epidote in the rock is probably derived from the feldspar.

309A.—From Bald Hill, northwest of Castleton. Same locality as 61B and 62B. Almost entirely composed of a felt-like mass of talc. There is some serpentine and remnants of a biaxial mineral with inclined extinction of 20° to 25° and having a cleavage at right angles to the fibers. Probably a pyroxene.

Area 5.—This is a small area to the south of Area 4 and is between this area and Area 6. It does not show on the roads to the east or the west and is probably not over a half mile in length. The width is not over a couple of hundred feet, but the boundaries are very indistinct.

Area 6. Castleton.—This area also has indistinct boundaries. The area is on the road leading north from Castleton to Flintville and extends westerly a distance of a mile and a quarter. In its widest portion it is about 600 feet broad. Specimens from the area are as follows:

342.—From the south edge of the area, in front of the house. A soapstone, greenish and with rusty cavities. The pits are due to the rusting out of magnetite crystals. Luster pearly.

343.—North edge of area. Between this and Area 4 is a micaceous soil. The specimen is a compact green chlorite rock with rusty cavities. The rock is flaky.

Area 7. Macton.—This area extends in a northeasterly-southwesterly direction through the village of Macton. It is about a mile in length and 500 feet in width. From the creek east of Macton to the store there are many serpentine boulders in the road and it is in place at the village (389). Five hundred and fifty feet north the phyllite (390) is in place. Most of the rock here found is a chloritic serpentine rock, and there is a great deal of soapstone. Just south of the store, however, the rock is quite compact serpentine and is dark-green. To the northeast the rock is easily traced back of the houses and up the hill to its ending under the chloritic gneiss. South of this, across the creek, is a chloritic gneiss of which (56B) is a specimen and slide. At the western end the rock is more difficult to trace. It is well covered by soil and is, in part, pasture land. It may be that there is a connection between this area and the soapstone knoll to the southeast (Area 9) but no rocks are exposed and it was impossible to trace the connection. The specimens are:

389.—A compact, medium-green serpentine with chlorite.

390.—Crinkled, somewhat compact, chloritized gneiss or phyllite.

1310.—A half mile east of Macton. Very compact, dark siliceous rock with some lighter spots, and containing crystals of a brown mineral which under the microscope shows rhombohedral cleavage of about 67° and shows that the brown color is apparently due to iron stain. Extinction about 40°. Cleavage good. The mineral looks like calcite but it is insoluble in boiling HCl. The interference figure is nearly uniaxial but the double refraction is not as high as calcite and no rings show.

*55B.—Chlorite epidote rock. Broad Creek below Pyle's house. Under the microscope typical chlorite epidote aggregate. Contains some carbonate and large white areas of quartz.

*56B.—South of the creek beyond the saw-mill. A chlorite gneiss. Fine-grained chlorite and mica gneiss finely banded. Small eyes of feldspar and quartz and flakes of mica and small crystals of pyrite. Under the microscope. Irregular grains and gneissic structure of chlorite, biotite, quartz, and feldspar.

Area 8.—Two small veins a half mile north of Macton at the fork in the road near W. S. Pyle's house. The strike of these two veins is more nearly east and west than any of the other rocks, and here appears an exception to the general rule that the serpentine follows closely the strike of the neighboring rocks. The rock here is soapstone and between this and Area 7 at Macton is a puckered chloritic slate. The two veins are distinct with the chloritic rock between and although the contact was not seen there is no doubt but that the two veins are entirely distinct. They can be traced but a short distance beyond the roads forming the fork. On either side the land is pasture land and deeply covered with soil so that no outcrops were visible. The rock was not seen in the stream to the east and it is possible that the dikes do not extend that far.

*52B.—Chloritic rock with octahedral magnetite at W. S. Pyle's house. Under the microscope shows typical, pleochroic chlorite in radiating tufts and aggregates. Contains magnetite. Isotropic, nearly colorless mineral with high refractive index. Possibly garnet.

*53B.—Chlorite rock, locally same as last. Under the microscope it is a typical chlorite in radiating groups. A highly polarizing mineral in large areas which Doctor Williams called muscovite. It seems more probable to me that it is talc, although no chemical tests were made.

Area 9. Soapstone Knoll.—A mile southwest of Macton and south of the road on the hilltop soapstone outcrops in great quantity. The boundaries were indeterminable on account of the covering of pasture land. The area may be a continuation of the Macton area but between the two there are no outcrops and it is impossible to say whether the two areas should be connected or not. The rock is a typical soft soapstone of a silvery-white color and somewhat stained by iron oxide.

Area 10. Mill Green.—This is a very narrow area extending for a mile and a quarter in a northeast-southwest direction and passing just to the south of Mill Green. At Mill Green the rock is a compact gneiss (439), consisting of quartz, biotite, and feldspar. The rock is banded in large masses and is very compact. To the east there is also a compact mica gneiss (540) which was taken 100 feet east of the road north from the Dublin road.

437.—A soft pearly-white soapstone. Slightly yellowish from iron oxide.

438.—A compact green serpentine. Contains magnetite in crystals.

534.—A brittle, schistose, fine-grained mica gneiss on one side of the specimen. The other side is chlorite. This specimen was taken from the contact between the serpentine and the gneiss at one of the few places in the county where the contact is visible. This specimen was taken 520 feet south of the T road one half mile southwest of Mill Green.

Area 11. Ady.—This is an area $2\frac{3}{4}$ miles in length and less than 500 feet in width at the widest portion. It extends from a point three-quarters of a mile southwest of Ady, through Ady and 2 miles to the northeast. To the north of this area the rock is mica gneiss (540). South of the east end it is phyllite (545). The rock of the east end of the area is chlorite schist and soapstone (541 to 544). At the center of the area the serpentine begins 130 feet east of the triangle in the road and continues as far as where the main road leads to Mill Green. Here there is little rock on the road besides the quartz. Just to the southeast of the small triangle is a vein of pyroxenite (550). From here the road as far as Ady is in serpentine only. At Ady it extends 210 feet south of the post office and then crosses the gneiss (553) which continues to Area 4.

The specimens from this area are:

541.—A compact white pearly soapstone with rusty cavities. Contains octahedral crystals of magnetite. The specimen is from the east end of the area.

542.—Same locality as preceding. The rock is the same as 541 and contains a vein of chlorite at the side.

543.—Same locality. Pearly-greenish soapstone unstained by iron oxide.

544.—Same locality. Pearly, greenish-white soapstone.

545.—Decomposed phyllite or gneiss. Quite compact. From the eastern end of the area.

550.—Pyroxenite from the southeast end of the small triangle in the roads at the center of the area.

a. Near schoolhouse. Altered pyroxenite, now green chlorite.

b. Same locality as last. Rusty, fine granular talc rock.

Area 12. Cherry Hill.—This area is about 2 miles long and three-quarters of a mile in width. The area is an oval whose northern limit passes through Cherry Hill. From here it extends a mile and a half east and three-quarters of a mile west. Along the road southwest from Cherry Hill are specimens (500, 501, 502). Beginning three-quarters of a mile southeast of Cherry Hill is (500) which is 310 feet before the first house. Between the two houses there is nothing but quartz in the road and the first rock in place is 200 feet beyond where (510) is in place. This continues along the road and is a chlorite-actinolite rock. Two hundred feet beyond the lane to the left is a 10-foot dike of (502) a quartz-gabbro. The serpentine is in place on either side of it. Five hundred feet southwest of the first building of Cherry Hill—the church—is a 200-foot stretch of road where there is nothing but quartz on the road. Then the serpentine comes in in place and in the woods back of the church to the creek and to Cherry Hill the only rock exposed is soapstone. North of Cherry Hill it extends only 140 feet where a yellow quartz sand comes in containing some mica. A mile and a quarter east, on the road, is (518) a rock consisting of a serpentinized mica schist containing crystals of quartz. Specimens (519 and 520) here also. There is much soapstone along the road (521, 522, and 523). Here also occurs an exceedingly great amount of opal in veins (524 to 529). There are many very large pieces of an opaque white opal showing a ropy exterior and stained with iron oxide. Some of the opal shows a greenish color and is not as opaque as the whiter kinds (524). The serpentine ends about 500 feet west of the house south of the lane. Up the creek to the east, about 600 feet north of the house in a gulch from the west, there is much serpentine (581) and to the west of this are numerous boulders of the same. Somewhere in this neighborhood chrome ore has been found in great quantity, but the possessor of the secret of its location died insane without revealing it. On the right of the creek is (582) a mica schist, in place, outcropping through the soil in immense exposures. Going north from Deer Creek to Cherry Hill there is mica schist on the road as far as 100 to 200 feet north of the house, then a rusty chloritic schist (589) to Cherry Hill. From this area the specimens are:

*501.—A light-green chloritic rock somewhat schistose. Very soft and easily crushed by the hammer. There are some dark stains between the layers.

Under the microscope the rock is seen to be made up of chlorite and actinolite. Cf. 69B. There is much magnetite in crystals, in beautiful cubes and octahedrons. There is a little quartz. The chlorite is green and pleochroic in slightly pleochroic blades with cross gashes. Extinction inclined.

502.—A 10-foot dike of quartz gabbro.

518.—Chlorite schist with quartz crystals and some serpentine.

519.—Chlorite-actinolite schist.

520.—Dark-green ripidolite.

521.—Pearly-white soapstone with fresh octahedral magnetite crystals.

522.—Skeleton quartz with limonite.

523.—Very rusty soapstone.

*524.—Serpentine with quarter-inch meshes of opal. Some rusty cavities. Under the microscope. An opalized serpentine. The opal has filled out the crystal forms of the original mineral in a similar way to the replacement by pure serpentine. The irregular fractures of some original mineral have been filled by opal and serpentine and a small amount of magnetite. From the appearance of the mineral in thin section it suggests olivine. There is in another part of the section a serpentinized mineral whose cleavage and general appearance suggests original bronzite. Talc occurs in a few places.

525.—Greenish veins of opal.

526.—Opaque white opal.

527.—Principally opal.

528.—Opal.

529.—Opal.

530.—A silvery-white mica rock like that of Deer Creek.

531.—Decomposed rock, serpentine or fibrous hornblende, full of rusty cavities. Contains much talc.

582.—Mica schist.

589.—Rusty chloritic schist.

Area 13. Chrome Hill.—This is a narrow area several hundred feet wide and extending about a mile and a half west of Chrome Hill. The general direction of this area is east and west, with rather a northwesterly direction. It differs in the direction of its strike from most of the serpentine areas but it still obeys the general rule of following the strike of the neighboring rocks. It is at this point that the general direction of the gneisses and mica schist changes from a northeasterly-southwesterly direction to a northwesterly-southeasterly one. It is possible that this area should be divided at the center forming two small areas. The rock here is very much decomposed and broken up and good exposures are rare. The serpentine-like rock was found both east and west of the center of the area but just east of Chrome Hill the rock was a crinkled mica schist. There are no exposures to the north of the road in the fields and the rock may not bend around as shown on the map.

Half a mile west of Chrome Hill on the northwest fork of the road the serpentine extends at least 540 feet along the road from the fork where it begins. It continues on the road east to Chrome Hill where it extends perhaps 60 or 70 feet north of the store at the corner. North of that is a mica schist (836) in place. Just east of the store is (641) a mica schist in place, and a quarter of a mile farther is (642) at the house, also a mica schist containing a few small garnets. Four hundred feet farther east, however, there is a schistose, compact, light-green serpentine (643). Just before the north and south road, three-quarters of a mill each of Chrome Hill occur (644, 645, and 646) actinolite talc schist, and here also was found the soapstone (647). The soapstone continues from 300 feet before the road half-way up to the house to the northeast. Then a sandy soil with large quartz boulders. The specimens are:

641.—Crinkled mica schist.

642.—Similar with a very few small garnets.

643.—Schistose, light-green serpentine, compact and hard.

644.—Actinolite schist.

645.—Same with some talc.

646.—Similar to last.

647.—White soapstone full of rusty cavities.

*46B.—An olivine-bronzite rock. Fresh. West of Chrome Hill. Under the microscope the rock shows olivine and bronzite fragments remaining. Magnetite occurs in large grains and along the fracture and cleavage cracks.

*47B.—A serpentinized bronzite rock from Chrome Hill. Under the microscope the slide shows remnants of much bronzite, now partially serpentinized. There is much magnetite in large grains and crystals.

Area 14. Coopstown-Jarrettsville.—This is an oval area located about a mile east of Jarrettsville on the road to Coopstown and is about a mile and a quarter long and three-quarters of a mile in width. It is from this area that the chrome ore, which formerly formed one of the chief industries of Harford County, was obtained. At the present time the workings are abandoned and have been for many years. The pits are full of water, the buildings are nearly in ruins, and the region is everywhere overgrown with timber and is typical of serpentine barrens.

On the road on the south side of the western boundary, half way between the long north lane and the first house to the south side of the road west of it, the serpentine is in place for about 100 feet, then to within a hundred feet of the road the road is sandy and micaceous. Here, however, the serpentine is in place. On the lane to the south the serpentine extends as far as the creek, on the other side of which the rock is mica schist. There are fragments of limonite (808) on the lane north. Soapstone (809) continues on the road for 200 feet east and here (810 and 811) were also taken. Just south of the house is serpentine (813) with crystals of pyroxene (?). On the lane northeast the serpentine continues across the creek and is in place on the west bank but on the east bank there is only fine sand and gray gneiss. No serpentine crosses the road leading south to Coopstown, the material in the road being a sandy mica schist (814). Extending west from the 551-foot bench mark the rock is sandy gneiss and this continues beyond the creek to the second house where the serpentine (821) begins. A half mile west and south beyond the creek at the house the rock is a dark serpentine (912). West of this on the creek there is no serpentine nor is there any to the south of the house although it occurs just at the house and north of it. There are no exposures in place to the east of the house but many boulders of serpentine occur halfway to the next house north of the creek at which point there are gneiss boulders in the creek which continue to the east. North of this house one-third of the distance to the road the rock is mica gneiss, the remainder of the distance to the road is serpentine. The specimens from this area are:

808.—Limonite with skeleton quartz crystals.

809.—Pearly-white soapstone with many rusty cavities.

810.—Similar to the last but with few cavities.

811.—Like 809.

*813.—A dirty-green pyroxene rock. Apparently somewhat altered to fibrous serpentine. The rock is somewhat iron-stained. Under the microscope the rock shows that it is almost entirely altered to serpentine. There are many fine inclusions of ore particles but no large crystals. The arrangement of the ore particles is in parallel lines which are in two series for each fragment, one series being at right angles to the other in some cases, but in the majority of cases is inclined. In the center of the fragments there remains a greenish-brown, slightly pleochroic remnant of the original mineral. The slide resembles 74B, a fibrous hornblende, except that in this specimen the rock is almost entirely altered to serpentine yet all the mineral fragments composing it retain their original cleavage lines, making up the entire rock. The rock was undoubtedly a hornblendite which in turn was derived from a pyroxenite.

821.—A pale-green serpentine with rusty cavities.

912.—Dark serpentine with iron-stained cavities.

1285.—A micaceous rock with veins of opal. Serpentine dark-green, somewhat fibrous and in parallel fibers. Under the microscope. Almost entirely altered to serpentine. There appear to have been two minerals in the original rock. The ore particles are arranged in some cases around subcircular centers, as formed by irregular cleavage cracks or breaks. This has the appearance of altered olivine although little of the original mineral remains. In some cases the centers of the areas are filled by iron-stained areas. In the majority of cases, however, the cleavage lines are regular and are rhomboidal, as would be the case of serpentine derived from an amphibole. The rock may have been an olivine-hornblende rock.

*1286.—Ripidolite rock. Under the microscope the rock consists of very pale-green plates. The mineral has a very good basal cleavage. It is slightly pleochroic, has parallel extinction, and polarizes with the usual dark-green color of chlorite. There are some irregular patches of ore but none fills cleavage cracks. There is very little serpentine.

*1287.—Purple and green fibers with much opaque white mineral filling in between. Under the microscope the slide shows bands of serpentine and a mineral which polarizes in a peculiar bright-blue, probably zoisite. The white layers are magnesite, soluble in hot HCl.

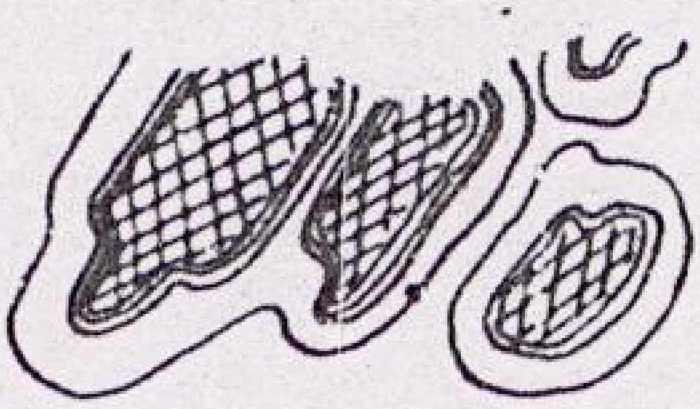


FIG. 9.—Showing central cleavage lines of serpentine surrounded by magnesite

Under the microscope they show a peculiar arrangement as shown in the figure. The central part of the areas is full of cleavage lines at 70° or 80°. Surrounding these central areas are layers of the magnesite with no cleavage, appearing as though they had been deposited around the former.

*1288.—Chromite ore. Chromite grains with a light-colored to purple and green mineral between the grains. Under the microscope the chromite grains form about three-fourths of the bulk of the slide. The section is so thick that the mineral does not show brown even on thin edges. Chemical tests show the composition to be chromite, however. The groundmass is fibrous and is almost entirely altered to serpentine. Extinction parallel.

*1289.—Fibrous serpentine, light-green and translucent. Under the microscope the greater part of the section shows complete alteration to a pale polarizing serpentine. There are fragments of a fibrous mineral which gives a biaxial interference and which polarizes a high yellow. It may have been fibrous hornblende.

Area 15. Cardiff-Cambria.—This area is about 2 miles in length and not over 500 feet in width. It extends in a southwesterly direction from Cardiff, ending just over the state line in Pennsylvania. The termination of the northeastern end is quite abrupt and the area does not thin down gradually as it does at the southwest end and as most of the other areas do. It is possibly that a fault has cut off the northern extension but there is nothing to prove its existence. Wells drilled on the extinction to the north do not strike serpentine but go through a chloritic schist.

The serpentine has been quarried just north of the railroad station for road ballast (397). At this point the rock to the south is mica slate as is also the rock to the northwest. Northwest of Cambria Station, just north of the first lane to the left, the serpentine (441) begins and it continues on the road north at least to within 210 feet before the fork in the road. At the west of the schoolhouse near the creek are the quarries where the specimens (442 to 450) were taken. These quarries are those mentioned in the preceding pages and Plate XIV. The saw-mill and quarries were apparently abandoned when visited by the author although some of the rock has since been sent from there for exhibition at the Pan-American and Charlestown expositions.

The western end of the area probably does not reach the road a mile west of Cambria although there were a few fragments lying along the road in a direct extension of the strip. The specimens are:

*397.—A very dark-green serpentine containing much transparent light-green serpentine. Specimen shows slickensides and some magnetite. The light and dark serpentine is mixed through the specimen. Under the microscope. Almost pure serpentine with a few carbonate patches. The ore occurs in dust-like particles in irregular areas. The serpentine polarizes in neutral blues and yellows in typical carnation-leaf sheaves.

399.—Phyllite.

*424.—Compact serpentine-talc rock. Under the microscope the rock is seen to consist of a mass of felty talc with a few stringers of zoisite and disseminated magnetite crystals. There is some carbonate and some serpentine.

*443.—A very compact, dark-blue serpentine. Somewhat reddish in spots due to iron stains. Under the microscope. The section is almost colorless and shows very much ore in irregular grains. The ore is entirely opaque although a few fragments show rusty edges. With crossed Nicols the entire section is almost opaque. Almost isotropic. With very high power there are a few small spots that look like zoisite appearing usually along the ore bands. It seems to be in fibers at right angles to the ore and where it seems to fill cracks it stands at right angles to the walls. The rock is almost entirely altered to opal.

444.—Very compact, dark-blue serpentine like the last and from same locality.

*445.—Light- and dark-green serpentine. Very schistose. Contains much talc almost white. Under the microscope. The section is almost entirely talc. There is a little carbonate. The ore which occurs is in crystals, grains, and as filling in cracks. These cracks are usually irregular as the fracture cracks of olivine might be. The rock may have been an olivine rock originally but there is only the disposition of the ore particles to serve as a possible guide.

*446.—A dark-blue serpentine like 443 but has a slaty look. Under the microscope the rock is very similar to 443. With crossed Nicols it is almost entirely dark. The ore particles which occur are scattered through the rock. There are many little grains with a very high index of refraction that are probably epidote.

447.—A fibrous serpentine.

448.—The same as the preceding.

Area 16. Pylesville-Clermont Mills.—This area is nearly 5 miles long but is only about 300 feet in width. It extends from a point 1 mile northwest of Pylesville in a southwesterly direction, nearly in a straight line. At a distance of 3 miles there is probably a break in the continuity.

Beginning at the east end 1 mile northwest of Pylesville on the road the serpentine is in place between the two houses as shown on the map (593). There is none north or south of this small outcrop. Through the field to the west the rock continues. East of the road some years ago there were a number of pits but they have now long since been filled up and hardly any trace of them remains. The pit farthest to the east was between the forks of the creek. There is no trace of serpentine or soapstone at this point. At the west of the road in the cellar of the house serpentine was cut through in excavation. Two miles west of Pylesville at the lanes north and south occurs a schistose, light-green talc (461). The limit to the north is at the house to the north of the road and the band is here about 210 feet wide. It does not extend to the south of the road. A mile farther southwest there is a compact, soapstone-like rock (677 and 678) in place just at the house. The strip is very narrow. A mile farther to the west (1 mile north of Clermont Mills) is a compact, light-green, typical serpentine. The specimen (476) is from the south side of the strip. This is 440 feet south of the house farthest to the south of the pair of houses. Two hundred and eighty feet south of the long lane there is a schistose-like rock (477) in place, and this is the last place here where the serpentine shows in the road although 600 feet farther south there is a decomposed rock (478) in the clay banks, but only in a very small place. One mile farther west where the creek crosses the road there is a strip of serpentine (472, 473) perhaps 50 or 75 feet in width just west of the creek. One half mile farther east and 2½ miles south of Harkins, there are many serpentine boulders (604) but none shows in place. The boulders are up to 3 and 5 feet in diameter and are about 100 to 125 feet south of the fork. North of this area there is mica schist which extends to the creek. From this area the specimens are:

414.—Greenish mica schist.

461.—Schistose, light-green talc rock.

472.—Pale-green and silvery talc schist; some actinolite?

473.—Dark-green, slickensided, very soft serpentine or talc.

476.—Typical, compact, light-green serpentine. Not schistose.

477.—Schistose serpentine-like rock.

478.—Pale-green schistose serpentine rock.

481.—Silvery soapstone with rusty cavities.

604.—Hornblende (?) crystals in a pink feldspar.

676.—Mica schist. Locality south of the following specimen.

*677.—Medium-green serpentine or talc with layers of white talc. Rock quite soft. Many rusty cavities. The white part softer than the green. Numerous talc veins running through it. Under the microscope between crossed Nicols the slide is almost opaque. The lighter particles show much like talc. The whole rock is probably a mass of interlaced talc scales. The slide is quite thick. There are numerous beautiful magnetite octahedrons.

678.—Same as last.

Area 17. Federal Hill.—This area extends southwest from Clermont Mills for a distance of about 4 miles. At the fork in the road beyond Branch Creek soapstone occurs in the road. On either side is mica schist. Northwest of Federal Hill about a mile at the lane the serpentine begins. It is about 400 feet wide in all and extends just around the bend in the road. At the house up the lane the serpentine occurs and extends to the north only and then on across the creek to the northeast. One mile farther southwest at the lane the rock is phyllite (743) and this continues up the lane as far as the bend. At this point to the sides of the lane through the fields the only rock seen is soapstone. Beyond this again mica schist. One half mile farther to the west, about 600 feet north of the bend, is serpentine and this continues for about 300 feet. On the lane west of this just at the house is a ledge of (747), a mica schist. One hundred feet farther up is (748), a schistose green hornblende rock. This only a very short distance—then mica schist on up to Deer Creek. The specimens are:

746.—A magnetite chlorite schist.

747.—Chloritic mica gneiss.

748.—A schistose, green, quartz hornblende rock.

Area 18. Little Deer Creek.—This is a narrow area about 2 miles long running parallel with the western end of area 17. The eastern end of the area is a green schist (738) and comes in at 150 feet east of the creek a quarter of a mile before the school. At the creek the strike is N. 60° E. and the dip 75° N. This rock continues nearly to the schoolhouse along the road and extends back of the schoolhouse to the creek. Beyond the school and around the bend in the road the rock is micaceous (739) and this continues around the bend and down to the southwest road, which is 310 feet before the mill is reached. Here a peridotite or gabbro (740). This continues to the creek. In front of the house is a ripidolite rock and also soapstone (741). Two hundred feet east of the creek the phyllite comes in (742). At the creek, however, the rock is soapstone (744) and 450 feet southwest serpentine (745) with pyrite. From here southwest for 460 feet the rock is all serpentine except a distance of about 100 feet in the center where no rock is exposed and the soil appears sandy. The specimens are:

738.—May be a chloritized gneiss. Mica, quartz, and a green mineral which looks like serpentine.

739.—Crinkled schist or chlorite schist.

740.—Gabbro?

741.—Ripidolite.

742.—Chloritized mica schist.

743.—Thin, laminated, pale-green schist.

744.—Pearly soapstone with rusty cavities.

745.—Compact serpentine containing pyrite (?). Dark-green with bands of lighter green. A typical serpentine.

Areas 19 to 28.—All of these areas occur in the gabbro and should be treated as part of that area. The areas are as follows:

19.—Carsins area.

20.—Hickory area.

21.—Area south of Hickory.

22.—Area south of Area 21.

23, 24.—Two areas north of Gibson.

25.—Belair area.

26.—Wimbledon area.

27.—Fallston area.

28.—Small area between 26 and 27.

Briefly the localities are these: At Carsins an area about a mile long and 400 to 500 feet wide.

South of Hickory there are three areas, the boundaries of the two to the south being impossible to determine since the area is a serpentinized phase of the gabbro and the rock grades into the gabbro. The area just at Hickory is about a mile in length and 400 or 500 feet wide.

The two areas north of Gibson appear like two small and narrow dikes which have been altered to serpentine.

East of Belair and to the south of the road to Churchville there is a peculiar fibrous hornblende rock. It shows crystals of hornblende as black spots in a lighter green groundmass.

Between Wimbledon and Fallston are three areas as mapped. The direction of these is nearly north and south following the direction of the gabbro boundary at that place.

A catalogue of specimens collected from these different areas is as follows:

Hickory area: 877, 878, 880, 881, 882, 883, 884, 885, 886, 887, 888, 952, 953, 970, 971, 972, 973, 1185, 1186, 1187, 1188.

Gibson area: 941, 942, 943, 944, 945, 946, 947, 948, 949, 950.

Belair area: 867, 868, 869, 966, 1119, 1120, 1221, 1222, 1223.

Wimbledon-Fallston areas: 850, 864, 865, 1017, 1018, 1019, 1020, 1021, 1022, 1023, 1024, 1025, 1026, 1027, 1028, 1057, 1058, 1059, 1060, 1061.

LIST OF MINERALS OCCURRING WITH THE SERPENTINES OF HARFORD COUNTY

Actinolite (Amphibole). (344), (380), 69B.[95]

Asbestos. (Area 16.)

Bronzite. (263A) (46B), (47B).

Calcite. (Area 2.)

Chlorite. (333c). Very common.

Chromite. (288). Common in Area 14.

Copper carbonate. (Area 14.)

[95] The numbers refer to the specimens described in the preceding pages. Only a few examples are given although most of these minerals occur many times.

Corundum. (A single loose crystal found in Area 12.)
Diallage. (Pyroxene.) (319), (263A).
Dolomite. (45B).
Epidote. (43B), (55B).
Feldspar. (263A). (Also occurs in large masses with quartz.)
Farnet? (52B).
Hornblende, green compact. (61B), (62B). Quite common.
Iron pyrites.
Limonite. (522).
Magnesite. (287).
Muscovite? (53B).
Olivine. (46B).
Opal. (524), (443).
Quartz. (69B). (Also occurs in large pure veins.)
Ripidolite. (286).
Serpentine.
Talc or steatite. (445). Very common.
Zoisite. (287).

GEOLOGICAL OCCURRENCE AND AGE OF THE HARFORD COUNTY SERPENTINES

As has been mentioned above, the serpentines of Harford County occur in the gneiss and the mica schists and, in general, follow the strike of these rocks very closely. They are clearly younger than the sedimentary gneisses and mica schists which are regarded by Bascom as of the Hudson River series in Cecil County and with which they occur for they cut through them.

With relation to the igneous rocks their age is not so clearly defined, at least in Harford County. Contacts with the gabbro were not found and where the serpentine touched the granite the latter rock was so much disintegrated by weathering that nothing could be seen. The most reasonable hypothesis is that the serpentine and the gabbro were practically contemporaneous in intrusion. This would seem to be indicated by the close relationship of several of the areas to the gabbro and the undoubted gabbroic origin of several of the masses. The more basic areas may have simply been differentiation facies of the gabbro magma.

SUMMARY AND CONCLUSIONS

The foregoing detailed descriptions bring out the following facts in regard to the areal distribution and mode of occurrence of the serpentine; the original rocks from which they were derived; and the processes or metamorphism through which the original rocks have passed to their present state of serpentization. These briefly stated are as follows:

In that part of the Piedmont Plateau which occurs in Hartford County there are, in the gneisses and mica schists, two series of long and narrow lenses of serpentine and other basic magnesian rocks. Considered as a unit the main body consists of one broad band of serpentine following the general strike of the gneiss, accompanied by a number of smaller, elongated masses which are more abundant on the north of the main area. The second and less prominent series is farther to the north and runs parallel to the first. Besides these there are several serpentinized areas in the gabbro which are probably entirely distinct from the others, being simply less feldspathic parts of the gabbro which have become serpentinized. There are in all 28 areas as indicated on the map and enumerated in the text.

Geologically the serpentines are intruded masses within the sedimentary series or are local facies of the gabbro. They trend approximately parallel to the strike of the older rocks and possibly follow the direction of minor folds of the sedimentary series. That the rocks were originally eruptives is shown by the study of the thin sections under the microscope. Contacts with the older rocks are rare and the whole region is so much weathered and covered with soil that the field phenomena of intrusion can seldom be observed.

The rocks from which the serpentines were originally derived apparently fall into three main divisions which, in turn, may themselves be simply modifications of a single original gabbroic magma.

The types recognized are:

I. Serpentines derived from feldspar-poor gabbros or from pyroxenites

IIa. Serpentines derived from pyroxene-amphibole-olivine rocks.

b. Serpentines derived from amphibole-olivine rocks.

III. Serpentines derived from pure olivine rocks.

The serpentines from the second class apparently represent two processes of serpentinization of the same original rock. In the first (a) the original pyroxene was changed to serpentine before it was entirely uralitized; in the second (b) and most general class, all the pyroxene was first changed to fibrous or compact amphibole and this, in turn, has been wholly, or in part, altered to serpentine. In several instances the rocks have been uralitized without serpentinization having taken place at all.

A final change is sometimes observed by which the serpentine is altered into a mass of talc and a carbonate from which much of the carbonate has apparently been removed.

Serpentine derived from feldspar-poor gabbros or pyroxenites are represented in the Glades (Area 2), Bald Hill-Scarboro-Deer Creek Area (Area 4), Macton Area (Area 7), Ady Area (Area 11), and Federal Hill Area (Area 17). In the majority of the thin sections examined from these areas there is little indication of feldspar, the slides showing an alteration to serpentine from hornblende which itself may have been, and probably was, derived from an original pyroxene. In other slides the profusion of epidote indicates an alteration from a rock containing feldspar. Besides the slides, many of the hand specimens, especially from the Bald Hill-Scarboro-Deer Creek area, show the gabbro-like character of the rock when it is but partially altered. The Little Deer Creek Area (Area 18) includes fragments of what look like gabbro or pyroxenite, and should probably be included here. All of the areas in the main gabbro mass to the south (Areas 19 to 28) show the characteristics of pyroxenites or feldspar-poor gabbros, and these areas should be included here. Area 5 and the Castleman Area are among those in the gabbro.

Serpentine derived from pyroxene-amphibole-olivine or amphibole-olivine rocks are represented by the areas at Cherry Hill (Area 12), Chrome Hill (Area 13), and Coopstown-Jarrettsville (Area 14). The thin sections of rocks from these areas indicate olivine-bronzite or olivine hornblende rocks. A single specimen from the Coopstown-Jarrettsville Area seems to have been a pure fibrous hornblende rock with no olivine but the other specimens from the same area show the presence of olivine.

Serpentines derived from original olivine rocks are shown by the specimens from the Cardiff Area (Area 15). In the thin sections from this area none of the original mineral remains, but the arrangement of the ore particles indicates an original olivine rock. It is quite probable that the serpentine of the Broad Creek Area (Area 2) is of the same origin for in a number of slides the ore dust is scattered through the rock in a way which suggests its derivation from an olivine rock.

Serpentines derived from rocks which are indeterminate, usually owing to the decomposed state of the rocks, are represented by Areal, the two small dikes north of Macton (Area 8), the soapstone knoll southwest of Macton (Area 9), that at Mill Green, and that between Pylesville and Clermont Mills (Area 16).

As far as determinable in Harford County, there is no evidence that any of the serpentines have been derived from limestones or dolomites, as held by Rand for the Fritz Island, Pennsylvania, serpentines; and by Britton for part of the serpentines of Staten Island.

Compared with the other serpentines of Maryland those of Harford County seem to have originated chiefly from pyroxenites, rather than from olivine rocks, to which they are usually ascribed in Cecil and Baltimore counties.

The changes through which the rocks have passed in the process of metamorphism to the present condition have already been indicated by the foregoing division of the serpentine into three classes.

Serpentines of the first class—that is, those which were derived from Feldspar-poor gabbro or pyroxenite—show an alteration of the pyroxene to hornblende. Williams speaks of the alteration of the pyroxene of the olivine-bearing rocks in the neighborhood of Baltimore as being first always to hornblende. In Harford County this alteration seems to have taken place as well in rocks which had no olivine as an original constituent. Subsequent to or contemporaneous with this uralitization, the hornblende was altered to serpentine but still resisting the form of the amphibole cleavage. The feldspar of the gabbro, when it occurs, is in every case entirely altered to epidote. Of this section 71B is a good example.

In the formation of serpentine from pyrozene-olivine rocks the change of the pyroxene also seem to have been first to hornblende. This is exactly the case described by Williams and is given by him as the origin of the Bare Hills serpentine. In Harford County the olivine is almost entirely altered to serpentine and the pyroxene to hornblende which in turn is, in some cases, nearly or entirely altered to serpentine. It retains in most instances the form of the amphibole cleavage as is shown by the arrangement of the ore particles. Slide 1285 is an interesting example for in this the "ore" is arranged in very minute particles along the rhomboidal cleavage of the amphibole. In serpentines derived from amphibole it is usually the case that the ore is massed in large grains or crystals.

The olivine rocks are only represented by the serpentines of Cardiff and possibly Broad Creek. Both of these are compact serpentines and are the areas in which the only workable deposits of serpentine occur. This would seem to indicate that all the massive serpentines are derived from an olivine rock.

In conclusion, all of the serpentines of Harford County whose origin could be traced—constituting the greater part of the areas described—have been derived from intrusive rocks; and that there is no indication of any of them being from sedimentary rocks. The original sources were, for the most part, pyroxenites or feldspar-poor gabbros, and were probably simply a phase of the main gabbroic invasion to the south, and were probably contemporaneous or nearly so. There are a few areas in which the serpentines were derived from peridotites; some of them from olivine-pyroxene rocks and other from what were probably pure dunites. Of the areas which were indeterminate none are of importance; all being of small size, or when long, very narrow.

It is a notable fact that the areas which are of olivine or of olivine-pyroxene origin, lie in two lines. The more important of the two is the one consisting of the Broad Creek, Cherry Hill, Chrome Hill, and Coopstown-Jarrettsville areas. Upon either side of this line are areas which were derived from pyroxene rocks. The other line includes the area at Cambria and may possibly also include the one on Little Deer Creek. Another point to be noted may be the fact that the Bald Hill-Scarboro-Deer Creek Area which seems most clearly to have had a gabbroic origin, and the Glades Area just to the north of it which may possibly be connected with it at a short distance beneath the surface, lies to the north of what appears to be a syncline pitching to the southeast, while to the south lies the great gabbro flow. If this narrow northward member is a contemporaneous part of the gabbro flow it may possibly indicate the other limb of the sheet with its inferred deep-seated connection.

PART IV

THE GABBROS AND ASSOCIATED INTRUSIVE ROCKS OF HARFORD COUNTY

BY

HERBERT INSLEY

THE GABBROS AND ASSOCIATED INTRUSIVE ROCKS OF HARFORD COUNTY

INTRODUCTORY

The area of gabbro and related basic igneous rocks which is discussed in this paper lies within the borders of Harford County, Maryland. It has a length within the County of about eighteen miles, and varies in width from 1½ to 3½ miles. In general the area has a northeast-southwest strike. To the south of this main gabbro belt there is another area of irregular outline consisting of rocks of gabbroic composition. (Plate I.) This paper deals only with the northern gabbro belt. The Susquehanna River cuts across the northern gabbro belt at the eastern boundary of the County, but beyond the river the same rocks form a belt through Cecil County (Maryland), Delaware and eastern Pennsylvania. At the southwestern end of the area, about 1½ miles from the boundary between Baltimore and Harford counties, the gabbro pinches out or disappears beneath the Baltimore gneiss, although it reappears again in Baltimore County only a few miles distant. Still farther to the south, in Virginia, North Carolina and South Carolina, gabbro areas are found, but they usually occur only as small, isolated patches.

All of the gabbros of Virginia, Maryland, Delaware and Pennsylvania are included within that portion of the Middle Atlantic Slope known as the Piedmont Plateau. The Middle Atlantic Slope is usually considered as that section of the eastern United States which sheds its waters directly into the Atlantic Ocean, and in which the principal rivers rise within the Appalachian Mountain system.[1] It is separable into three distinct zones—the Appalachian Mountains, the Piedmont Plateau and the Coastal Plain.

The Piedmont Plateau stretches to the northeast into New Jersey. Here it merges, in an indefinite way, into the New England Plateau. To

[1] McGee, W. J., Am. Jour. Sci. (III), vol. xxxv, 1888, p. 120.

the south it reaches as far as Alabama. Throughout its length the Plateau is approximately parallel to the Atlantic coast line. This region is bounded on the west by the Appalachian Mountains. In Maryland and Virginia the boundary is represented by the long, narrow crest of the Blue Ridge. To the east the rocks of the Piedmont Plateau disappear beneath the flat-lying sediments of the Coastal Plain. The rivers, which usually have a steep gradient in the Plateau, find a much flatter surface when they reach the Coastal Plain, and thus they show different types of valleys in the two areas. In the Piedmont Plateau of Maryland the master-streams often cut directly across the strike of the principal rock formations. These streams are characterized by valleys with steep slopes, often exhibiting entrenched meanders. Deer Creek in Harford County is an excellent example of such a stream. In general the master-streams are superimposed, showing no relation at all to the structure of the rocks over which they flow. The tributaries, however, are more often consequent upon the structure of the rock formations of the region.

The Piedmont province as a whole is a highly dissected plateau sloping gently to the eastward. The scenery, especially in Maryland, is characterized by rolling hills and broad, fertile valleys. Throughout the region, particularly in the areas occupied by gabbros and granitic rocks, there is a very heavy mantle of soil. This makes geological field-work especially difficult, as outcrops are scarce. Often one finds areas covering three or four square miles where the character of the underlying rock is only indicated by the nature of the soil and a few small boulders scattered on the surface. Because of this, the location of boundary lines of rock formations has often been somewhat arbitrary.

It is the purpose of the writer in this paper to give detailed descriptions of petrography and structure only where they will throw some light on the relations of the different rock masses and give some clue to the cause of the different contact phases of the gabbro that have been developed. The unravelling of these difficulties has been hindered by the lack of good rock exposures and by the complex structure that is everywhere characteristic of the Piedmont Plateau.

AREAL DISTRIBUTION OF ROCK TYPES

Geological work in Harford County has been carried on at various times within the last twenty-five years by the Department of Geology of the Johns Hopkins University and by the Maryland Geological Survey. In this way an idea of the formations in the County has been formed and a map has been published by the Maryland Geological Survey showing the general distribution of the rocks. Thus far, no very detailed work has been done except in the serpentine areas.

The Piedmont Plateau of Harford County may be roughly divided into two parts—northwestern and southeastern. The rocks of both these sections never fail to show the effects of regional matamorphism. Sometimes the pressure has been so great as to completely obliterate all traces of original characteristics. In a general way, however, most of the northwestern section is composed of rocks that were originally sedimentary, while the metamorphosed rocks of the southeastern section were principally intrusive in origin.

QUARTZITES, MARBLES AND SLATES

Most of the northwestern section is made up of mica schists and phyllites, but there are two small areas of other rocks. At the western boundary of the County there is an inlier of Baltimore gneiss, surrounded by quartzite. The quartzite is lithologically related to the Setter's quartzite, often considered to be of Lower Cambrian age, which shows extensive exposures in Baltimore County. The quartzite consists of quartz and muscovite in thin layers. Well developed slender tourmalines, sometimes stretched by movements of the rock, are characteristic of this formation.

Bordering the quartzite area on the southeast is a small area of marble and metamorphosed limestone. Marble and limestone of the same age have been named Cockeysville in Baltimore County. Phlogopite is a very prevalent constituent of this rock. What scanty evidence is available seems to indicate that this formation also is of Lower Cambrian age.

Another small area, an outlier of rocks somewhat younger than the mica schist, is found at the northern boundary of Harford County near Cardiff. This area consists of quartzite and quartzose conglomerate overlain by slates. The quartzites are metamorphosed limestones, dolomites, and limestone breccias. The Peach Bottom slates which overlie the quartzites are extensively quarried for roofing slate near Delta, Pennsylvania, just across the Maryland-Pennsylvania border. Both formations have been provisionally assigned to the Upper Silurian.

MICA SCHIST AND PHYLLITE

By far the most prevalent rock in the northwestern section is the mica schist. The chief mineral in this rock is generally sericite or muscovite, arranged with the long axis parallel to the schistosity. Quartz, feldspar, and epidote are often associated with the mica. Garnets are very abundant, although they may be considered as an accessory constituent. The effects of powerful and long-continued regional metamorphism are well shown by the intricate crinkling and folding of the laminations of the schists. There seems to be no doubt that these schists were originally argillaceous sediments, now greatly altered both in appearance and mineral content by regional metamorphism. The age of the mica schist is still undecided. If the formations which underlie it, the Setter's quartzite and Cockeysville marble, are Cambrian, and the overlying formations, the Cardiff quartzites and Peach Bottom slates, are of Upper Silurian age, then the mica schist lies somewhere between the two. The evidence bearing on the age of any of these metamorphosed formations is at best fragmentary and inconclusive. If this schist is to be correlated with the Wissahickon of Pennsylvania, to which some of the evidence points, then the age may be pre-Cambrian.[1] The strike of this formation is quite uniformly east of north. The dip of the stratification, when shown, is to the southeast, and varies from 30° to 80°.

[1] Bliss, E. F. and A. I. Jonas, U. S. Geol. Survey Prof. Paper 98B, 1916.

SERPENTINE

Within the mica schist area as well as in the main gabbro belt, dikes and small stocks of intrusive material, now wholly altered to serpentine, are common. There is no doubt that the serpentines were originally intrusive peridotites and pyroxenites, now thoroughly altered by regional metamorphism. A short description of the serpentine will be given in the chapter on petrography.

BALTIMORE GNEISS

South of the main gabbro belt there are four long, rather narrow belts of rock of gneissic character. These rocks are considered to be the oldest (pre-Cambrian) of any in the whole Piedmont Plateau of Maryland, and are grouped together under the name of Baltimore gneiss. Long-continued regional metamorphism has so acted upon them that their original character has often been entirely obliterated. All the evidence available seems to show that they consist of an igneous complex with inclusions and intercalations of sedimentary rocks.[3] These gneisses vary in composition from a very acidic biotite granite to a very hornblendic diorite. Rocks of the same character are found in Baltimore County to the southwest and in the region about Philadelphia to the northeast.[4] The gneissic structure shows a northeast strike, parallel in general to the trend of the formations of the Piedmont Plateau. Its general dip where determinations can be made is to the southeast.

GRANITE

Granites are also found occupying large areas in this region. In composition they vary from typical biotite granites to granites carrying considerable amounts of hornblende. In places they exhibit a decidedly gneissic phase, while elsewhere the mineral grains are unoriented and the granite appears as the ordinary massive phase. Although orogenic movements have undoubtedly affected these granites, they nowhere show the tremondous effects of pressure exhibited by the Baltimore

[3] Williams, G. H., 15th Ann. Rept. U. S. Geol. Survey, 1894, p. 665.
[4] Bascom, F., U. S. Geol. Survey Phila. folio (No. 162), 1909.

gneiss and the mica schist. Keyes[5] and Williams,[6] who studied the granites of apparently the same age in Baltimore County, consider them to be much younger than the Baltimore gneiss and even younger than the gabbro. Granite is found principally in the region south of the main gabbro belt, althought there is a narrow strip of it extending for some distance along the northern border of the gabbro. Like the other formations of the Piedmont region, the granites show a northeast-southwest trend.

GABBRO

Two extensive areas composed of rocks of gabbroic composition are found in Harford County. To the southeast there is a large area with an irregular outline but showing to some extent the same northeast-southwest trend revealed by the other formations of the Piedmont Plateau. Remnants of sediments of Mesozoic and Cenozoic age belonging to the Coastal Plain formations are found overlying the gabbro in this area. The other gabbro area has been referred to in preceding pages. It is a long, narrow belt showing to a marked degree the same northeast-southwest trend. Belair, the county seat of Harford County, lies within the boundaries of this belt. In both areas the gabbro is of two types—(1) the original hypersthene gabbro, and (2) meta-gabbro containing secondary hornblende and other alteration products. As will be shown in a later chapter the meta-gabbro has undoubtedly been derived from the hypersthene gabbro. Both types, with their intermediate forms, will be described in detail in the chapter on petrography. Here as elsewhere in the Piedmont Plateau orogenic movements have profoundly altered the rock but nowhere does the gabbro show the marked degree of alteration exhibited in the Baltimore gneisses. At present there is no decisive evidence as to the form of this intrusive magma, whether a batholith, a laccolith, or a sill. Its long, narrow form, and the shape of the intrusive bodies which border it on the north, would suggest that this body is a sill. The fact that the structures of the

[5] Keyes, C. R., 15 Ann. Rept. U. S. Geol. Survey, 1894, pp. 685–740.
[6] Williams, G. H., Idem, pp. 657–684.

adjoining formations have in general a northeast strike and a dip to the southeast would also suggest that this magma had been intruded along a plane of weakness, and that it also probably dips now in a southeast direction. Certain surface indications are characteristic of these gabbro areas. Polygonal blocks with a coating of rusty-red, clay-like substance strew the ground in these areas. Often the interior of these blocks is found to be remarkably fresh, with little or no weathering effects. The soil, too, is often characterized by a deep red color, although sometimes, on account of variation in composition of the gabbro, the soil has a light buff color.

CONTACT ROCK

At or near the contact of the gabbro with the Baltimore gneiss there are outcrops of limited extent, of contact rocks varying in composition and texture. These will be considered in detail in the chapters dealing with petrography and contact phases.

DIKES AND VEINS

In Cecil County, just to the east of Harford County, a number of diabase dikes have been mapped. Thus far only four have been discovered in Harford County, all of these lying within the main gabbro belt, with the possible exception of one, which may extend across the contact into the granite. These dikes, as well as those of Cecil County, have a general northeast-southwest strike, thus parallelling the trend of the other formations of the region.

Pegmatites of the usual coarse-grained variety, consisting of quartz, feldspar (orthoclase and albite), mica (biotite and muscovite), and some accessory minerals, are found in a few places in Harford County, particularly along the Susquehanna River. One large pegmatite dike has been intruded into the gabbro and is very well exposed in the cliff at the edge of the Susquehanna River about a mile north of Castleton. The relation of the pegmatites to the gabbro will be discussed in another place. Although pegmatites may be present in many places in the gabbro area, they are concealed by the heavy mantle of soil. Apparently pegmatite dikes are fewer in number in Harford County than in Cecil County, where at least thirteen dikes have been mapped.

Quartz veins are numerous throughout the whole Piedmont region in Harford County. Usually their presence is indicated only by the abundance of quartz boulders which strew the surface of the ground in the vicinity of the veins. These boulders are composed almost wholly of white sugary quartz. The veins were undoubtedly formed by deposition from circulating waters in cracks or fissures caused by orogenic movements.

PETROGRAPHY

A petrographical description will be given of only those rocks intimately related to the gabbro in composition or closely associated with it in areal distribution.

HYPERSTHENE GABBRO

Hypersthene gabbro is the prevalent and typical rock of the main gabbro belt. A peculiar feature of this area is the absence of true norites, which are typical of the gabbro areas of Cecil County,[7] Delaware,[8] and eastern Pennsylvania.[9] On the other hand, true gabbros are also absent, hypersthene always being present in such quantities that it must be considered as an essential constituent. Hypersthene gabbro merges almost imperceptibly into meta-gabbro. Small quantities of hornblende are present in practically every specimen, so that a real distinction cannot be made in this region between hypersthene gabbro and meta-gabbro.

The presence of gabbro in a region is usually indicated by the large quantity of polygonal blocks with a rusty-red weathering surface strewn about on the ground. The soil as well often has a characteristic red color. The fresh specimens of hypersthene gabbro vary greatly both in color and size of grain. The grain of the rock often changes abruptly

[7] Bascom, F., Maryland Geol. Survey, Cecil County, 1902, p. 125.
[8] Chester, F. D., U. S. Geol. Survey, Bull. 59, 1890, p. 22.
[9] Bascom, F., Philadelphia folio, 1909.

from coarse to fine. Individual mineral particles, however, rarely reach a length of more than a centimeter. Color may vary from light gray to very dark gray. A purplish tinge is very characteristic of unaltered hypersthene gabbro. The variation in color is due to the relative amounts of the mineral constituents present in the specimen. Although gneissic structure is often prominent in formations adjacent to the gabro and in some of the contact facies of the gabbro, it is the exception rather than the rule within the main gabbro body. Feldspar, diallage, and hypersthene can be identified in hand specimens of hypersthene gabbro without the aid of a microscope.

Under the microscope the rock is seen to be holocrystalline, the individual mineral constituents showing allotriomorphic to hypidiomorphic forms. The essential primary mineral constituents of the hypersthene gabbro are basic plagioclase, hypersthene, and diallage. The relative amounts of these constituents vary considerably. Often a thin section shows a composition of 80 per cent plagioclase. At other times the specimen is composed almost wholly of hypersthene and diallage. At such times the rock is really pyroxenite and not hypersthene gabbro.

The accessory primary constituents of the hypersthene gabbro are magnetite, apatite, quartz, and pyrite. Except in the contact phases, quartz is never abundant enough to be considered an essential constituent. The accessory minerals often occur as minute inclusions within the other minerals. Apatite, especially, is usually found included within the plagioclase crystals.

The plagioclase commonly has an allotriomorphic form. Maximum extinction angles measured on sections at right angles to (010) give values of 40° to 45°, corresponding to compositions of Ab_3An_7 to Ab_2An_3. The plagioclase is therefore an acid bytownite. Polysynthetic twinning lamellae formed after the albite law are very common in all fresh individuals. At times combinations of twinning after both pericline and albite laws are seen. Inclusions in the feldspar are very common. Often these are dust-like particles, which are present at or near the center of the crystal. The particles are so minute that optical determination is not possible. Apatite inclusions are abundant.

Hypersthene is allotriomorphic as a rule, although hypidiomorphic individuals have been observed in specimens that seem to show a slightly different type of crystallization from that usually found in the hypersthene gabbro. The parallel extinction and strong pleochroism, greenish to reddish brown, distinguish hypersthene from diallage, with which it is constantly associated. Well-developed cleavage planes parallel to (110), (100), and (010) are characteristic of the mineral. Inclusions of magnetite and hair-like needles arranged along cleavage lines are common. Williams[10] concluded that the peculiar metallic reflection seen in many thin sections was due to inclusions of plates of a reddish-brown color lying parallel to the brachypinacoid. These plates were regarded as brookite by Kosmann.

Diallage usually occurs in allotriomorphic, irregular grains, rarely hypidiomorphic. It shows a faint, light green color under the microscope, without any apparent pleochroism. Diallage may be recognized by the prismatic cleavage and well-developed parting parallel to the orthopinacoid. A secondary parting parallel to the clinopinacoid is sometimes present. Maximum extinction angles in sections parallel to the clinopinacoid have a value of 39°. Inclusions are not common in diallage.

Magnetite and apatite are the most common accessory constituents. Although they are often abundant they rarely occur except as minute particles. Apatite is frequently an inclusion in plagioclase, where it can be observed in sharply defined, idiomorphic crystals. Quartz and pyrite sometimes occur as primary accessory constituents, although quartz is frequently found in veinlets running through the rock. Garnet has been observed only in one or two sections of hypersthene gabbro. It is sometimes quite abundant, however, in contact phases. Olivine has never been noted in specimens of hypersthene gabbro from Harford County, although it has been described in a few instances from both Cecil and Baltimore counties.

[10] Williams, G. H., U. S. Geol. Survey Bull. 28, 1886, p. 24.

Meta-gabbro

The term meta-gabbro is used here to indicate those rocks derived from hypersthene gabbro by processes of meta-morphism alone. Exposures of meta-gabbro are found distributed within the gabbro area in a most irregular manner. Although meta-gabbro may very well have some relation to zones of greater pressure in the region, the localities containing this rock seem to have no regular arrangement. The transition from true hypersthene gabbro to meta-gabbro is not marked. Almost every specimen of hypersthene gabbro shows the presence of at least a small amount of secondary hornblende. Megascopically the change is not noticeable unless hornblende becomes prominent, when the rock takes on a green color and fibrous hornblende can be seen without the use of the microscope. A milky appearance of the feldspar also indicates that a metamorphic change has taken place.

Under the microscope this change can be observed in all stages. Generally pyroxene is the first mineral to undergo alteration. The method of alteration of hypersthene differs slightly from that of diallage. The work of Williams[11] has shown that hypersthene requires the presence of plagioclase to effect its alteration to green hornblende, the lime and alumina of the plagioclase being necessary for this transformation. The formation of a double rim around hypersthene individuals has often been observed. The inner rim is composed of colorless, fine needles arranged at right angles to the edge of the hypersthene crystal, while the outer one is green with all the characteristics of fibrous or compact green hornblende. An analogous colorless rim around olivine bas been called tremolite by Tornebohm.[12] Finckh[13] noted the same double alteration rim around pyroxene in the gabbro of northern Syria. He also called the inner rim tremolite. All the optical properties of these inner colorless rims as observed in the thin sections seem to agree with those of tremolite. Alteration may continue until the hypersthene has entirely disappeared, its place being taken by fibrous or compact hornblende, sometimes with a core of colorless tremolite needles.

[11] Williams, G. H., loc. cit., p. 42.

[12] Törnebohm, A. E., Beues Jahrb., 1877, p. 384.

[13] Finckh, L., Zeits. deutsch. geol. Gesell., Bd. L, 1898, p. 97.

The change of diallage to hornblende may be, and usually is, a direct one without the intervention of material from other minerals. As in hypersthene the change begins around the edges of the diallage crystal. The transformation then proceeds along cleavage cracks or other paths of least resistance. It is not unusual to find diallage crystals in a specimen entirely transformed to hornblende, with no trace of the original mineral remaining. Williams[14] concluded that in the case of diallage the change might not only be one of uralitization with chemical change, but also one of true paramorphism. He and others also found that the alteration product was sometimes brown hornblende. Brown hornblende has not been observed in specimens of Harford County gabbros. Rose[15] noticed that when augite changed to fibrous hornblende, magnetite and calcite often formed between the needles.

The secondary hornblende is easily recognized under the microscope by its striking pleochroism in greens and blues, and its cleavage angle of about 55° on the basal section in compact varieties. The arrangement of aggregates and the peculiar fraying out of fibers from the compact hornblende are characteristic of the fibrous variety.

The alteration of pyroxene to hornblende is a very common one in basic igneous rocks. Almost every occurrence of gabbro in regions where dynamic metamorphism has been active shows this change. Such an alteration was first noted by Gustav Rose in 1830. It was Williams who was first able to discover the true nature of this change by his detailed study of the gabbros in the vicinity of Baltimore (loc. cit.) the norites of the Cortlandt series,[16] and the greenstones of the Menominee and Marquette districts[17] (58). Since that work, this change has been observed by Finckh, Bonney, Miller,[18] Teall,[19] Loughlin, Hecker, and many others.

[14] Williams, G. H., Am. Jour. Sci., (III), vol. xxviii, 1884, p. 261.

[15] Rose, G., Zeits. deutsch. geol. Gesell. Bd. XVI, 1864, p. 6.

[16] Williams, G. H., Am. Jour. Sci. (III), vols. xxxi, 1886; xxxiii, 1887; xxxv, 1888; xxxvi, 1888.

[17] Williams, G. H., U. S. Geol. Survey, Bull. 62, 1890.

[18] Miller, W. J., Jour. Geol., vol. xxi, 1913, p. 168.

[19] Teall, J. J. H., Geol. Mag. dec. III, vol. i, 1886, p. 484.

It is generally thought that the transformation of pyroxene to hornblende is the direct result of dynamic action. In some instances, however, the change has probably been brought about by some kind of metasomatic replacement, although here too dynamic action undoubtedly prepared the way for the activity of the solutions.

Another important result of metamorphic action is the alteration of the basic plagioclase. This usually begins a little later than the change pyroxene to hornblende. The first change in the feldspar is often to a number of crystallites of epidote and zoisite. These form at about the same time. Usually the first formation of the secondary minerals is at or near the center of the plagioclase crystal. Sometimes, however, the epidote appears at the boundary of the plagioclase, apparently as a reaction product of the plagioclase and pyroxene. Epidote and zoisite, as a rule, have well-developed crystal faces. Both can be readily recognized by their relatively high indices of refraction, while zoisite is distinguished from epidote by its much lower double refraction, usually showing a peculiar blue interference color in sections of the ordinary thickness (.03 mm.). The chemical compositions of epidote and zoisite seem to indicate that they are formed as a result of both dynamic action and processes of weathering. Further alteration of the plagioclase results in the combination of minerals called saussurite. Microscopic examination of the Harford County gabbros shows saussurite to be composed of zoisite, epidote, and secondary albite. Cathrein[20] was the first to show that saussurite is usually composed of these three minerals with some accessory actinolite and tremolite. The secondary albite often occurs as large, clear, irregular grains without twinning, in which zoisite and epidote are included. In color, translucency, and occurrence, the albite resembles quartz very closely.

When the gabbro approaches a pyroxenite in composition, as it sometimes does, the product of metamorphism is a rock composed almost wholly of hornblende with some accessory epidote or zoisite. Megascopically this has something of the appearance of meta-gabbro, except that the green color is more pronounced, due to the greater development

[20] Cathrein, A., Zeits. Kryst. Min., Bd. vii, 1883, p. 56.

of fibrous green hornblende, and the white or colorless particles of feldspar are absent.

Veinlets of quartz and sometimes of albite traverse specimens of hypersthene gabbro and meta-gabbro. The veinlets show aggregates arranged in a mosaic fabric, indicating some crushing effects after crystallization has been completed. These depositions are only indirectly the results of dynamic effects, the pressure opening the cracks and thus allowing solutions to deposit these minerals in the veins.

In many places weathering has produced secondary minerals very different from those caused by the action of dynamic metamorphism. Chlorite is one of the most common of these products of weathering. It is quite usual to find small quantities of chlorite in both hypersthene gabbro and meta-gabbro, although it is most often found accompanying the secondary hornblende in the meta-gabbro. Chlorite is recognized by its occurrence as elongated plates or fibers in radiating or irregular aggregates. It is usually colorless, although green chlorite showing considerable pleochroism is sometimes seen. Between crossed nicols chlorite shows a distinctive, faint gray interference color of the first order. The combination of dynamic metamorphism and weathering may result in the formation of a chlorite-epidote rock in which sharply defined, colorless or pale-yellow crystals of epidote are surrounded by scaly or platy aggregates of chlorite. Such aggregates have been noted in other localities.[21] Pyrite is often found in small quantities in these altered gabbros as a product of weathering.

In the extension of the gabbro region in Baltimore County, Cecil County, Delaware and Pennsylvania, the products of dynamic metamorphism and weathering are found to be quite similar to those of Harford County. Williams was the first to describe the gabbros in the vicinity of Baltimore and to note the alteration to "gabbro-diorite." Later the basic rocks of Cecil County were described by Leonard[22] and Bascom[23] (1). "Gabbro-diorite" from Delaware has been de-

[21] Williams, G. H., U. S. Geol. Survey Bull. 62, 1890, p. 56.
[22] Leonard, A. G., Am. Geol., vol. xxviii, 1901, pp. 135–176.
[23] Bascom, F., Maryland Geol. Survey Cecil County, 1902, pp. 83–148.

scribed by Chester[24] (10), and a rock of the same character from the Philadelphia district has been described by Bascom.[25] In these localities chlorite has been found in the gabbros and in its alteration products.

SERPENTINE

North of the gabbro area as well as within the area itself there are a large number of serpentine bodies varying greatly in dimensions and shape. The largest body in part adjoins the gabbro area. It is thirteen miles long and about a mile wide. Other bodies vary in dimensions down to those only a few hundred feet in length. A detailed and careful study of the serpentine areas in Harford County has been made by Johannsen.[26] He concludes that most of the peridotites and pyroxenites from which the serpentine has been derived were intrusive into the other rocks of the region. The relations of the serpentine within and adjoining the gabbro area bear out this conclusion, for only in a few cases have transitions been found within the gabbro area between the pyroxenite and the hypersthene gabbro. Contacts are rarely exposed, but wherever found they are quite sharp.

Of the appearance of the mineral and the rock, Johannsen says:—"Megascopically it is a compact dirty-green to black mineral with a splintery fracture and a greasy or pearly to waxy lustre. The color of the rock depends upon the amount of pure serpentine present, and upon the amount of magnetite and chromite; the pure serpentine being of an oily-green color, but, with much finely divided magnetite, approaching a black. Chlorite gives it a dirty-green color. . . . . The mineral is often megascopically of a fibrous structure; sometimes it is laminated and is often interlaced with talc or chlorite. . . . . Serpentine often forms entire rock masses and is generally quite compact and massive, although at times it is schistose and thinly laminated. The color varies from green to yellow or brownish red and often shows clouds and streaks on account of the magnetite occurring in it. . . . . The rock

[24] Chester, F. D., U. S. Geol. Survey Bull. 59, 1890.

[25] Bascom, F., Philadelphia folio, 1909.

[26] Johannsen, A., This volume, part iii.

is composed primarily of the mineral serpentine but it generally also contains fragments of the mineral from which this was derived, such as olivine, bronzite, diallage, diopside and hornblende. Chlorite is often present in large quantities and gives the rock a dirty-green color."

Under the microscope, serpentine appears to be made up of fine fibers, thin prisms, or thin laminated plates. The index of refraction is low, the double refraction fairly low (about 0.013), and the extinction is parallel to the fibers. It may easily be confused with chlorite, especially when in fibers or plates. Serpentine is frequently associated with fibrous green hornblende and talc. Masses of hornblende in many instances are mingled with the serpentine in the same thin section. The hornblende is undoubtedly an alteration product of pyroxene. Talc is considered by some to be a weathering product of hornblende,[27] while by others it is considered as an alteration product of both serpentine and hornblende.[28]

Johannsen considers the serpentine of Harford County to be derived from four sources:—(1) feldspar-poor gabbros or pyroxenites, (2) pyroxene-amphibole-olivine rocks, (3) amphibole-olivine rocks, (4) pure olivine rocks. Serpentine cannot be considered as an alteration by paramorphism because of the difference in chemical composition between it and the rocks from which it has been derived. It is rather the result of some form of replacement by the action of solutions. It should, perhaps, be considered more the result of weathering processes than the result of dynamic metamorphism, although undoubtedly dynamic forces have crushed and shattered the original rock and thus made the alteration easy.

Cases oi alteration of feldspar-poor gabbros to serpentine have not been observed by the writer, alteration usually resulting in a mixture of fibrous hornblende, chlorite, and epidote.

The presence of olivine within the gabbro area has not been observed, although traces of it have been found by Johannsen in several places within the serpentine areas. This fact is of some significance in deter-

[27] Williams, G. H., U. S. Geol. Survey Bull. 28, 1886, p. 58.
[28] Bascom, F., Maryland Geol. Survey, Cecil County, 1902, p. 134.

mining the age relations of the two bodies, and will be considered in another chapter.

Baltimore Gneiss

The Baltimore gneiss, already mentioned in the description of rock types of the county, adjoins the gabbro area for some distance to the south. It varies greatly in composition, in places being composed almost wholly of hornblende, or hornblende and mica, while elsewhere it is composed chiefly of quartz and feldspar. The gneiss often found near the gabbro contact is a very hornblendic phase containing feldspathic lenses or bands. The gneissic structure is usually quite apparent, although sometimes this rock is so extremely hornblendic that the structure is obscured. A number of thin sections were made from specimens of hornblende gneiss taken near the southwestern end of the gabbro area. The specimens vary in color from a dark gray to almost black, depending upon the relative quantity of hornblende present. Bands of feldspar and quartz are very numerous in some specimens, while in others they are almost entirely lacking. Hornblende, quartz and feldspar can be seen with the naked eye.

Under the microscope the hornblende gneiss is seen to be composed of compact green hornblende, acid plagioclase, and quartz. Accessory constituents are orthoclase, biotite and pyrite. The hornblende is always green and usually well crystallized with marked cleavages. The crystals are commonly arranged with their long axes parallel to the gneissic structure in the rock, and sometimes they have been bent and broken as the result of dynamic action. The feldspar is mostly acid plagioclase. Measurement of extinction angles shows it to have a composition of about $Ab_{85}An_{15}$, an acid oligoclase. Clear, glassy, untwinned feldspars are frequent. There is undoubtedly some orthoclase present. Quartz also is very abundant. Both quartz and feldspar are commonly arranged in mosaic patterns due to crushing of the rock. Pyrite, although an abundant accessory constituent, occurs only in fine particles. The plagioclase is often found undergoing alteration to epidote. At times the epidote crystals become fairly large, although minute crystallites are more common. Chlorite sometimes occurs as a decomposition product of the hornblende.

GRANITE

Granite occurs in long, narrow belts with a northeast-southwest trend in areas north and south of the main gabbro belt. (Plate I.) Four isolated areas are found along the Susquehanna near Lapidum and Havre de Grace.

As a rule the granite is a light-gray to white rock, although in places segregations of biotite may give it a much darker color. The color is decidedly lighter than that of the average Baltimore gneiss. At times the granite develops a definite gneissic structure. This structure, however, is probably due to the formation of secondary muscovite in plates perpendicular to the direction of application of the dynamic forces. Nowhere is this gneissic structure as pronounced as in the Baltimore gneiss. At other times the granite presents a very massive appearance, no gneissic structure being visible. Megascopically, feldspar, quartz, biotite and muscovite are easily distinguished. Under the microscope the feldspar is found to be principally an acid plagioclase, which extinction angles show to be of the albite-oligoclase series. A subordinate amount of orthoclase is also present. The mica is usually considerably smaller in quantity than the feldspar. Biotite occurs in irregular plates. Most of the muscovite is probably secondary, although a small amount is undoubtedly primary. Hornblende is sometimes found in small quantities, but never sufficient to be considered anything more than an accessory constituent.

DIABASE

Although a number of diabase dikes of considerable extent have been found intruding both the gabbro and the granite in Cecil County, thus far only four short diabase dikes have been mapped in Harford County, all of them within the main gabbro belt. These dikes differ from those in Cecil County in the amount of metamorphism to which they have been subjected. Where outcrops are not available the diabase dike usually reveals its presence by the number of cubical boulders scattered about the surface. These boulders almost invariably possess a coating of rusty yellowish-red material caused by weathering. Where exposures show the contact between gabbro and diabase it is found to be clear and distinct. There is no transition zone between the two types of rock, and no contact metamorphism. When a fresh specimen of diabase can be obtained it shows a greenish-black color with very fine grain. Usually the individual mineral grains cannot be distinguished without the aid of the microscope. Under the microscope it is at once apparent that the rock has been subjected to considerable metamorphism, although the ophitic texture is still plainly visible. The occurrence of the plagioclase indicates that it was the first mineral to crystallize. Plagioclase crystals have lath-like forms with idiomorphic shapes. The other chief constituent of the rock is a green, usually compact hornblende which acts as a matrix for the plagioclase. In a few cases remnants of pyroxene are found enclosed in the hornblende. The relation of the pyroxene to the hornblende shows that the latter mineral is a secondary alteration product of the former. The hornblende often contains minute crystallites of a clear, colorless mineral arranged parallel to the cleavage lines. Because of their small size it is impossible to determine accurately the optical properties of these bodies, although they correspond quite closely to those of quartz. In the majority of cases the plagioclase crystals have been altered to an aggregate of epidote and zoisite. These aggregates are so arranged that the ophitic texture has still been preseverd. Determination of the extinction angles of the unaltered plagioclase gives values corresponding to a composition of about $Ab_{25}An_{75}$. The plagioclase thus belongs to the labradorite-bytownite series. Magnetite is frequently present in small isolated grains. The presence of a small amount of chlorite in a few of the sections indicates some weathering of the hornblende.

The diabase dikes of Cecil County are very similar in occurrence to those of Harford County. In Cecil County, however, these dikes have been subjected to much less metamorphism than those of Harford

County. Leonard[29] states that the diabase of Cecil County is composed of lath-shaped crystals of feldspar, irregular grains of augite, and a little magnetite; and Bascom[30] says that the constituents are "remarkably fresh," although she notes some alteration of pyroxene to green hornblend and chlorite. Instances of the alteration of the usual constituents of diabase to hornblende, chlorite and epidote are very common in the literature. Williams[31] has carefully described diabasic rocks from the Menominee and Marquette districts of Michigan with well-developed ophitic texture in which the augite has been altered to fibrous or compact green hornblende and the feldspar to epidote or saussurite. Finckh[32] has noted a diabase with ophitic texture intrusive into the gabbro of northern Syria, in which pyroxene has been uralitized and feldspar altered to epidote. Similar alterations of ophitic diabase have been described by Loughlin,[33] Palache,[34] and many others.

CONTACT PHASES

Along or near the southern border of the main gabbro belt there are several small districts in which rock types are found with compositions and textures quite different from the principal rock types of the region. The rocks of these districts will be considered in detail.

One of these districts lies about half a mile to the east of Berkley near the west bank of the Susquehanna. It has an east-west trend, and is not more than an eighth of a mile in width nor more than a half-mile in length. The predominant rock of this area is a quartz epi-diorite, that is, a rock having the mineralogical composition of a quartz diorite, but in which some of the essential constituents are secondary alteration products. The transition between this rock and the hypersthene gabbro to the north is concealed under the cover of soil. Outcrops are few and far between. Megascopically the rock is holocrystalline,

[29] Leonard, A. G., Sm. Geol., vol. xxviii, 1901, p. 155.
[30] Bascom, F., Mary and Geol. Survey Cecil County, 1886, p. 141.
[31] Williams, G. H., U. S. Geol. Survey Bull. 62, 1890, pp. 138–146, 168–175.
[32] Finckh, L., Zeits. deutsch. geol. Gesell., Bd. L, 1898, p. 143.
[33] Loughlin, G. F., U. S. Geol. Survey Bull. 492, 1912, p. 102.
[34] Palache, C., Univ. Cal. Dept. Geol. Bull., vol. I, 1896, p. 174.

medium to fine-grained, with a greenish-gray color. In the hand specimen clear, glassy, bluish quartzes, feldspar (both clear and milky), hornblende, biotite, and a small amount of pyrite can be seen. Under the microscope the rock is seen to be composed chiefly of quartz, basic plagioclase, saussurite, chlorite, hornblende and pyrite. The feldspar is in part basic plagioclase, usually showing zonal development. Measurement of extinction angles shows the interior to have a composition of labradorite-bytownite, while the outer zone has a composition of andesine-labradorite. Usually the feldspar has been more or less completely altered to a mixture of epidote and secondary untwinned albite. The large quartz grains are either single individuals or they have been crushed into mosaic aggregates. Undulatory extinction is very common, both in the large grains and in the particles making up the mosaics. Green hornblende is another of the principal constituents, sometimes making up half of the rock. Although no pyroxene can be detected in the section the hornblende has all the characteristics of a secondary mineral. The fibrous variety is very prominent. Chlorite also occurs in considerable quantities, evidently produced as a decomposition product of the hornblende. Biotite is present only in isolated particles.

South of this district meta-gabbro, consisting mostly of amphibole and chlorite, makes its appearance. This is succeeded by the ordinary meta-gabbro, and just to the south of this is found a rock which apparently marks a transition zone between ordinary hypersthene gabbro and quartz epi-diorite like that half a mile to the north. Megascopically this is a greenish-gray rock of varying grain in which can be seen glassy quartz grains (as large as ¼ inch in diameter), greenish-black amphibole, and milky feldspar. The microscope shows the rock to be composed of saussurite, augite or diallage, quartz, chlorite, hornblende, phlogopite, zircon, and garnet. The saussurite is made up of large secondary albite crystals, usually without twinning, which act as a matrix for great numbers of crystallites of epidote and zoisite. Diallage is present in various stages of alteration to hornblende and chlorite. Chlorite, particularly, is very abundant in this rock. Quartz is either in large grains, often crushed, or in veinlets with mosaic fabric. Phlogopite is fairly abundant. It is recognized by its occurrence in irregular plates with low index of refraction, fairly high double refraction, very small optic angle (practically 0°), and negative optical character. Small crystals of zircon, characterized by good crystal form, very high index of refraction, high double refraction, and positive uniaxial character, are frequently found. Garnet is also a common accessory constituent of the rock. The presence of phlogopite and garnet indicates the influence of a kind of contact action between the typical hypersthene gabbro and this more acid phase.

Because of soil covering there is no continuous outcrop, and therefore the gradations between the transition rock and the quartz epi-diorite itself cannot be observed. About a quarter of a mile south of the transition phase there is an exposure showing material very similar in character to that of the quartz epi-diorite in the area east of Berkley. Megascopically this rock is grayish-green with phenocrysts of clear, glassy quartz grains as large as a quarter of an inch in diameter. The groundmass is green with a decidedly laminated appearance. Under the microscope the rock is seen to be composed of quartz, saussurite, chlorite, hornblende, biotite, pyroxene, and pyrite. Quartz usually occurs as a mosaic aggregate, although single large grains are sometimes seen. Saussurite here consists of epidote and secondary albite, the albite acting as matrix for the epidote. Chlorite is present in fairly large quantities, evidently the result of the weathering of secondary hornblende. Green hornblende, usually fibrous, is quite common in this rock The thin section sometimes shows a remnant of diallage surrounded by this fibrous hornblende, although in most instances the pyroxene has entirely disappeared. The area itself is wedge-shaped and half a mile wide at its broadest part. The contact with the Baltimore gneiss to the south is not exposed, but it seems very probable that this phase continues to the contact with the Baltimore gneiss without a recurrence of the typical hypersthene gabbro.

Another type of rock, evidently the result of contact metamorphism, is found near the border of the gabbro area just south of Darlington.

Megascopically it has the appearance of an augen-gneiss. Numerous eyes of a milky white color, the largest an inch in diameter, are closely imbedded in a groundmass of chlorite laminae. The eyes are only a fraction of an inch apart in some places. The chlorite laminae are wrapped about the feldspar eyes in the manner characteristic of augen-gneisses. The rock is not very resistant and on exposed surfaces weathers easily to a rusty brown color. Crinkling and kneading of the rock indicate that it was at one time quite plastic and viscous.

Under the microscope the eyes are seen to be composed of acid plagioclase of the albite-oligoclase series. Pressure subsequent to crystallization has elongated the crystals, although they still retain their cleavage faces and some suggestion of their original crystal form. The groundmass is made up of chlorite, quartz, acid plagioclase, and tourmaline with a small amount of biotite. Quartz and feldspar occur as fine grains in mosaic aggregates. Fine plates and fibers of chlorite with the characteristic low double refraction are abundant. Sometimes these plates are arranged in radiating aggregates, but usually they have a roughly parallel direction. With the naked eye this parallel arrangement of the chlorite laminae is still more apparent. Tourmaline in long, slender crystals with the characteristic strong absorption and triangular or six-sided cross-section is present in fairly large quantities. The effect of dynamic metamorphism is better seen in the groundmass than in the eyes, for the chlorite laminae have been drawn out and bent, and the slender tourmaline crystals have been broken.

Because of lack of exposure the transition between this contact augen-gneiss and the Baltimore gneiss cannot be seen. As will be shown later there seems to be but little doubt that this is a contact phase of the Baltimore gneiss.

Immediately to the west of this augen-gneiss, in the region including Mountain Hill, there is a large area, two and a half miles long and from one-half to three-quarters of a mile wide, in which rocks somewhat similar to the quartz epi-diorite of the area east of Berkley are found.

Megascopically these are coarse to medium-grained, holocrystalline rocks, gray in color. Schistosity is usually lacking. Quartz, feldspar, biotite and hornblende are visible in the hand specimen. Quartz is often present in fair-sized, clear, glassy grains much like those of the Berkley area.

Under the microscope quartz, basic plagioclase, secondary hornblende, and biotite appear as the predominant minerals. Garnet, magnetite and pyrite are the usual accessory constituents. A little pyroxene (probably diallage) is sometimes present. Quartz occurs as large single individuals, often crushed into mosaic patterns. The primary feldspar is a basic plagioclase in which zonal developments are almost always found. Measurement of maximum extinction angles in the zone at right angles to (010) gives values of 40° for the interior of the feldspar and usually 27° for the outer zone. These values correspond to compositions of $Ab_{30}An_{70}$ (labradorite-bytownite) for the interior of the crystal, and $Ab_{50}An_{50}$ (andesine-labradorite) for the outer zone. Unlike the plagioclase of the typical hypersthene gabbro these crystals often show well-developed terminations and clear-cut crystal faces. Metamorphism has had some effect upon these epi-diorites, for the plagioclase has often been altered to saussurite, a mixture of zoisite, epidote, and secondary albite. Hornblende usually occurs as the fibrous green variety, although compact forms are sometimes seen. It is undoubtedly secondary, as in a few instances remnants of pyroxene can be seen undergoing alteration to hornblende. Biotite is also quite common in these rocks, usually appearing in large irregular flakes, and exhibiting the characteristic basal cleavage, strong pleochroism (deep brown to light yellow), very small axial angle with negative optical character, fairly low index of refraction, and medium double refraction. Inclusions in hornblende, biotite, and primary feldspar are numerous in these epi-diorites. Garnet is a very common inclusion in all three minerals. It is recognized by its high index of refraction, isotropic character, and well-developed rhombic dodecahedral form.

The presence of biotite and the absence of chlorite and any decided schistosity are characters which distinguish these epi-diorites from those of the Berkley area. In that area the schistosity and the presence of chlorite are probably due to the greater degree of metamorphism to which the rocks have been subjected. In fact, the very presence of chlorite laminae has probably given the appearance of schistosity to the rock.

About one mile south of Gibson there is another very small area of epi-diorite. The rock here is almost identical with that of the Mountain Hill area. Immediately adjoining this is a small area containing augen-gneiss very similar to that of the area near Darlington. In a few places in this area the feldspar eyes are not well developed, but the feldspathic materials have been concentrated into lenses about which the chlorite laminae are wrapped.

DIFFERENTIATION AND CONTACT METAMORPHISM

Although the same minerals are to be found in general throughout the main mass of the unaltered hypersthene gabbro, there is a great deal of variation in individual specimens, even in those that have been collected within a few feet of each other. These variations are principally due to differences in size of grain and to differences in the relative quantities of the essential minerals present. As already noted the rock may be so feldspathic in some places that the pyroxenes become very subordinate, while in other places feldspar may decrease in quantity so much that the rock becomes a pyroxenite. Abrupt variations in grain are also common. Although no definite cause can be assigned for these rapid variations, they are undoubtedly due to differences in physical conditions in different parts of the magma. Differences in temperature and pressure might easily cause differences in rates of crystallization and thus in size of grain as well. Such differences in temperature and pressure would also cause variations in chemical composition through changes in rates of diffusion, etc., and thus there would be a difference in the relative quantities of minerals present in the solidified rock. The fact that the same essential constituents are present throughout the main gabbro area would seem to indicate, however, that in general composition and physical conditions did not vary greatly in different parts of the molten magma.

On the other hand, the epi-diorites show that there were decided, although local, differences in chemical composition and physical conditions within the areas where these rocks are present. In comparison with the whole gabbro area these epi-diorite areas are quite small. The petrography of these four areas at once shows the similarity in composition of their rocks. Indications of the presence of original pyroxene are very apparent, although the pyroxene itself has often been wholly altered to secondary hornblende. Zonal feldspars have been formed in all these districts, and these zonal feldspars show approximately the same composition. Biotite is a common mineral constituent, although some of the districts show a greater development of biotite than others. Garnet is also frequently found, although it may be regarded as an accessory constituent of these rocks. Chlorite, it is true, is present in large quantities in the epi-diorites of the two northern regions while there is very little in the rocks of the two other epi-diorite regions. Its presence in the northern regions may be easily explained by the exposure of these regions to weathering. Both of the northern areas are very close to the Susquehanna River, where relief is very distinct and marked and where, consequently, circulating waters have much greater activity.

Leonard[35] has described quartz diorites and quartz-mica-hornblende diorites from Cecil County very similar to the epi-diorites of Harford County. In Cecil County the diorites cover an area apparently greater than in Harford County but, like the epi-diorites of Harford County they are found only as a belt along the southern border of the main gabbro area. The same large blue quartz phenocrysts, zonal feldspars, hornblende and mica were observed. Leonard, however, noted the presence of orthoclase which has been found by the writer. He did not mention the presence of any traces of unaltered pyroxene, although he found fibrous hornblende to be very abundant. It is very probable that the quartz diorite and quartz-mica-hornblende diorite of Cecil County belong to the same type of rocks and have the same origin as the quartz epi-diorite and quartz-mica epi-diorite of Harford County.

[35] Leonard, A. G., Am. Geol., vol. xxviii, 1901, pp. 140–146.

An examination of the location of the epi-diorite areas shows at once that they are all found at or near the contact of the gabbro with the Baltimore gneiss. Two of these areas adjoin areas in which a peculiar augen-gneiss is found, a rock which is very evidently the result of some contact action. The contact of the epi-diorite with the augen-gneiss has not been discovered, but the augen-gneiss has been strongly folded and kneaded so that it gives the suggestion of having been in a semi-viscous state at some time in its history. It seems quite probable that were the direct contacts revealed they would show a transition zone between the augen-gneiss and the epi-diorite. Such a graduation has often been shown to be a common occurrence at contacts with intrusive rocks.

The epi-diorite shows considerable difference in composition from the typical hypersthene gabbro. The principal distinguishing feature of the epi-diorite is the presence of the large blue quartzes. Zonal feldspars are common in these rocks, but they have never been observed in the hypersthene gabbro. The interior of the zonal feldspar is slightly more acid than the typical feldspar of hypersthene gabbro, while the outer zone is decidedly so. Garnets also are present in the epi-diorites but are exceedingly rare in the hypersthene gabbro. Biotite is never found in hypersthene gabbro of this region, although it is a frequent constituent of the epi-diorite. Nevertheless the epi-diorite shows distinctly a closer relationship to the gabbro than it does to the Baltimore gneiss. The presence of pyroxene or the alteration products of pyroxene at once distinguishes this rock from the Baltimore gneiss. The epi-diorites are massive, rarely showing a gneissic structure except in the two northern districts, where a schistosity has been developed consequent upon the formation of chlorite. Hornblende is often fibrous in the epi-diorite, whereas in the Baltimore gneiss it is usually compact with distinct cleavage angles and fairly well-formed crystal faces. The basicity of the feldspars in the epi-diorite is a characteristic that must distinguish it from the Baltimore gneiss.

The epi-diorite thus shows by the presence of pyroxene, its general location, and the character of the feldspar, that it has undoubtedly been derived from the magma of gabbroic composition, while the presence of quartz and the greater acidity of the feldspar would indicate that there had been an addition of material from a more acidic source. The explanation which seems to fit the facts is that the gabbro magma locally assimilated some of the Baltimore gneiss. The assimilation of material of a more acidic composition would cause the formation of a slightly different suite of materials, like that found in the epi-diorites. The zonal feldspars were the result of continually increasing acidity in the solution from which they crystallized.

It is also probable that the magma from which the epi-diorites were formed remained molten longer than the rest of the gabbro magma. In the larger of the two epi-diorite areas found close to the Susquehanna River there is a transition zone developed between hypersthene gabbro and epi-diorite in which there is a rock whose mineral assemblage would indicate that some contact action had taken place between the hypersthene gabbro and the epi-diorite. This rock has already been described. The presence of phlogopite, which is not found in either the gabbro or the epi-diorite, would suggest contact action. Zircon and garnet are present in unusual quantities. The longer period of fluidity of the epi-diorite was probably due mostly to the greater quantity of gases held in solution by the epi-diorite than by the gabbro. Gases would be likely to collect near the outer part of the molten magma, and they would probably also be absorbed by the magma through action on the Baltimore gneiss. The assimilation of material from the Baltimore gneiss may have also lowered the melting point, although more acidic rocks are generally thought to have higher melting points. Cases are often cited where mixtures of two substances have lower melting points than the substances themselves. That the intrusive magma had some effect upon the Baltimore gneiss is clearly shown by the formation of augen-gneiss and by the crumpling and wrinkling of the gneiss near the contact in several places. The indications of softening of the gneiss are unmistakable. If the actual contact between the gneiss and the gabbro could be seen still greater effects on the gneiss might be observed.

The augen-gneisses, so often found near the epi-diorite bodies, show every evidence of having been derived from the Baltimore gneiss. The feldspar is an acidic plagioclase, quite characteristic of the gneiss. No basis plagioclase is present. Quartz, which is always abundant in the augen-gneiss is also characteristic of the Baltimore gneiss, while it is very rare in the gabbro. The exceedingly well-developed gneissic structure at once indicates a close relationship to the Baltimore gneiss. In places the formation of eyes is only suggested, although the feldspathic materials are concentrated into lenses. The segregation of feldspathic bands is not uncommon in the Baltimore gneiss. Tourmaline is no doubt the result of pneumatolytic action. The development of chlorite in the augen-gneiss is very similar to a development of a chlorite schist noted by Chatard[36] at the contact of a dunite with hornblende gneiss. It is impossible to say what the original mineral was, from which the chlorite has been formed. Since hornblende is often a very abundant mineral in the gneiss, it seems quite probable that chlorite is a decomposition product of hornblende in this instance. The evidence of the structure and mineral composition of the augen-gneiss indicates that the heat of the intrusive body had raised the temperature and increased the activity of solutions within the gneiss. These solutions have deposited material around centers already present and thus the feldspar eyes have been built up. Augen-gneisses built up by such a process of deposition from solution have often been described. Sometimes this has been accomplished in schists or gneisses without the aid of heat from a neighboring igneous body. Berg[37] describes an augen-gneiss formed by the production of new quartz crystals between schist lamellae by deposition from circulating waters. Fenner[38] mentions an augen-gneiss in the Highlands of New Jersey, concerning which he says:—"Certain phenomena suggest that a force of crystallization may at times have been an effective factor in separating the layers. Aggregates of microcline and quartz crystals in the form of augen are seen,

[36] Chatard, T. M., U. S. Geol. Survey Bull. 42, 1888.
[37] Berg, G. E. W., K. Preuss. geol. Landesanst. Jahrb., Bd. xxviii, 1907, p. 647.
[38] Fenner, C. N., Jour. Geol., vol. xxii, 1914, p. 605.

inclosed by curving bands of schist." Fenner concludes that the pre-Cambrian gneiss of that region was caused by the injection of a thinly fluid granitic magma between the layers of an original rock of laminated structure. Williams[39] has described a case of contact metamorphism in the rocks of the Cortlandt series near Peekskill, New York, where mica schists have been greatly affected by the intrusion of a mica diorite. At some distance from the contact the mica schists are highly crystalline, but not much crumpled or metamorphosed. "As we follow them, however, across the strike they become more and more puckered and filled with lenses or eyes of quartz containing garnet and other minerals. In the schists themselves are developed staurolite, cyanite and garnet. The intensity of the metamorphic changes is directly proportional to the nearness of the schists to the massive rocks." Judd[40] has noted many instances of increase in the growth of feldsgar in massive rocks after solidification. He says (op. cit. p. 185):—"That, as a result of contact metamorphism, many well-defined mineral species are developed in the midst of solid rocks, the crystals growing at the expanse of and deriving their materials from the surrounding detrital fragments, has long been recognized." Harker[41] in a study on the migration of material during the metamorphism of rock masses concludes that the size of individual crystals of secondary minerals increases toward the contact with the intrusive rock. This, he thinks, is due to the fact that migration of material within a rock mass undergoing metamorphism has more latitude when the temperature is higher. Van Hise[42] thinks that contact effects are often brought about by heat and increased action of circulating waters near a molten magma. Not only the formation of the feldspar eyes but also the pronounced development of chlorite in the Harford County augen-gneiss was probably caused by the increased activity of the heated solutions.

The augen-gneiss one mile south of Gibson seems by its location to be more of an inclusion in the gabbro than a true contact rock. The

[39] Williams, G. H., Am. Jour. Sci. (III), vol. xxxvii, 1888, p. 255.
[40] Judd, J. W., Quart. Jour. Geol. Soc. London, vol. xlv, 1889, p. 182.
[41] Harker, A., Jour. Geol., vol. I, 1893, p. 577.
[42] Van Hise, C. R., Mon. U. S. Geol. Survey, vol. xlvii, 1904, p. 488.

lack of exposures between this place and the Baltimore gneiss, however, makes the location of any definite contact impossible.

From a review of the evidence given above, therefore, it is very probable that the augen-gneiss is a phase of the Baltimore gneiss produced by the heating and increased activity of solutions within the Baltimore gneiss because of the proximity of the molten gabbro magma. together with the action of some pneumatolytic solutions from the gabbro magma.

Contacts of the granite with the gabbro are not usually visible, but good exposures of gabbro and granite within a very few feet of each other have been observed. Nowhere has any decided contact metamorphism of either the gabbro or granite taken place. In one place granite has intruded the gabbro in the form of a relatively narrow dike about a mile long. Some of the specimens from this dike appear slightly harder and less friable than specimens of granite collected from other exposures in the region. There has been no change because of contact action in size of grain, texture, or kinds of minerals developed in the granite.

On a geologic map of Harford County published by the Maryland Geological Survey in 1904, the gabbro is shown extending across the county line into Baltimore County. Examination of exposures at or near the county line shows that the gabbro belt dies out or is covered by Baltimore gneiss before it reaches the county line. The Baltimore gneiss in this region is a very hornblendic, dark-colored phase, sometimes quite massive in appearance and often resembling gabbro very closely. A description of these rocks has already been given. The composition of the feldspar, the arrangement of the hornblende crystals, the abundance of quartz, and the structure indicate that the rocks here are to be classified as Baltimore gneiss and not as hypersthene or meta-gabbro.

RELATION TO BASIC INTRUSIVES OF ADJOINING AREAS

While in many respects the hypersthene gabbro of Harford County is very similar to the gabbros described from Baltimore County and Cecil

County, Maryland, Delaware and Pennsylvania, it is lacking in some phases characteristic of these other areas and shows some phases that thus far have not been described from the other areas.

Williams was the first to describe gabbros from the region around Baltimore. Gabbro occurs in the Baltimore region in a few areas of irregular shape. Hypersthene gabbro is found very similar to the hypersthene gabbro of Harford County, in which bytownite, hypersthene and diallage are the only essential primary constituents. Intimately associated with hypersthene gabbro is gabbro-diorite, which has essentially the same physical characteristics and the same mineral content as the meta-gabbro of Harford County. The gabbro-diorite has been produced from the hypersthene gabbro through the alteration of pyroxene to hornblende by the action of regional metamorphism. The gabbro-diorite often shows the alteration of feldspar to saussurite as well. Peridotites and pyroxenites are associated with the gabbro, but are a younger eruption. Gabbros and pyroxenites and peridotites were probably derived from the same parent magma. Williams has described one specimen of olivine gabbro from the Baltimore region. So far no olivine gabbro has been found in Harford County.

The basic intrusives of Cecil County have been described by Leonard and by Bascom. The main gabbro area in this county is a continuation of the gabbro belt of Harford County. There are also a few smaller isolated areas of gabbroic rock. Here are found hypersthene gabbro and meta-gabbro (gabbro-diorite) so prominent in Baltimore and Harford counties, although norite is the predominant phase in Cecil County. The norite is a hypersthene-bytownite rock with no essential diallage. Norite and hypersthene gabbro belong to the same intrusive mass, and are simply differentiation phases of that mass. Two specimens of olivine norite have been described by Leonard. Intrusions of pyroxenite and peridotite are found. Here too they are seen to be younger than the gabbro. Dikes of diabase, pyroxenite, peridotite and pegmatite cut the norite and gabbro. Diorites, very similar in composition to the epi-diorites of Harford County, form a narrow strip along the southern border of the gabbro. These rocks have been described.

The belt of gabbro continues from Cecil County, Maryland, through Delaware. The gabbros of Delaware have been described by Chester, who found in them several phases quite different from the gabbros of Maryland. In all of the gabbros and associated rocks of Delaware quartz is an abundant accessory constituent. The predominant type is hypersthene gabbro quite similar to that of the Maryland areas, with the exception of the presence of quartz. By addition of brown hornblende which Chester thinks may be original the hypersthene gabbro passes into a gabbro-diorite. This gabbro-diorite becomes hornblende gneiss with the imposition of a gneissic structure. By the addition of biotite and quartz as important constituents the hypersthene gabbro becomes "gabbro-granite." This may be closely related in composition and origin to the quartz-mica epi-diorite of the Harford County region. The "norite" which Chester has described is a rock "composed mainly of a very fine-grained mixture of quartz and plagioclase, which, in hand specimens, appears quite homogeneous; in this ground mass are porphyritically developed larger grains of hypersthene and magnetite with generally a few shreds of biotite" (p. 22). The gabbro-diorites (metagabbros) of Iron Hill, Delaware, as described by Chester, are very similar to those described by Williams from the Baltimore region. The alteration of feldspar to epidote in the Delaware region has also been noted.

Gabbros closely related to those of Maryland have been described by Bascom from the region included in the Philadelphia folio. The area mapped as gabbro includes norite, hypersthene gabbro, and true gabbro. These rocks are differentiated by the presence or absence of hypersthene or diallage. In all three forms of gabbro, labradorite or labradorite-bytownite is the usual feldspar present. This region is exceptional in that garnet is a usual accessory constituent in the gabbro. The development of secondary hornblende does not seem to be as prevalent in the gabbro of this area as it is in the gabbro of Maryland.

AGE RELATIONS OF GABBRO AND ASSOCIATED ROCKS

The age relations of some of the rocks associated with the gabbro are still quite uncertain. Lack of good exposures at contacts and the complicated structure of the Piedmont Plateau make determination difficult.

There is no doubt, however, that the gabbro is younger than the Baltimore gneiss. In Harford County gabbro is intrusive into the gneiss. The contact action of the gabbro on the gneiss also indicates that the gabbro is younger than the gneiss. In Cecil County the same age relations probably hold true as at least part of the granite (the Port Deposit granite) which has been considered older than the gabbro is undoubtedly a phase of the Baltimore gneiss. Williams and Keyes considered the gneiss of the Baltimore region to be the oldest formation present, for there it has been intruded by granite, gabbro, and still more basic igneous bodies. The evidence of the younger age of the gabbro is conclusive in the Philadelphia region where there are a number of dikes and small stocks of gabbro which have been intruded into the Baltimore gneiss. Another line of evidence which indicates the younger age of the gabbro is the amount of metamorphism which it has undergone compared to the metamorphism of the Baltimore gneiss. The Baltimore gneiss everywhere shows indications of having been acted upon by powerful orogenic movements. The Baltimore gneiss is probably made up of ancient sedimentaries and igneous complexes but the original nature of these rocks has been so obscured that it is now practically impossible to draw any distinction between original sedimentary and igneous bodies. All of the phases of this formation have been intensely laminated with the mineral constituents drawn out into parallel bands. The gabbro, on the other hand, rarely shows any traces of gneissic structure, and where such structure is present it is much less pronounced than in the Baltimore gneiss.

The granite which appears in the Harford County region in dikes and tongues of considerable extent is younger than both gabbro and gneiss. It is not only intrusive into the gneiss but in one place is found as a short dike within the gabbro area. The same relation of gabbro to granite holds true in Baltimore County. Keyes[43] found that "the granites penetrate and break through all the rocks of the region—gabbros, diorites, pyroxenites, and gneisses." Hobbs[44] (26) found considerable evidence in the region around Ilchester, Maryland, that the granites are younger than the gabbros. Numerous dikes of granite cut the gabbro in this region. In Cecil County, however, evidence as to the age relation of granite and gabbro is not so clear. Leonard[45] concludes that there is no definite evidence to show the age relation of gabbro and granite. He notes, however, that pegmatite dikes are intrusive into the gabbro and says in this connection:—"The pegmatites are more recent than the basic rocks and serpentines and since the latter have originated from non-feldspathic types the acid dikes are also younger than most of the peridotyte and pyroxenyte." Grimsley[46] has made a detailed study of the granites of Cecil County. He has divided the granites into two districts; a northwestern district which is called the Rowlandville area, and a southeastern one called the Port Deposit area. The granites of the Port Deposit area are much more foliated and gneissoid than those of the Rowlandville area. Grimsley concludes (op. cit. p. 103) that all of the granites "are probably older than the more basic gabbros which bound them on the north and northwest," but he also says, in comparing the Rowlandville and Port Deposit areas that "the rocks near Port Deposit . . . . represent either an older intrusion, or a zone of maximum dynamic action."

Bascom also divided the granites of Cecil County into two areas; an area of more gneissic biotite granite (the Port Deposit area), and an area of less gneissic hornblende-biotite granite (the Rowlandville area).

In discussing these two granites and their relation to the gabbro it is significant that the Cecil County geological map, published by the Maryland Geological Survey in 1902, shows no gabbro intrusions into the area of the Rowlandville granite while there are several large intru-

[43] Keyes, C. R., 15th Ann. Rept. U. S. Geol. Survey, 1894, p. 738.
[44] Hobbs, W. H., Dissertation, Johns Hopkins University, 1888.
[45] Leonard, A. G., Am. Geol., vol. xxviii, 1901, p. 174.
[46] Grimsley, G. P., Jour Cincinnati Soc.Nat. Hist., vol. xvii, 1894.

sions of gabbro into the area of the Port Deposit granite. It is also noteworthy that no contacts between the gabbro and Rowlandville granite have been found that would throw any light on the age relations. It is quite possible that two ages of granite may be represented and that one, the Rowlandville, may be of the same age as the granites of Baltimore and Harford counties which have been considered to be younger than the gabbro. The other, the Port Deposit granite, is no doubt a facies of the Baltimore gneiss.

The pegmatite dikes which are intrusive into the gabbro furnish more evidence on the relative age of the granite. Williams[47] divides the pegmatites of the Baltimore region into two classes; (1) segregation pegmatites which are really quartz veins carrying a little feldspar, and (2) intrusive pegmatites which show the usual coarse-grained aggregates of quartz, feldspar, biotite or muscovite, and other accessory minerals. Pegmatites of the latter class show characteristics which caused Williams to conclude that they were of intrusive origin. They agree essentially with the granitic intrusives in mineralogical and chemical composition: they are often very close to some granitic body: their composition is quite independent of that of the rocks which surround them. At the same time the presence of unusual minerals in the pegmatites makes it seem probable that the intrusion was accompanied by pneumatolytic action or by the presence of considerable water. The one large pegmatite dike which has been found within the gabbro area shows the same characteristics that Williams found in the intrusive pegmatites of the Baltimore region. This dike is undoubtedly younger than the gabbro. It therefore seems probable that the pegmatite here is contemporaneous with the granite, just as it has been found to be in the Baltimore area.

The quartz veins which can be traced in many places in the gabbro area by the trails of quartz boulders which are left on the surface undoubtedly had an entirely different origin. Orogenic movements subsequent to the solidification of the gabbro opened cracks and fissures which were later filled by minerals, principally quartz, deposited by

[47] Williams, G. H., 15th Ann. Rept. U. S. Geol. Survey, 1894, p. 679.

circulating waters. Sometimes these veins are represented only by small and isolated lenses while at other times they become so large that it is possible to quarry the quartz. Tourmaline and occasionally feldspar are also present in these veins. The formation of quartz veins probably was not confined to any one geologic period.

Concerning the age relation of the ultra-basic rocks to the gabbro there seems to be a close agreement between the students of the related areas of Maryland and Pennsylvania. The relation of the peridotites and pyroxenites to the gabbro in the region around Ilchester indicates that they are younger than the gabbro. Both Leonard and Bascom concluded after a study of the field associations in Cecil County that the rocks from which the serpentines were derived were younger than the gabbro. Bascom considered the serpentines of the Philadelphia region to be contemporaneous with or subsequent to the gabbro in age. Johannsen found the same relations to hold true in Harford County. Here the bodies which by alteration have formed serpentine are usually in the shape of dikes or stocks. These bodies vary widely in size. In several places serpentine is encountered within the gabbro area. The occurrence in the field shows it to be of an intrusive nature. No transition zones are found between the typical hypersthene gabbro and the serpentine and the contacts are usually sharp and abrupt. Within the gabbro there are two or three small areas of pyroxenite which show gradations into the true hypersthene gabbro but these seem to be local differentiation phases of the gabbro and not to be related to the typical serpentines so often found.

The relation of the serpentine to the granite is not as definite as that of the serpentine to the gabbro. The association of the two types in the field in Harford County does not give any real clue as to their age relations. The evidence of one locality in the Ilchester region led Hobbs to the conclusion that the ultra-basic rocks were a later intrusion into the granite. Keyes (33, p. 692), however, thinks that the granites are the youngest eruptives of the Baltimore region, intrusive into both the gabbros and the ultra-basics.

The relation of the diabase to the other intrusive rocks of Harford

County is still a matter of some uncertainty. Several diabase dikes break through the gabbro and are therefore certainly younger than the gabbro. At present there is no conclusive evidence to show that they are younger than the granite or the serpentine. More work in this region may reveal the presence of diabase dikes cutting the granite and the ultra-basic rocks. Both Leonard and Bascom have considered the diabase dikes of Cecil County to be continuations of the great Triassic dike which Lewis[48] traced through eastern Pennsylvania as far as the Maryland border. Certain characteristics distinguish the diabase of Harford County from that of Cecil County. In the specimens of diabase described from Cecil County both the augite and plagioclase are comparatively unaltered, the development of secondary hornblende and epidote being noted only in a few instances. In Harford County, however, unaltered pyroxene is rarely found and the alteration of plagioclase to epidote is very common. Secondary hornblende and epidote are the usual constituents of the diabase. It is evident that the diabase of Harford County has undergone much more metamorphism than has that of Cecil County. This does not, of course, prove that the Cecil County diabase is younger than the Harford County diabase but it is an indication that such may be the case. Diabase dikes have often been noted in other areas as intrusive into gabbros, apparently occurring as later off shoots of the parent magma. Loughlin in his investigation of the gabbros and associated rocks at Preston, Connecticut, has cited the occurrence of diabase dikes very similiar to those of Harford County in which the pyroxene has been altered to uralite and the feldspar altered to saussurite. These dikes have broken through the gabbro and Loughlin concludes that the upper portion of the main gabbro magma consolidated and became ruptured while the lower portion was still molten. The lower portion then welled upward into the net-work of fissures, forming dikes. Diabase of two district ages has been described in eastern Pennsylvania,[49] one pre-Cambrian and the other Triassic. The pre-Cambrian diabase is characterized by considerable

[48] Lewis, H.C., Proc. Am. Phios. Soc., vol. lxxii, 1885, pp. 438–456.
[49] Jonas, A. I., Am. Mus. Nat Hist. Bul., vol. xxxvii, 1917, pp. 173–181.

alteration; augite has been altered to chlorite, and feldspar to saussurite. This diabase has been called pre-Cambrian because it has undergone considerable alteration and because it is intrusive only into pre-Cambrian rocks among which gabbro of apparently the same age as the Harford County gabbro is included. The other type of diabase is intrusive into Triassic shales and shows none of the alteration effects so characteristic of the pre-Cambrian diabase. It is quite probable that the diabase of Harford County is also much older than the Triassic diabase of Cecil County and the areas farther north. These older dikes may in fact be off-shoots of the same parent magma from which the gabbro came.

Any decision as to the true age of the gabbro and related intrusives of Harford County must rest in large part upon the age of the mica schists and phyllites which border these rocks on the north and west and into which dikes and stocks of the ultra-basics have been intruded. If these schists and phyllites are to be correlated with the Wissahickon mica gneiss of eastern Pennsylvania which Bliss and Jonas have found to be pre-Cambrian in age, then it is very probable that the intrusives also are pre-Cambrian. The meta-gabbro of eastern Pennsylvania has been called pre-Cambrian by these authors and there seems to be little doubt that this rock and the gabbros of Maryland are part of the same great intrusion.

A study of the field relations and associations of the different eruptive types—granite, gabbro, and ultra-basic rocks—at once suggests that they all originated from a common source. Williams was the first to propose such an origin for the eruptive series in the neighborhood of Baltimore. Referring to this series he says:—"While this wide range of petrographic types can not be positively shown to have originated from a single magma, their relationships in the field are so intimate and the instances of the gradual passage from one to the other are so common, that this seems not to be an improbable hypothesis." Leonard considered the eruptives of Cecil County to be differentiation products of a single parent magma. Bascom also thinks it highly probable that the igneous rocks of Cecil County are the differentiation products of a single magma, differentiation taking place both before and after intrusion. The conclusion that these types were derived from a single parent magma through differentiation before and after intrusion seems to be the one most probable for the eruptive series of the Maryland Piedmont Plateau. Examples of series of eruptive rocks, differing considerably in composition in each member, but nevertheless considered as having been derived from a common parent magma, have often been cited in the literature. Notable examples are the Cortlandt Series and the igenous complex of Garabal Hill in the Southern Highlands of Scotland.[59]

SUMMARY

1. In Harford County, Maryland, gabbro has been intruded into the ancient, highly crystalline schists and gneisses. The gabbro has the shape of a belt reaching almost all the way across the county but only three and a half miles wide at its broadest part. Its shape and the structure of the gneisses into which it has been intruded suggest that the gabbro may be in the form of a sill or sheet with a dip to the southeast.

2. For purposes of description two predominant varieties of gabbro have been recognized in this area, hypersthene gabbro and meta-gabbro. Study of the two types shows, however, that the meta-gabbro is only an alteration product of the hypersthene gabbro, due to the action of regional metamorphism. These two varieties grade into each other almost imperceptibly.

3. With the exception of a few small areas the whole of the unaltered gabbro is a hypersthene gabbro in composition, almost always containing the same mineral constituents. The relative amounts of these mineral constituents vary widely and abruptly, however. The grain of the rock also varies abruptly. These variations are thought to be due to change in physical conditions within the solidifying magma.

4. Near the contact of the gabbro with the Baltimore gneiss are areas

[59] Dakyns, J. R. and J. J. H. Teall, Quart. Jour. Geol. Soc. London, vol. xlviii, 1892, pp. 104–121.

which contain quartz epi-diorites and quartz-mica epi-diorites with a slightly coarser grain and a different mineral composition from the main mass of the gabbro. Field relations and microscopic study of these rocks indicate that they have been formed by assimilation of some of the adjacent Baltimore gneiss. They probably solidified somewhat later than the main mass of the gabbro.

5. Augen-gneisses are often associated with these epi-diorites. Their structure and mineral content indicate that the augen-gneisses have been derived from the Baltimore gneiss principally through contact action of the gabbro. The heat of the intrusive gabbro magma has increased the activity of solutions within the gneiss, causing feldspar eyes to be deposited and perhaps increasing the formation of chlorite. Pressure and heat from the gabbro have also caused kneading and crinkling of the gneisses.

6. The gabbro belt of this county is probably a part of the same intrusion as the gabbros, hypersthene gabbros, and norites of eastern Pennsylvania, Delaware, Baltimore County and Cecil County. At present, with the scarcity of evidence in Harford County and adjoining regions, it is impossible to determine exactly the age of the gabbros and associated intrusives. If the schists of the northern part of the county which have been invaded by the serpentine are to be correlated with the Wissahickon mica gneiss, then it seems probable that the age of the intrusives is pre-Cambrian.

7. The gabbro shows quite clearly its age relative to the associated igneous formations—granite, altered peridotites and pyroxenites, and diabase. The gabbro is undoubtedly younger than the Baltimore gneiss into which it is intrusive. The granite, however, is younger than the gabbro, as is indicated by their field relations in Harford County and Baltimore County. The serpentines, altered peridotites and pyroxenites, are also younger than the gabbro, although their age relative to the granite is not indicated by any evidence so far available in Harford County. The diabase is certainly younger than the gabbro, while evidence from other sections of the Piedmont Plateau indicates that it is probably also younger than the other igneous formations. Differences

in degree of alteration in this diabase and in the diabase of Cecil County seem to show that the diabase of Harford County was formed at an earlier date. It may be closely related in time to the other igneous intrusions.

8. Evidence from this and adjoining areas makes it seem very probable that all the intrusive bodies except those which form portions of the Baltimore gneiss are products of a common parent magma, considerable differentiation having taken place in the parent magma before intrusions of the present igneous formations began.

9. Regional metamorphism and the activity of solutions which often accompanies that force have profoundly altered all the intrusive rocks of the region as well as the sedimentaries. Peridotites and pyroxenites have been converted to serpentine; gabbro has been altered to metagabbro, with change of pyroxene to hornblende and feldspar to saussurite; granite has become somewhat foliated; and diabase has been uralitized.

INDEX

F

G

H

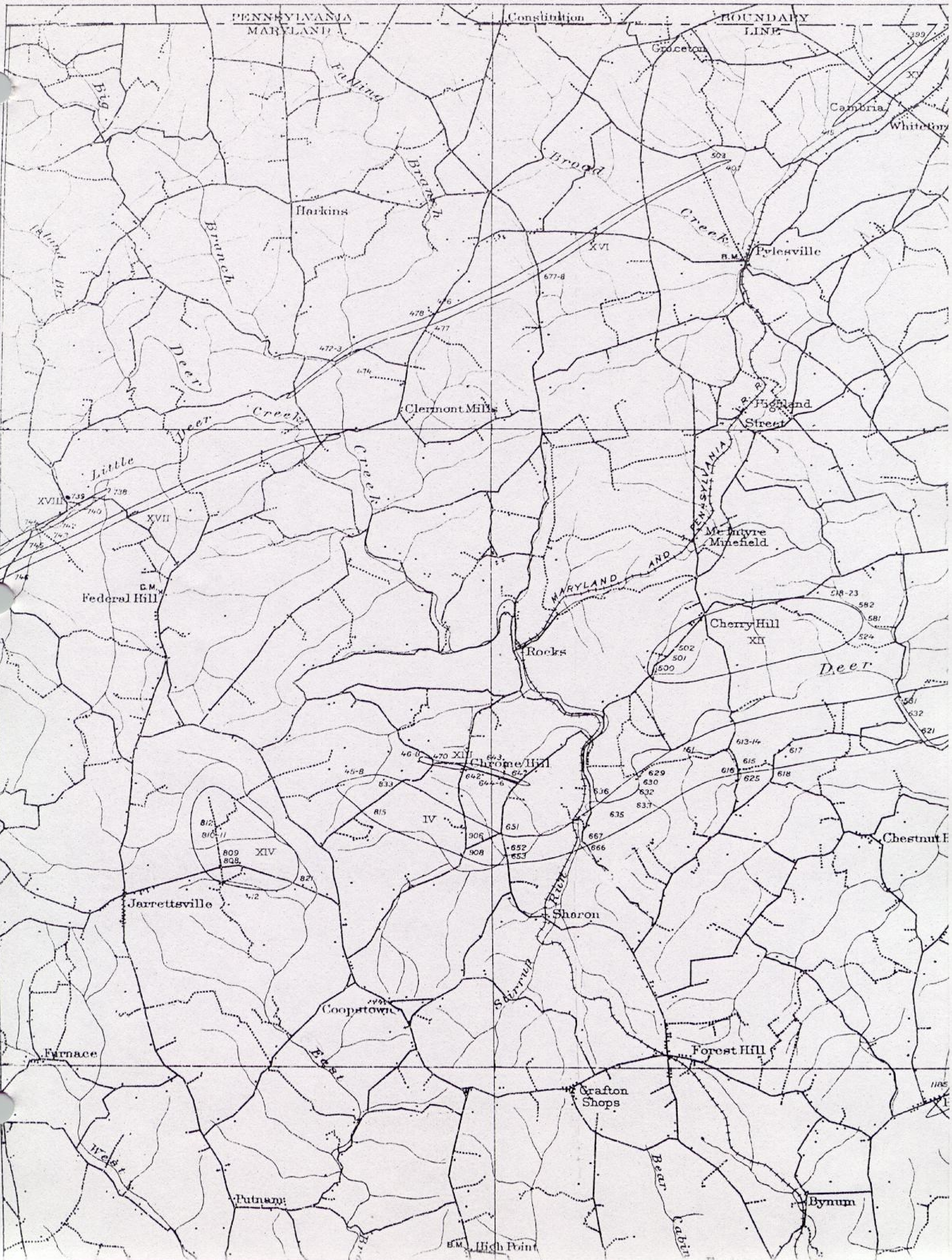
I

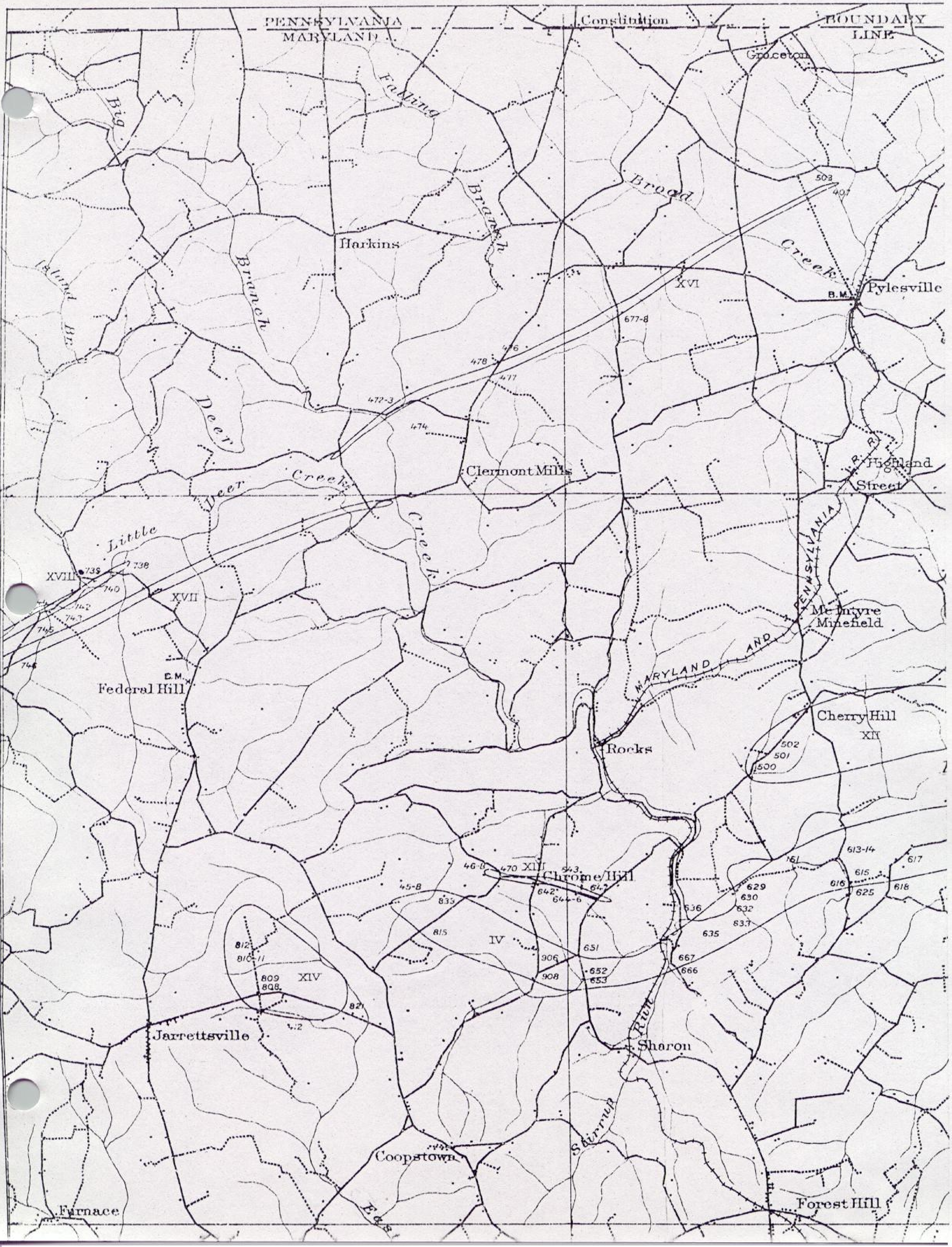
J

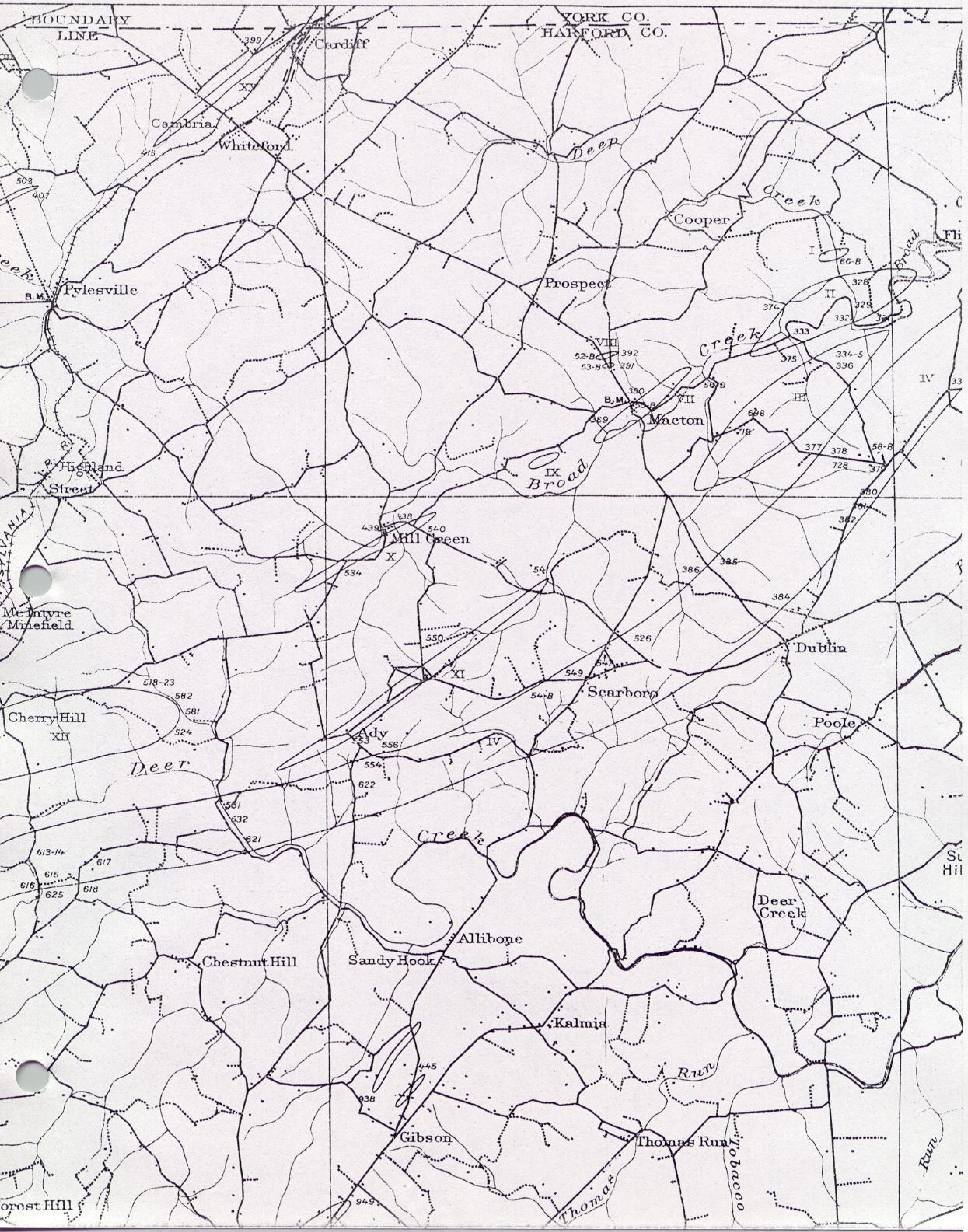
K

L

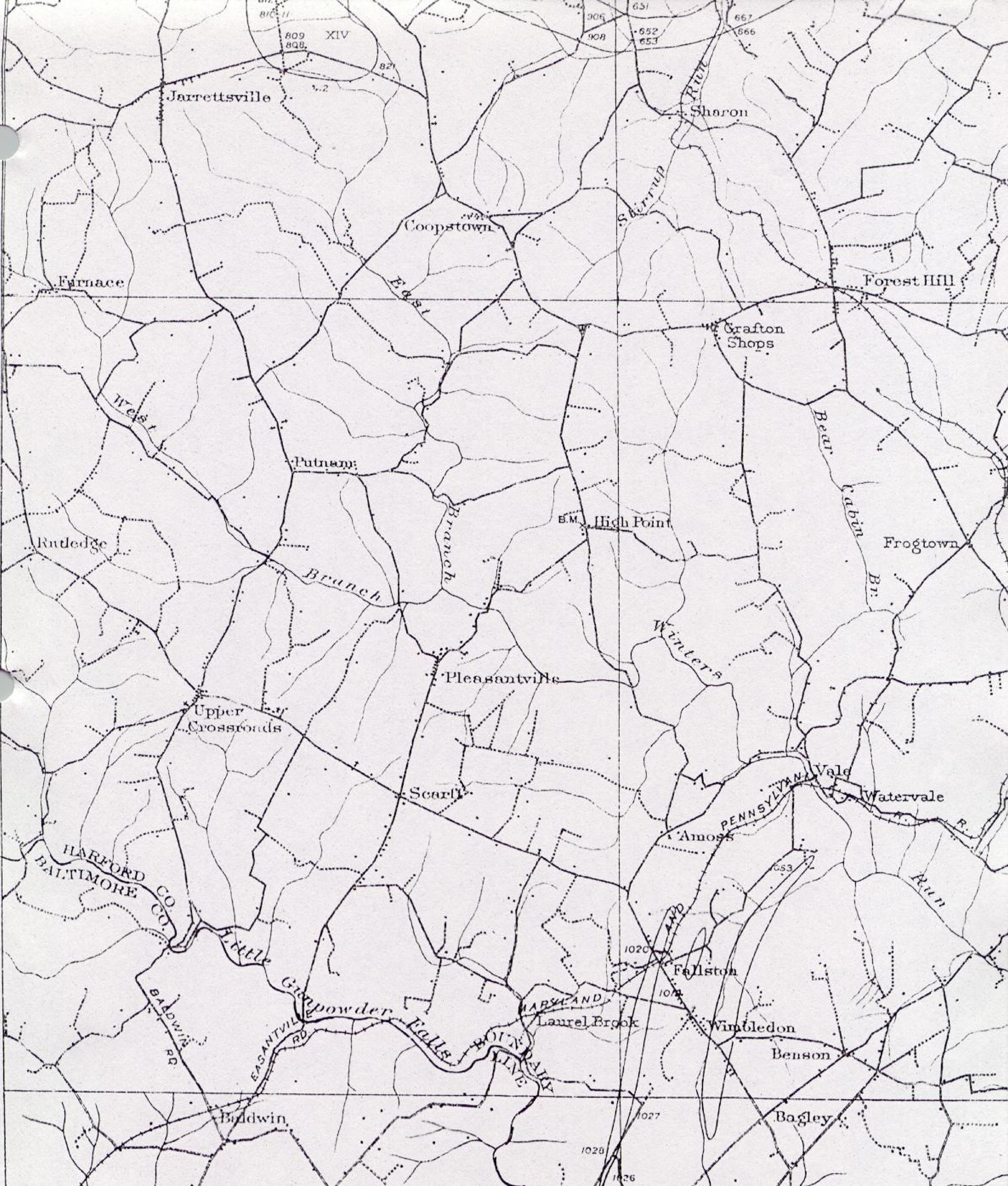
M


PENNSYLVANIA
MARYLAND
Constitution
BOUNDARY
LINE
Graceton
Cambria
Whiteford
Big
Falling
Branch
Broad
Creek
Harkins
Branch
Pylesville
XVI
Deer
Creek
Clermont Mills
Highland
Street
Little
Deer
Creek
XVIII
XVII
Federal Hill
MARYLAND AND PENNSYLVANIA
McIntyre
Minefield
Rocks
Cherry Hill
XII
Deer
Chrome Hill
XIII
IV
XIV
Jarrettsville
Sharon
Run
Stirrup
Coopstown
East
Furnace
Forest Hill
Grafton
Shops
West
Bear
Cabin
Putnam
Bynum
High Point
Chestnut


PENNSYLVANIA
MARYLAND
Constitution
BOUNDARY
LINE
Groceton
Big
Falling
Branch
Broad
Creek
Harkins
Island Br.
Branch
503
407
XVI
Pylesville
B.M.
677-8
476
478
477
472-3
474
Deer
Clermont Mills
Highland
Street
Little
Deer
Creek
Creek
XVIII
739
738
740
742
743
745
746
XVII
B.M.
Federal Hill
PENNSYLVANIA
MARYLAND
AND
R. R.
McIntyre
Minefield
Cherry Hill
XII
502
501
500
Rocks
613-14
617
615
616
625
618
629
630
632
633
635
636
667
666
46-8
470
XIII
643
Chrome Hill
642
644-6
45-8
833
815
IV
651
906
652
653
908
812
810-11
809
808
XIV
821
Jarrettsville
Run
Sharon
Stirrup
Coopstown
Furnace
Forest Hill


BOUNDARY LINE
YORK CO.
HARFORD CO.
Cardiff
Cambria
Whiteford
Deep
Creek
Cooper
Prospect
Pylesville
B.M.
Broad
Creek
Broad
Macton
B.M.
Highland
Street
Mill Green
Mc Intyre Minefield
Cherry Hill
Deer
Creek
Ady
Scarboro
Dublin
Poole
Allibone
Sandy Hook
Chestnut Hill
Kalmia
Deer Creek
Run
Gibson
Thomas Run
Tobacco
Thomas
Run


YORK CO.
HARFORD CO.
Deep
Creek
Cooper
Prospect
Macton
Broad
Creek
Broad
Mutton Ids.
Long Id.
Persimmon Id.
Hickorynut Ids.
Wildcat Pt.
Bald Friar
Creek
Ross Id.
Flintville
Stump Id.
Meadow Ids.
Indian Rk. Mills Id.
Long Id.
Castleton
Run
Peddler
Mill Green
Dublin
Scarboro
Poole
Ady
Hollands Branch
Creek
Sugar Hill
Mountain Hill
Deer Creek
Allibone
andy Hook
Cedar Hill
Glenville
Schoolhouse Hill
Kalmia
Run
Mill
Graveyard
Creek
Gibson
Thomas Run
Tobacco
Run



Map showing Serpentine areas

Scal

Map showing Serpentine areas in Harford County, and rock specimen numbers.

Scale, one inch equals one mile

ecimen numbers.