STATE OF MARYLAND
BOARD OF NATURAL RESOURCES
DEPARTMENT OF GEOLOGY, MINES AND WATER RESOURCES
JOSEPH T. SINGEWALD, JR., *Director*

BULLETIN 9

REFRACTORY CLAYS OF THE MARYLAND COAL MEASURES

By
Karl M. Waagé

Part I
REFRACTORY CLAYS IN THE COAL MEASURES OF THE GEORGES CREEK, CASTLEMAN, AND NORTHERN UPPER POTOMAC BASINS OF MARYLAND

Part II
GEOLOGY AND REFRACTORY CLAY DEPOSITS OF THE CASTLEMAN BASIN

BALTIMORE, MARYLAND
1950

COMPOSED AND PRINTED AT THE
WAVERLY PRESS, INC.
BALTIMORE, MD., U. S. A.

COMMISSION ON
GEOLOGY: MINES AND WATER RESOURCES

ARTHUR B. STEWART, *Chairman* . . . . . Baltimore
G. VICTOR CUSHWA . . . . . Williamsport
HARRY R. HALL . . . . . Hyattsville
JOSEPH C. LORE, JR. . . . . Solomons Island
MERVIN A. PENTZ . . . . . Denton

PREFACE

The two most important mineral products of western Maryland are coal and refractory clay. The magnitude of the industries engaged in their production is measured by the following statistics of annual production published by the Maryland Bureau of Mines.

	Coal	Refractory Clay
1939	1,467,850 tons	69,220 tons
1940	1,437,160	79,587
1941	1,717,215	106,039
1942	2,016,418	119,464
1943	2,074,102	142,309
1944	1,957,411	81,605
1945	1,837,267	58,034
1946	2,106,145	73,275
1947	2,252,050	202,054
1948	1,780,067	131,579

In 1902, the Maryland Geological Survey published "Report on the Coals of Maryland" by William Bullock Clark and others. A second report on the coals of Maryland was published in 1922 by the Maryland Geological Survey under the title "The Coal Formations and Mines of Maryland" by Charles K. Swartz and Wm. A. Baker, Jr. During the period from January 1945 to July 1946, the United States Bureau of Mines drilled 26 core drill holes in the Georges Creek and northern part of the Upper Potomac coal basins to explore the coal seams under the Big Vein seam. The results of these explorations have been published by the United States Bureau of Mines in Technical Paper 701, 1947, on "Preparation Characteristics of Maryland Coals" by W. L. Crentz and Thomas Fraser, and in Technical Paper 725, 1949, on "Investigation of Lower Coal Beds in Georges Creek and North Part of Upper Potomac Basins, Allegany and Garrett Counties, Md.", by Albert L. Toenges, Louis A. Turnbull, Lloyd Williams and others. During the period from May 1947 to May 1949, the United States Bureau of Mines continued the exploration of Maryland coal resources by drilling 40 core drill holes in the Castleman coal basin. The results of this exploration will be published by the United States Bureau of Mines.

Paralleling the two reports on the Maryland coals, the Maryland Geological Survey published two reports dealing with the refractory clays. The first was a general "Report on the Clays of Maryland" by Heinrich Ries published in 1902. The second report on "The Fire Clays of Maryland" by A. S. Watts, H. G. Schurecht, Charles K. Swartz, and G. M. Hall was published in 1922. Bulletin 9 on "Refractory Clays of the Maryland Coal Measures" likewise parallels

the recently published reports and the pending report by the U. S. Bureau of Mines on the coals of Maryland.

The refractory clays of western Maryland occur in the same formations as the coals and are intimately associated with the coals, the clay beds constituting the underclays of the coal beds. The strategic minerals needs during World War II were the stimulus to the two-core-drilling projects of the United States Bureau of Mines. Strategic minerals needs during World War II likewise focused attention upon the high-alumina clay resources of the United States and led to the cooperative investigation of the refractory clays of western Maryland by the United States Geological Survey and the Maryland Department of Geology, Mines and Water Resources. This investigation was started in June 1945, and carried on in close cooperation with the core drilling of the United States Bureau of Mines to the close of the drilling in the Castleman Basin in May 1949. The core drilling was as valuable and serviceable to the refractory clay investigation as it was to the coal explorations. It was a fortunate combination of circumstances that both investigations coincided in time. Though several geologists participated in the geologic investigation of the drill hole cores, Dr. Karl M. Waagé of the United States Geological Survey early in the Georges Creek drilling program took over full responsibility for the stratigraphic interpretation of the drill cores in conjunction with his responsibility for the refractory clay investigation. As a result of this really threefold cooperation on the part of the United States Bureau of Mines on the one hand and the United States Geological Survey and the Maryland Department of Geology, Mines and Water Resources on the other hand, Bulletin 9 is not only a valuable contribution to the knowledge of the refractory clay resources of western Maryland, but also contributes much to the knowledge of the coal seams and is an outstanding advance in the correct and exact interpretation of the stratigraphy of the coal measures as high in the series as the refractory clays occur.

The Bulletin comprises two parts. Part I deals with the geology and stratigraphy of the Maryland coal measures as a whole and with their refractory clays. Part II is a more detailed account of the geology and refractory clay resources of the Castleman coal basin.

The Bulletin describes comprehensively and thoroughly the irregular areal distribution of the various types of refractory clays and the variations in quality of the clay in the different clay horizons. It delimits the known reserves in the areas in which these clays have been mined and points out the more favorable areas for prospecting in the search for additional reserves. Especial stress is laid on the restricted areal extent of individual bodies of high-grade refractory clay to make it clear that this important mineral industry in western Maryland can be sustained only through systematic and intelligent exploration for undiscovered bodies of clay to replenish the reserves as the known reserves are depleted.

The Department of Geology, Mines and Water Resources is indebted to the United States Geological Survey for its very generous contribution to and cooperation in this investigation and for the privilege of publishing the results and to Dr. Karl M. Waagé for the unusual thoroughness with which the work was done and for the completeness with which the results are presented.

JOSEPH T. SINGEWALD, JR., *Director.*

CONTENTS

ILLUSTRATIONS

REFRACTORY CLAYS OF THE MARYLAND COAL MEASURES

BY

KARL M. WAAGÉ

ABSTRACT

Detailed stratigraphic study of the underclays of the Maryland coal measures by the U. S. Geological Survey in cooperation with the Maryland Department of Geology, Mines and Water Resources was made possible by U. S. Bureau of Mines core-drilling programs in the Georges Creek, Upper Potomac, and Castleman coal basins. The rocks studied include the Pottsville and Allegheny formations and the lower half of the Conemaugh formation. Results of the study are presented in two parts. Part I gives the stratigraphy of the coal measures, the details of the underclay zones, and the stratigraphic and geographic distribution of refractory clays in the Georges Creek, Castleman and northern Upper Potomac basins. Part II describes the refractory clay deposits of the Castleman basin and offers guides for future clay prospecting.

The Pottsville formation thickens appreciably from northeast to southwest in the Georges Creek and Upper Potomac basins as the number of units in the formation increases both by addition at the base of the formation and by intercalation within it. In the coal basins to the west the Pottsville formation shows greater uniformity in thickness. Strata in the Pottsville and lower part of the Allegheny formations are highly variable in thickness and lateral extent and coal beds are discontinuous; groups of coal beds rather than individual coal beds are used in correlation. As a rule the contact of the Pottsville and Allegheny formations is indefinite and the two units cannot be mapped separately. The upper part of the Allegheny formation is less variable than the lower part and includes persistent coal beds. The Conemaugh formation, which reaches its greatest thickness in western Maryland, is divided into an upper and lower member on the basis of lithology. The lower member, from the base of the formation to the top of the Barton coal, is typified by the pronounced regularity in thickness and lateral extent of its strata and by the presence of marine shales and zones of red shale and clay. The upper member has less regular strata, very few redbeds, and no marine zones.

Clays occur as the underclays of coal beds and are also present in the redbeds of the Conemaugh formation. The redbeds grade laterally into coal-bearing beds, and their clays are inferred to be genetically related to underclays. Three principal kinds of material are present in the underclay zone. Plastic clay, generally

impure, is the most common and is present in all underclay zones. In the underclays of the Upper Kittanning and higher coal beds lime-pellet clay and argillaceous limestone occur as a lateral phase of the plastic clay. Indurated clays, or claystones, are commonly present in the underclay zones of the Allegheny and basal Conemaugh strata. Where all three kinds of material are present the plastic clay and its calcareous phase ordinarily overlie the claystones. Beds gradational between the underclay zone and the sandstone beneath it consist of a silty or sandy phase of whichever kind of underclay material is locally present at the base of the underclay zone. Repetition or reversal of the preferred sequence of materials in the underclay zone indicates a compound underclay; such underclays were probably formed when the cycle of deposition was interrupted and partly or completely repeated.

Two varieties of claystone (flint clay and semiflint clay) are the principal refractory clays. Plastic and semiplastic clays are rarely of refractory grade. Silt and sand, calcareous matter, and iron, chiefly in the form of siderite, are the most common impurities in the underclay zone and locally affect the value of the refractory clay. Clay of refractory grade is present in all the underclay zones in the Allegheny formation and in a few zones in the lower member of the Conemaugh formation. The character and distribution of all the underclay zones that could possibly contain minable bodies of refractory clay are described in detail.

Refractory clays have been mined from the Maryland coal measures since 1841. The Mount Savage clay bed has been the principal source of refractory flint clay; refractory and semirefractory soft clay has come from the Mount Savage, Lower Kittanning, and Middle Kittanning beds. Until 1947 production was entirely from refractory products plants located in the north end of the Georges Creek basin. In that year a new plant in the Castleman basin began production. At present (1950) the production of refractory products in western Maryland is not up to capacity and a shortage of raw clay appears imminent.

Specific data on the distribution of refractory clay deposits are given for the Castleman basin which is the least known of the coal basins that have facilities for the manufacture of refractory products. The Mount Savage clay, Bolivar clay, Middle Kittanning clay and Upper Kittanning clay, in order of their probable importance, are the only clay beds that are likely to contain bodies of refractory flint clay. The Mount Savage clay is the best prospective source. Refractory and semirefractory soft clay seldom occurs outside of the Mount Savage, Lower Kittanning, and Middle Kittanning clay beds. It is common locally in the weathered zone of outcrop of these units but seldom persists at depth. Commercial bodies of both flint and plastic clay are lenticular in shape and few in number. Reserves of refractory clay in the Castleman basin are critically low and extensive programs of systematic prospecting for new clay bodies are necessary to forestall an acute shortage of raw clay in the near future.

PART I. REFRACTORY CLAYS IN THE COAL MEASURES OF THE GEORGES CREEK, CASTLEMAN, AND NORTHERN UPPER POTOMAC BASINS OF MARYLAND

Introduction

BASIS FOR PRESENT STUDY

The present study of clay deposits in western Maryland was undertaken as a cooperative project between the Maryland Department of Geology, Mines and Water Resources and the U. S. Geological Survey. Though primarily concerned with refractory clays the work was intimately associated with two diamond core-drilling projects conducted by the U. S. Bureau of Mines to investigate coal reserves (Project 818 in the Georges Creek and north end of the Upper Potomac basins and Project 823 in the central part of the Castleman basin). Fortunately this drilling explored a section of the coal measures that includes the interval within which lie the high-grade clays of the northern Appalachian bituminous coal fields. Through cooperative agreement with the U. S. Bureau of Mines opportunity was afforded to study the drill cores and sample the clays. As a result a large amount of information on the stratigraphy of the coal measures and on the character and relationships of the clay beds was obtained.

In addition to the subsurface data furnished by the drilling, data were obtained by surface exploration in the Castleman basin, consisting of areal geologic mapping, some preliminary prospecting work, and study of the known clay deposits. U. S. Bureau of Mines Project 818 was begun late in January 1945 and completed in July 1946; 26 holes with a total footage of 22,350 feet were drilled. In May 1947 Project 823 was begun. The last of 40 drill holes totaling 25,205 feet was completed in May 1949. Field work in the Castleman basin was carried on concurrently with work on the Bureau of Mines projects from June 1945 through July 1946, and during the summers of 1947 and 1948. Drill cores were logged and sampled for clays throughout the duration of both projects.

PURPOSE AND SCOPE OF THE REPORT

Efficient exploration for clay deposits requires (1) a thorough geologic study of the character and distribution of rock formations that are likely to contain clay beds and (2) the systematic prospecting of these formations. Part I attempts to fulfill the first requirement by presenting in detail the geology of the clay-bearing portion of the Maryland coal measures. This geologic background is

intended to serve as a general guide to prospecting for clays of refractory grade in the Maryland coal basins.

Prior to 1945 the search for minable bodies of refractory-grade clay in western Maryland was restricted to the Georges Creek basin because it was the only coal basin with facilities for the production of refractory products. The construction of a refractory products plant in the Castleman basin during 1945 and 1946 attracted attention to the lack of knowledge of the clay beds in that basin and prompted the study presented in Part II. The primary purpose of this study has been to evaluate the known clay deposits and to delimit those parts of the basin that merit additional prospecting.

PREVIOUS GEOLOGIC WORK IN THE MARYLAND COAL MEASURES

Because of the economic importance of the coal-bearing beds a considerable amount of geologic work has been done in western Maryland. The results of much of this work have been published in the early reports of the Maryland Geological Survey; some have appeared in publications of the U. S. Geological Survey and in various scientific periodicals. In the county reports of the Maryland Geological Survey a complete bibliography for Garrett County up to 1902 is given by Martin (1902, pp. 67–81), and a similar one for Allegany County up to 1899 is given by O'Hara (1900, pp. 69–83). The most informative publications on the geology of the Maryland coal measures since 1902 are those by Clark, Martin, et al. (1905), Martin (1908), Swartz, Price, and Bassler (1919), and Swartz and Baker (1922).

The stratigraphy of the Maryland coal measures was treated in detail by C. K. Swartz in the Second Report on the Coals of Maryland, Part I of Volume XI of the Maryland Geological Survey (Swartz and Baker, 1922). This report rectified the errors of earlier reports and established a standard section for the coal measures of Maryland. The first comprehensive report on Maryland clays, including those of the coal measures, was given by Ries (1902). The clays of the coal measures were the subject of Part II of Volume XI of the Maryland Survey in which A. S. Watts and H. G. Schurecht discussed the technical aspects of the clays, and G. M. Hall, E. B. Mathews and C. K. Swartz discussed clay in general, specific clay localities, and the geology of the clay-bearing strata. Other mention of Maryland clay deposits was made by Ries (1903 and 1927, pp. 446–455) and Leighton (1941) but their information was derived principally from the volumes of the Maryland Geological Survey.

ACKNOWLEDGMENTS

The initial geologic work on Project 818 was carried on by Charles W. Merrels, 2d, and Norman Denson, both of the U. S. Geological Survey, who accumulated the data on coal, and by the writer who accumulated the data on clay. With the transfer of Merrels and Denson to other assignments the writer assumed responsibility for all geologic work. During the spring and early summer

of 1946, C. N. Bozion of the U. S. Geological Survey assisted the writer with both the drilling project work and the clay work.

During the writer's absence in the early part of the summer of 1948, when U. S. Bureau of Mines Project 823 was begun in the Castleman basin, Thomas W. Amsden of the Maryland Department of Geology, Mines and Water Resources accumulated the data from the drill cores and also aided in getting field data for the geologic map of the basin. Thereafter the writer was responsible for both the geologic work on the drilling program and the geologic mapping and clay work. In this work he was assisted by Herbert P. Bangs, Jr., who accumulated the drilling data during the winter and helped with the areal mapping during the summer. All field work was completed by May 1949.

The writer is indebted to his coworkers and assistants from the Federal and State Geological Surveys, whose names have already been mentioned, for their help in collecting the data on which this report is based. He is also grateful to the men of the Fuels and Explosives Division of the U. S. Bureau of Mines for their friendly cooperation. Special thanks are due Lloyd Williams, Project Engineer for the Bureau of Mines, for his cooperation and willing assistance during both projects.

Field work in the Castleman basin could not have been carried out without the willing help of many individuals; space permits mention of only a few of them. John J. Rutledge, then chief of the Maryland Bureau of Mines, and Frank Powers, his successor, then District Engineer for the same organization, were helpful in acquainting the writer with the region. The writer is particularly indebted to J. Max Mathias for the benefit of his considerable experience with the Maryland refractory clays and for his willingness to help at all times. The clay exploration and geologic work in the Castleman basin was benefited appreciably by the help and stimulating interest of Louis Morgart of Jennings and by the unselfish assistance of Harry Miller, whose extensive knowledge of the mines in the Castleman basin was invaluable.

GENERAL GEOLOGY OF THE MARYLAND COAL MEASURES

DISTRIBUTION OF THE COAL MEASURES

The coal-bearing strata of Maryland consist of a series of relatively thin alternating units of sandstone, siltstone, shale, coal, clay, and limestone of Pennsylvanian and Permian age. The standard subdivisions of the Pennsylvanian strata, in ascending order, are the Pottsville, Allegheny, Conemaugh, and Monongahela formations; the Permian strata are included in the Dunkard group, which consists of the Washington and Greene formations. These subdivisions are shown graphically in Figure 1, a skeleton section of the Maryland coal measures. The base of the coal measures section is recognized everywhere as the contact of the Pottsville formation with the underlying red shales of the Mississippian Mauch Chunk shale.

The strata of the coal measures are contained in three roughly parallel structural troughs that trend northeastward across the western end of the state in Allegany and Garrett Counties. Older strata of different character are exposed

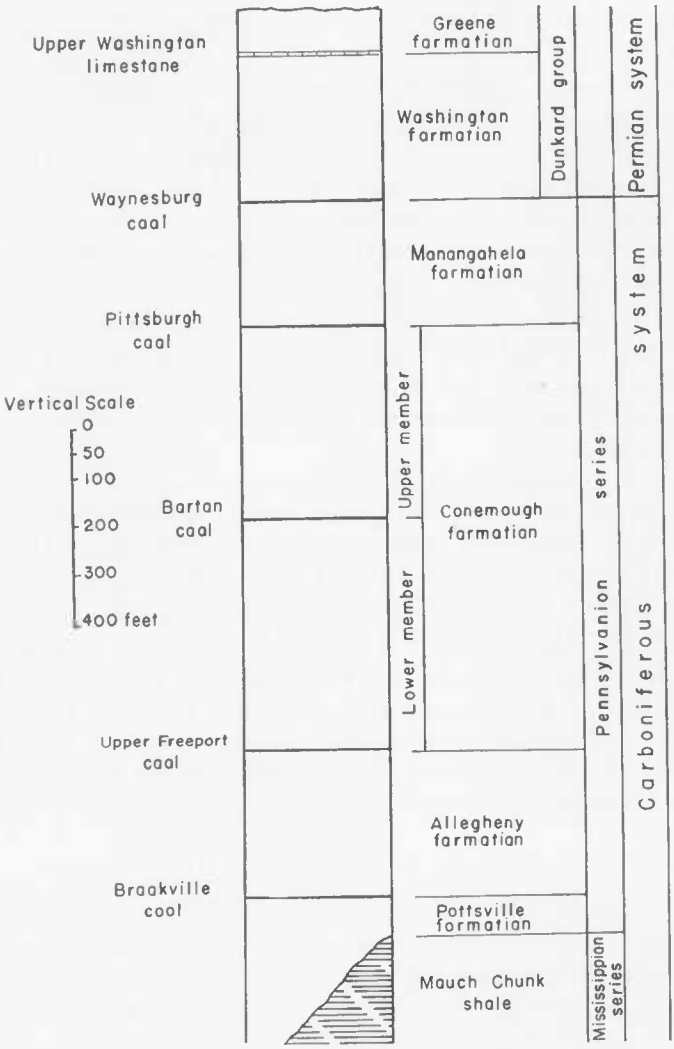


FIGURE 1. Subdivision of the coal measures of Maryland

on the anticlines that separate the troughs. Five separate coal fields, or coal basins, are recognized within the three troughs; their distribution is shown in Figure 2. The eastern trough is continuous across the State but is divided geo-

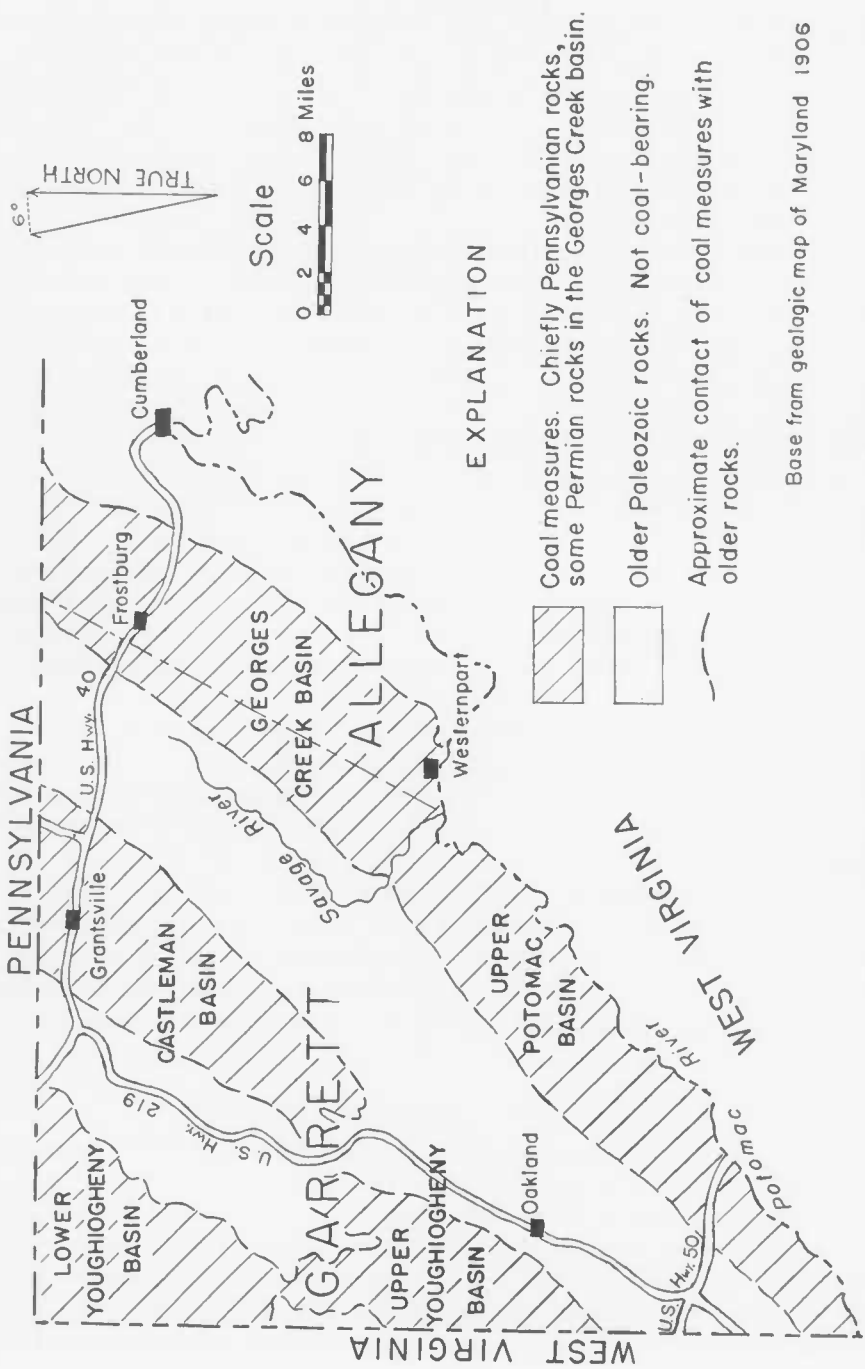


FIGURE 2. Distribution of the coal measures in Western Maryland

graphically by the Potomac and Savage Rivers, which breach the flanks of the trough at the latitude of Westernport. That part of the trough lying north of the rivers has been named the Georges Creek basin for the stream that drains it to the south. The southern part of the trough, through which the Potomac River flows, has been named the Upper Potomac basin. Only the northwest side of this basin lies in Maryland, as the Potomac River marks the Maryland-West Virginia boundary.

The central trough is divided structurally into two parts by a low transverse anticline. The larger northern part, drained to the north by the Casselman River, is known as the Castleman basin. The southern part of the trough is called the Upper Youghiogheny basin. The westernmost trough occupies the northwest corner of the State and is called the Lower Youghiogheny basin. The two basins take their name from the Youghiogheny River, which flows across both structures in its northward course through Garrett County.

Because the intensity of folding of the three troughs decreases to the northwest, the eastern trough is the deepest structure and contains the thickest section of coal-bearing beds. The deepest part of the eastern trough is in the central part of the Georges Creek basin southeast of the town of Frostburg. Here the Pottsville, Allegheny, Conemaugh and Monongahela formations are present and total between 1600 and 1800 feet in thickness. An additional 350 to 400 feet of strata belonging to the Dunkard group overlie the Pennsylvanian rocks.

The eastern trough becomes more shallow to the north and to the south of the central part of the Georges Creek basin. In the northern part of the Upper Potomac basin only a few small remnants of Monongahela strata are present and the youngest beds throughout most of the basin belong to the Conemaugh formation.

The central and western troughs contain no Monongahela strata. In this area the Castleman basin is the deepest basin and its deeper northern portion is underlain by beds in the middle and upper part of the Conemaugh formation. In the Upper and Lower Youghiogheny basins the youngest beds are those of the middle part of the Conemaugh formation, except for a few remnants of upper Conemaugh strata in the latter basin.

CLASSIFICATION OF THE COAL MEASURES

The earliest comprehensive studies of the coal measures of North America were made between 1836 and 1842 by the Geological Survey of Pennsylvania under the direction of H. D. Rogers. When this work was begun in 1836 the coal measures were designated as the twelfth formation of the Paleozoic strata of Pennsylvania (Rogers, 1836, p. 16). In the following year Formation XII was restricted to the Siliceous Conglomerate (Pottsville formation of the present terminology) at the base of the coal-bearing beds and Formation XIII

was added to include all coal measures above the conglomerate (Rogers, 1838, p. 71). In the Third and Fourth Annual Reports of 1839 and 1840 Rogers further subdivided the coal measures by breaking Formation XIII into an upper part, the Monongahela series,[1] and a lower part, the Allegheny series. The dividing line between these two units was approximately in the middle of what is now the Conemaugh formation.

Subsequently Rogers (1858, p. 109 and 1859, pp. 16–20) abandoned this classification in favor of a fivefold division of the coal measures, which he considered to be a more natural grouping of the strata. The basal unit, which he called the Seral conglomerate, was Formation XII under a new name. Above this came the Lower Productive Coal Measures, extending from the top of the Seral conglomerate to the top of the Freeport coal bed; the Lower Barren Coal Measures extending from the top of the Freeport to the base of the Pittsburgh coal bed; the Upper Productive Coal Measures from the Pittsburgh to the top of the Waynesburg coal bed, and the Upper Barren Coal Measures from the Waynesburg coal to the top of the coal measures. Except for occasional minor differences in the placement of the boundaries these five units have been employed ever since as the major divisions of the coal measures. The present names for the Pennsylvanian units were introduced between 1870 and 1880. J. J. Stevenson (1873, pp. 15–32) revived Rogers' names Allegheny series and Monongahela series and applied them to the Lower and Upper Productive Coal Measures respectively. Platt (1875, p. 8) introduced the term Conemaugh series for the Lower Barren Coal Measures. The Seral conglomerate was renamed the Pottsville conglomerate by J. P. Lesley (1876). The Upper Barren Coal Measures were not renamed until 1891 when I. C. White (1891, p. 22) called them the Dunkard Creek series, a name that was subsequently shortened to Dunkard series.

Rogers was guided in his classification by the relative productivity of different parts of the coal measures and, although he chose their boundaries arbitrarily, his divisions do have gross characteristics peculiar to them and have proven to be very useful in dealing with the complex stratigraphy of the coal measures section. Rogers chose coal beds to mark the boundary between divisions; thus the top of the Waynesburg coal bed marks the contact of Dunkard strata and the underlying Monongahela beds. Farther downward the base of the Pittsburgh coal bed marks the boundary of the Monongahela and Conemaugh, and the top of the Upper Freeport coal marks the contact of the Conemaugh and Allegheny. These boundaries are distinct in most areas because the coal beds on which they are based are persistent and easily identified. Such is not the case with the Allegheny and Pottsville boundary. Rogers (1858, p. 17) says in defining this contact, "It is, therefore, impossible to

[1] Rogers (1839, p. 87) first called this the Pittsburgh Series but changed the name the following year (1840, p. 150).

assign a well-defined permanent horizon of separation; but considerations of convenience dictate that we place an arbitrary boundary at the bottom of the first or lowest considerable coal-seam." Because this part of the coal measures section lacks persistent coal beds in much of the northern bituminous coal fields the "lowest considerable coal-seam" is not everywhere the same bed. As a result there is commonly disagreement from area to area as to exactly where the boundary of the Allegheny and Pottsville should be drawn.

In Maryland, Swartz (Swartz and Baker, 1922, p. 42) placed the Pottsville and Allegheny boundary "at the top of the massive sandstone lying beneath the Mount Savage coals." The basal coal of his "Mount Savage coals" he called the Lower Mount Savage coal. Although this is a thin and discontinuous bed it is doubtless a correlative of what has been called the Brookville coal in Pennsylvania, a horizon that has long marked the Allegheny and Pottsville contact in that State.

In naming the top of the sandstone underlying the Lower Mount Savage (Brookville) coal as the Pottsville and Allegheny boundary, Swartz presumably considers the top of the first sandstone under a limiting coal bed to be a more suitable boundary than the top or bottom of the coal bed itself. As the entire sequence from the coal downward to the base of the sandstone beneath is a gradation there is no theoretical basis for this position. From a practical viewpoint the top or base of a coal bed is a far more definite horizon for division than the top of a sandstone that generally grades imperceptibly upward into a silty underclay.

Since the recognition of sedimentary cycles in the Pennsylvanian, there has also been a move to shift the boundaries of some of the subdivisions to the base of the sandstone underlying the limiting coal beds. Because this horizon is a sedimentary break there are theoretical grounds for this position. The Pennsylvanian subcommittee of the National Research Council Committee on Stratigraphy (Moore et al., 1944, p. 683) moved the Pottsville and Allegheny contact from the Brookville coal downward to the base of the Homewood sandstone, reasoning that a clastic deposit of this type ". . . rather than a coal bed, logically belongs at the base of a series." However, it is stated in the same paragraph that "All agree that the top of the Alleghenyan series belongs at the top of the Upper Freeport coal." As the Pennsylvanian subdivisions are arbitrary by definition there is little reason for readjusting Rogers' original boundaries. The fact that adherents to a genetic subdivision are openly inconsistent indicates that there is little practical value in its adoption.

The majority of state geological surveys and most American geologists classify the Pennsylvanian rocks as a system and the Pottsville, Allegheny, Conemaugh, and Monongahela divisions as series. On the further subdivision of these series into formations and members there is not general agreement. The U. S. Geological Survey holds to the original classification of the Penn-

sylvanian rocks as a series within the Carboniferous system; the Pottsville, Allegheny, Conemaugh, and Monongahela divisions are classified as formations. This report follows the usage of the U. S. Geological Survey and the classification employed is shown in Figure 1. The only departure from previous usage is the subdivision of the Conemaugh formation into two members. The large number of lithologic units recognized as subdivisions of the Pottsville, Allegheny, and Conemaugh formations in this study are necessarily considered to be informal units of less than member rank. Terminology of these lesser units follows that used in western Pennsylvania, which is the standard terminology for the northern Appalachian bituminous coal fields. Some local names have been retained where correlations are not conclusive or where the names have gained more than local usage.

LITHOLOGIC CHARACTER OF THE COAL MEASURES

The general stratigraphic features of the Maryland coal measures can best be understood by treating the coal measures section as a whole and ignoring, for the moment, its somewhat misleading subdivision into formations. Basically the section consists of repetitions of a sequence of five principal rock types which are, in ascending order, sandstone, clay, limestone, coal, and shale. Scores of such sequences follow one upon another, the sandstone of one sequence resting disconformably on the shale of the sequence below it. The individual sequences and the rock units within them vary in thickness, lateral extent, and in the type of rocks they contain. As a result the coal measures are not uniform throughout but change gradually in character from one part of the section to another.

The principal differences between parts of the coal measures section are the result of changes in the degree of irregularity in the thickness and lateral extent of the rock units. Where the strata are highly irregular[2] coal beds are discontinuous and sandstones are the dominant lithologic type, tending to occur in thick lenses of limited lateral extent. Where the strata are relatively regular individual coal beds are persistent over large areas and sandstones are second in importance to clays and shales. All stages of gradation can be found between the extremes of regular and irregular strata; abrupt changes from one to the other have not been noted in any part of the Maryland coal measures.

Other differences between parts of the coal measures section result from the appearance of different rock types, a feature closely associated with the degree of irregularity of the strata. In highly irregular strata there is little variety in rock type and the principal rock units are sandstone, dark gray to black shale

[2] The adjectives *irregular* and *regular* are used in the description of stratigraphic units throughout the remainder of the report. Unless otherwise stated, these adjectives imply irregularity and regularity in both the thickness and the lateral extent of the units designated by the nouns modified.

and clay, and coal. As the regularity of section increases, certain rock types change and other rock types appear. One of the first changes that take place is that the clay beneath the coal beds becomes lighter in color and contains beds of argillaceous limestone. Beds of red clay and shale and black shale with marine fossils make their appearance in parts of the section with markedly regular strata.

The subdivisions of the coal measures in the northern Appalachian coal fields, based as they are on the separation of the coal-bearing parts of the section from the parts that contain little coal, do not correspond very closely to other more fundamental changes in the lithologic character of the coal measures. In Maryland the Pottsville and Allegheny formations both consist predominantly of sandstone and dark-gray siltstone with lesser amounts of shale, clay, and coal. Other than an increase in the number of coal beds little change in character is evident from one division to the other as the Pottsville formation and the lower part of the Allegheny formation together constitute a zone of irregular strata. In the upper half of the Allegheny formation the strata gradually become more regular, several persistent coal beds are present and fresh-water limestone occurs locally in the clays beneath the coal beds. Thus a major change in the coal measures section takes place within the Allegheny formation. The combined Pottsville and Allegheny formations in Maryland range in thickness from a minimum of 335 feet in the north end of the Georges Creek basin to a maximum of more than 600 feet at the south end of the Upper Potomac basin. The difference is due to progressive thickening of the Pottsville formation to the southwest.

The Conemaugh formation as a whole differs from the underlying Allegheny formation in possessing more varied lithologic types and in having a considerably lower percentage of sandy strata. The trend toward regularity of strata begun in the upper part of the Allegheny formation is continued and reaches a maximum, for the Maryland coal measures section, in the lower half of the Conemaugh formation. This part of the Conemaugh is particularly striking in lithologic character as it contains a well-defined succession of beds including persistent coal beds, fresh-water limestones, fossiliferous marine shales, and beds of red clay and shale. In contrast the upper part of the Conemaugh formation in Maryland rarely contains redbeds, lacks the fossiliferous marine shales and, because the strata are less regular, the coal beds are less persistent. The change from the markedly regular and varied strata in the lower part of the Conemaugh to the less regular strata in the upper part is a gradual one.

The Conemaugh formation reaches its maximum thickness for the Appalachian coal fields in the Georges Creek and Castleman basins and in adjacent parts of Somerset County, Pennsylvania. The greatest thickness recorded in Maryland is 928 feet, which is the thickness indicated by a composite of two diamond-drill-hole sections in the north half of the Georges Creek basin.

The Monongahela formation is similar in lithologic character to the upper part of the Conemaugh formation, but the presence of several thick and persistent coal beds in the lower two-thirds of the formation, including the well-known Pittsburgh coal bed at its base, provides a contrast between the two units. In Maryland the Monongahela formation, which is preserved in its entirety only in the Georges Creek basin, is about 250 feet thick. Above the Monongahela formation in this area lie 350 to 400 feet of coal measures of Permian age included in the Dunkard group. These beds are similar to the strata in the upper part of the Conemaugh formation and differ from the Monongahela strata in their lack of thick and persistent coal beds.

TERMS RELATING TO COAL BEDS

Two terms, "coal horizon" and "coal group", are used throughout this report in describing the coal-bearing strata. Both terms have been used before in the literature on the coal measures. In this report they are defined as follows:

Coal horizon.—Where a coal bed is absent its position in the section is marked by the contact of the shale that normally overlies the coal with the clay that normally underlies the coal. Specifically the coal horizon is the plane of contact between the shale and clay. Used in a more general sense a coal horizon is a position in the stratigraphic section at which a coal bed is likely to occur or does occur. Thus the Upper Kittanning horizon refers to that position in the Allegheny section at which the Upper Kittanning coal bed occurs.

Coal group.—In the zone of irregular strata in the Pottsville formation and lower part of the Allegheny formation the coal beds are nonpersistent and vary in number from place to place. Here the application of names to individual coal beds is impracticable and a flexible terminology is needed. The discontinuous coal beds are clustered or grouped within fairly well defined units that consist largely of argillaceous rocks; these are separated from one another by sandstone units. The term "coal group" is used for coal-bearing units of this type that contain two or more discontinuous coal beds.

STRATIGRAPHY OF THE CLAY-BEARING ROCKS

THE SECTION STUDIED

Refractory clays of the northern Appalachian bituminous coal field are limited in their stratigraphic range to the lower part of the coal measures section. In most parts of the field the highest refractory clay horizons in the section are in the lower third of the Conemaugh formation. In Maryland the Conemaugh formation is divisible into an upper and lower member at the horizon of the Barton coal, which occurs approximately in the middle of the formation. This stratigraphic study is restricted to that part of the coal measures lying

below the Barton coal. In this part of the section are found all the refractory clay horizons in the Maryland coal basins.

The following discussion of the stratigraphy of the Pottsville, Allegheny, and lower member of the Conemaugh formation is based primarily on the data from the U. S. Bureau of Mines drilling projects in the Georges Creek, Upper Potomac, and Castleman basins. On the projects a total of 66 holes was drilled, 32 of which were begun above the Barton coal and 28 below this coal bed but above the Lower Bakerstown coal, which lies about midway between the Barton coal and the base of the Conemaugh formation. The remaining six holes started in the basal part of the Conemaugh formation. Most of the holes were bottomed after penetrating the Brookville coal horizon which marks the base of the Allegheny formation in Maryland. To furnish stratigraphic control, eight holes were continued through the Pottsville formation and bottomed in the Mauch Chunk shale of Mississippian age. Where possible the drilling data were supplemented by field observations, logs of holes drilled by private companies, and information from sources listed in the bibliography. Locations of the drill holes in the Georges Creek and Upper Potomac basins are shown on Figure 3, and those in the Castleman basin on Plate 8.

POTTSVILLE FORMATION

General Character

The Pottsville formation crops out in the rims of the several coal basins of Maryland. The sandstones and conglomerates near the base of the unit form the high ridges that border the basins. The abrupt outer sides of these ridges are characterized by cliffs where the sandstones are hard and massive and by steep slopes with large float blocks of sandstone where the lithology is more varied. In most places the outcrop of the uppermost beds of the Pottsville formation extends a short distance down the forested back slopes of the ridges. An exception to this location of the Pottsville occurs in the northern part of the Georges Creek basin where the Pottsville formation is thinnest. Here the outcrop of the Pottsville formation is largely confined to the outer cliff-face of the ridge, whereas the crest is formed by sandstones in the lower part of the Allegheny formation.

In Maryland, the Pottsville formation is considered to include the beds lying between the Mississippian Mauch Chunk shale and the base of the Brookville coal (the Lower Mount Savage coal of Swartz, 1922). The beds in this interval consist of a variable number of sandstone units separated by dark gray and black siltstones, claystones, and shales. Sandstone is the predominant lithology and siltstone and claystone are second in frequency of occurrence. Together these three rock types comprise between 85 and 90 per cent of the total thickness of the Pottsville; shale and coal make up the remainder.

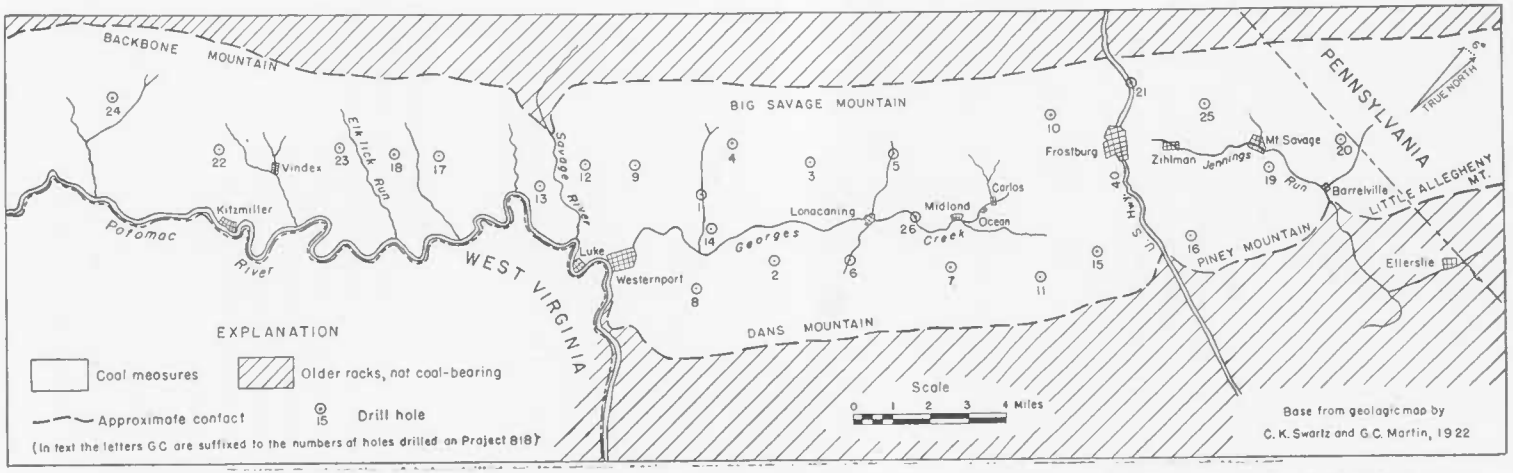


FIGURE 3. Location of holes drilled by U. S. Bureau of Mines, Project 818, in the Georges Creek and Upper Potomac coal basins of Maryland.

A gradual increase in the thickness of the Pottsville takes place southwestward from the northeast end of the Georges Creek basin, where drill hole 20-GC, located just south of the Pennsylvania state line, penetrated about 60 feet of Pottsville strata between the horizon of the Brookville coal and the Mauch Chunk shale. Southwestward through the Georges Creek basin and in the north end of the Upper Potomac basin, the thickness of the Pottsville formation increases to approximately 330 feet in 32 miles airline from hole 20-GC. About 22 miles farther southwest, in the part of Tucker County, West Virginia, adjacent to the Maryland state line, Reger (1923, p. 127) measured

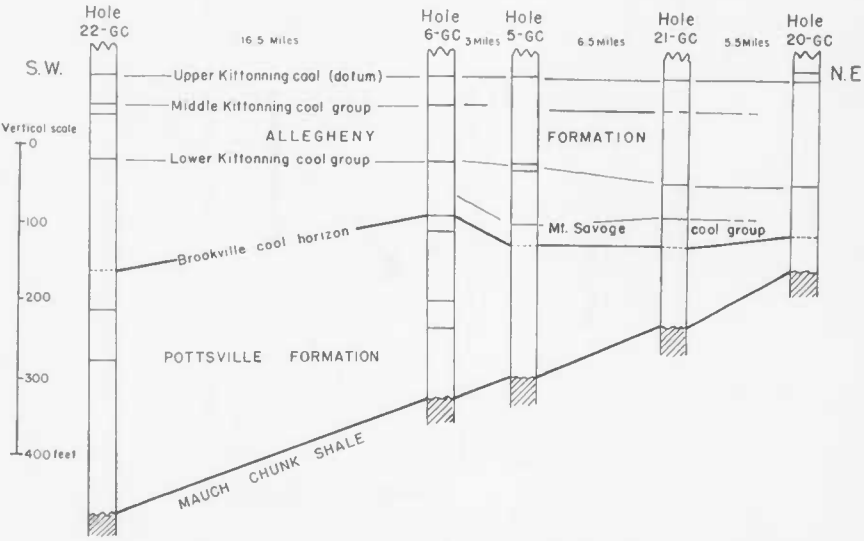


FIGURE 4. Progressive thickening of the Pottsville formation to the southwest in Georges Creek and Upper Potomac basins shown by partial sections from U. S. Bureau of Mines drill holes.

444 feet of strata in the interval between the Brookville coal equivalent, which is the Upper Mercer coal of Reger's section, and the Mauch Chunk shale.

The thickening of the Pottsville formation to the southwest in the Georges Creek-Upper Potomac trough is shown graphically in Figure 4. This increase in thickness is part of a regional stratigraphic trend and represents the northern edge of a great wedge of Pottsville sedimentary rocks that attains a maximum thickness of 9000 feet in Alabama and contains the commercial coal beds of the southern Appalachian bituminous fields.

West of the Georges Creek-Upper Potomac trough the coal basins of Maryland show a relatively uniform thickness of the Pottsville formation. In the Castleman basin two drill holes penetrated 180 and 200 feet of Pottsville rocks. Just north of the Maryland-Pennsylvania line, in the continuation of the

Castleman basin, a drill hole of the Union Fire Brick Company penetrated 205 feet of Pottsville rocks. In the Upper and Lower Youghiogheny basins, the westernmost basins in Maryland, and in adjacent Preston County, West Virginia, sections of the Pottsville described in bulletins of the geological surveys of both states show that the thickness of the Pottsville ranges between 180 and 250 feet.

The Pottsville and Allegheny Boundary

Swartz (Swartz and Baker, 1922, p. 43) indicated the correlation of his Lower Mount Savage coal of Maryland with the Brookville coal of Pennsylvania, placing the upper boundary of the Pottsville formation at the top of the sandstone (Homewood) below this coal. Ashley (1945) in his review of the Pottsville and Allegheny boundary problem, pointed out that the Brookville coal in the middle Allegheny valley area in Pennsylvania was originally misidentified and called the Craigsville coal, whereas the name Brookville was applied to a lower bed now known to be the Upper Mercer coal. That Swartz's correlation of the Lower Mount Savage coal was with the true Brookville coal horizon is substantiated by a footnote (Swartz and Baker, 1922, p. 43) in which he stated his belief that the Craigsville coal of the middle Allegheny area was the equivalent of the Brookville coal. The detailed work of Renick (1924) corroborated this belief.

Interpretation of the data from the recent drilling projects in western Maryland substantiates Swartz's correlation of the Lower Mount Savage coal with the Brookville coal and the latter name is adopted here in place of the former. The name Mount Savage coal is herein applied only to the Upper Mount Savage coal of Swartz's terminology. Throughout western Maryland the Brookville coal, or its horizon, lies approximately 275 to 300 feet below the Upper Freeport coal. The Pottsville and Allegheny boundary is taken as the base of the Brookville coal where it is present, or at its horizon as indicated by associated strata.

Subdivisions of the Pottsville Formation

Lithologic units within the Pottsville formation are difficult to define. The dominant units, which consist of sandstone and conglomeratic sandstone, are locally discontinuous and vary in number from place to place. This variation is due in part to the addition of new units as the Pottsville thickens southwestward, but much of the variability results from sharp local changes in the character and thickness of the individual beds. Some sandstones thicken greatly in a short distance, coalescing with adjacent sandstone beds to exclude the intervening argillaceous units. Some sandstone units also grade laterally, within a short distance, into interbedded siltstone and fine-grained sandstone and thence into silty argillaceous beds.

One of the principal difficulties in attempting to subdivide the Pottsville of western Maryland is the lack of key beds which would serve as means of correlation with the more clearly delimited units of the Pottsville formation of adjacent states. The persistent marine horizons in the upper part of the Pottsville formation of West Virginia and other states in the southern Appalachian region, and the Mercer marine horizon in northwestern Pennsylvania and in Ohio are not found in the Maryland Pottsville formation. Swartz (Swartz and Baker, 1922, pp. 34–41) reported fossil shells from several horizons in the Pottsville of the Georges Creek basin but they were undiagnostic forms and correlation of the horizons with marine zones elsewhere was made solely on attending physical criteria. Persistent beds of distinctive lithology are also lacking. Certain coals have distinctive partings and "splits" within local areas but none are recognizable by these characters beyond limited portions of the individual coal basins.

A comparison of the intervals between the several coal horizons of the Pottsville formation and more persistent horizons higher in the section is of some value in correlation. However, the accuracy of this method is limited in its application to the Pottsville formation by the fact that there are no widely persistent coal beds in the lower part of the Allegheny formation to use as control horizons. The first easily identifiable and persistent horizon above the Pottsville formation in most of the Maryland basins in the Upper Kittanning coal, a horizon too far above the coal beds of the Pottsville formation to afford precise control, considering the known variability in thickness of the intervening beds.

Correlation within the Pottsville formation of Maryland depends primarily on matching similar sequences of beds. In the three western coal basins uniformity is apparent in the gross sequence of the sandstone beds and argillaceous units within the formation. Here five to seven subdivisions of the Pottsville formation can be recognized locally. In the eastern coal basins the pronounced increase in thickness to the southwest introduces complexities in the Pottsville formation, and the number of recognizable divisions increases from three in the north end of the Georges Creek basin to fifteen in the south end of the Upper Potomac basin.

Castleman Basin.—In the Castleman basin the Pottsville formation is about at its average development for western Maryland as a whole. Throughout the basin the formation ranges from 150 to 250 feet in thickness and consists of several sandstone units separated from one another by dominantly argillaceous strata that are locally coal-bearing. In Figure 5 the relations of these units to one another are shown graphically in sections of two drill holes that penetrated the Pottsville. The Homewood sandstone, Mercer coal group, Upper Connoquenessing sandstone and Sharon sandstone are the most persistent units in the formation and they can be recognized throughout most of the

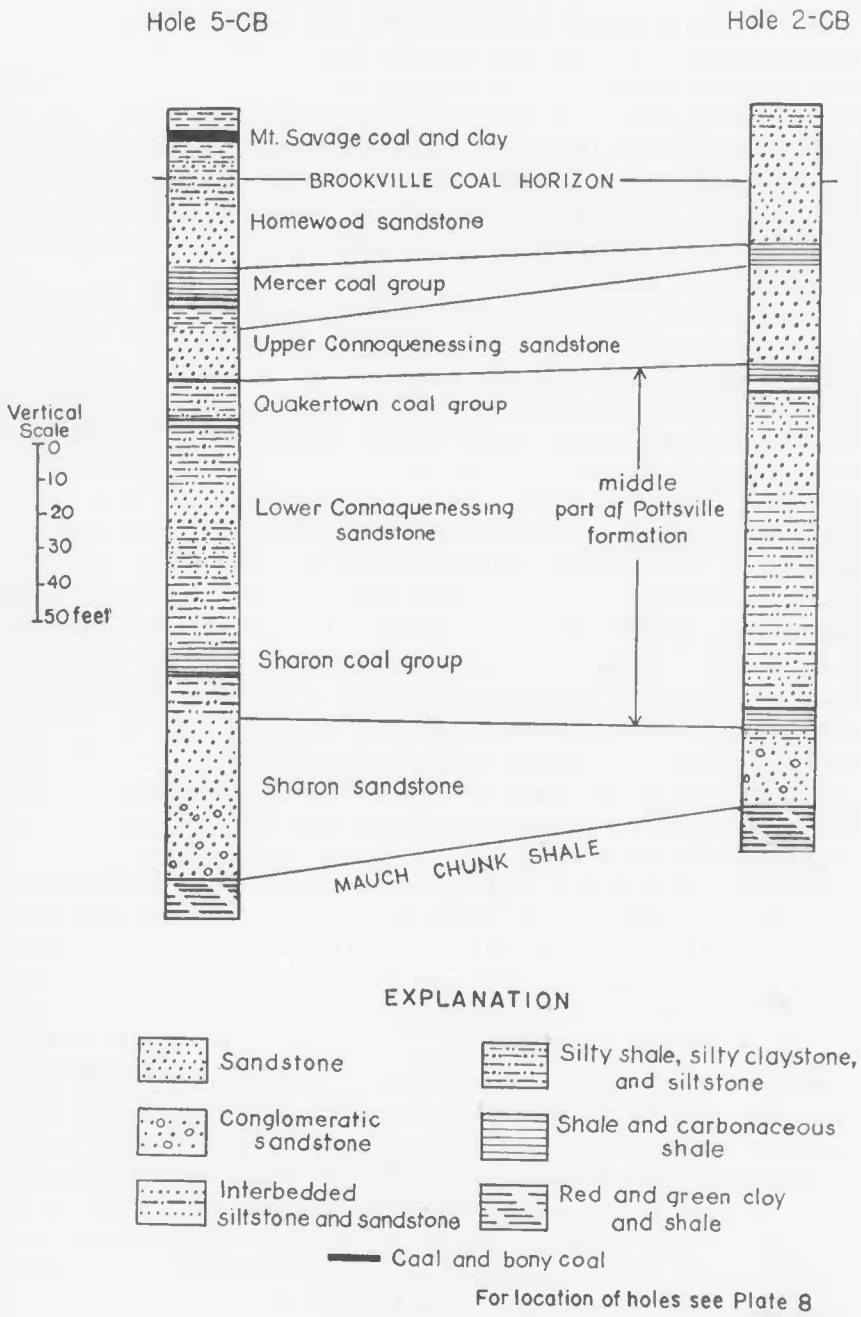


FIGURE 5. Sections of the Pottsville formation from U. S. Bureau of Mines drill holes in the Castleman basin.

Castleman basin in spite of the fact that they vary in thickness and character from place to place. The sandstone units are commonly represented by massive beds of medium-grained to conglomeratic sandstone but each unit locally grades laterally into a less prominent phase of siltstone with interbeds of fine-grained sandstone. This change is generally accompanied by a decrease in the thickness of the unit. The Mercer coal group consists of a zone of dark-gray and black shale, clay and silty shale, and clay from a few feet to 25 feet in thickness. A bony coal as much as 4 feet thick is present in many parts of the basin.

The sequence of rock units in the middle part of the Pottsville formation, between the base of the Upper Connoquenessing sandstone and the top of the Sharon sandstone, is less well defined. In most places this interval consists of a clastic zone of silty clay, siltstone and sandstone lying between two zones of argillaceous beds that locally contain thin, discontinuous coal beds. The clastic zone varies abruptly, both vertically and laterally, in the amount of sandstone it contains. Commonly a single massive sandstone bed is present near the top of the zone but as many as three sandstone beds have been observed in drill-core sections. In some parts of the basin the entire clastic zone is composed of siltstone and silty clay which grade imperceptibly into the argillaceous units above and below. It is this variation in the lithologic character of the clastic zone that obscures the relations of the beds in the middle part of the Pottsville formation. Where sandstone is present a threefold division is possible and the clastic zone is called the Lower Connoquenessing sandstone; the overlying and underlying argillaceous zones are called, respectively, the Quakertown and Sharon coal groups. Where the clastic zone is chiefly siltstone and silty clay and one or both of the argillaceous zones are in a silty phase it is not possible to recognize the subdivisions.

The seven subdivisions of the Pottsville formation that can be recognized in parts of the Castleman basin where the sandstone units are prominently developed and where the threefold character of the middle part of the formation is discernible have been traced by means of drill-hole records into Somerset County, Pennsylvania. The terminology provisionally applied to these units (see Figure 5) follows the terminology used for the subdivisions of the Pottsville in Pennsylvania. The names of the units are considered provisional because they were originally applied to rocks exposed in counties along the western border of Pennsylvania where rocks of the Pottsville formation differ in many respects from those in Somerset County. No detailed stratigraphic study of the Pottsville formation has been made between these two areas. Swartz (Swartz and Baker, 1922, p. 39) also used the Pennsylvania terminology for subdivisions of the Pottsville formation in Maryland, basing his correlation on the general similarity in the sequence of units of the Pottsville formation in the two States. The nomenclature of the subdivisions of the Pottsville in this report differs

from that used by Swartz in its omission of the names of individual coal beds and in the use of the term "coal group" to include the coal-bearing argillaceous units between the sandstone units. This change to a more flexible terminology is justified by the absence of persistent coal beds and the great variability, in thickness and character, of the coal-bearing units in the Pottsville formation in Maryland.

Georges Creek and Upper Potomac Basins.—Five drill holes that penetrated the Pottsville formation furnish most of the data on the subdivisions of the formation in the Georges Creek and Upper Potomac basins. Columnar sections from these holes are shown in Figure 6. The only one of the holes with a section of the Pottsville formation similar to that in the Castleman basin is hole 6-GC. In this hole the Mercer coal group is represented by about 15 feet of beds that lie between a thin Homewood sandstone and a thick section of the Upper Connoquenessing unit, which is composed predominantly of interbedded siltstone and sandstone. Beneath the Upper Connoquenessing beds are the three subdivisions of the middle part of the Pottsville, the Quakertown coal group, Lower Connoquenessing sandstone, and Sharon coal group. The remaining 75 feet of the section consists of a zone of conglomeratic sandstone about 20 feet thick that is separated from the thick medium-grained sandstone at the base of the section by 5 feet of siltstone. It is possible either to interpret the entire 75-foot section as the Sharon sandstone or to restrict the Sharon to the conglomeratic sandstone and consider the siltstone and basal sandstone as additional units not represented in the section of the Pottsville formation in Castleman basin. Comparison with other drill-hole sections, as shown in Figure 6, favors the latter interpretation.

Southwestward from hole 6-GC the Pottsville formation thickens. In hole 22-GC four units are present below the Sharon sandstone. The zone of silty shale underlying the Sharon sandstone and the thick sandstone below the shale may be represented in hole 6-GC as the correlation in Figure 6 suggests. Two additional units, a thick zone of silty shale and shale and a thin basal sandstone bring to eleven the total number of units recognizable in hole 22-GC. Additional units come in at the base of the section in the south half of the Upper Potomac basin, but no drill records are available for this area. Reger (1923, p. 127) gives a measured section from the continuation of the Upper Potomac basin into the Fairfax district in Tucker County, West Virginia, next to the southwest corner of Maryland. Here four additional units—two coal horizons and two conglomeratic sandstones—are present below what appears to be the correlative of the basal sandstone in hole 22-GC. Therefore, at its maximum development in Maryland, in the southwest end of the Upper Potomac basin, the Pottsville formation includes at least fifteen lithologic units totaling between 400 and 450 feet in thickness. No names are given to units below the Sharon sandstone in the Pottsville formation. The accurate correlation of sections of

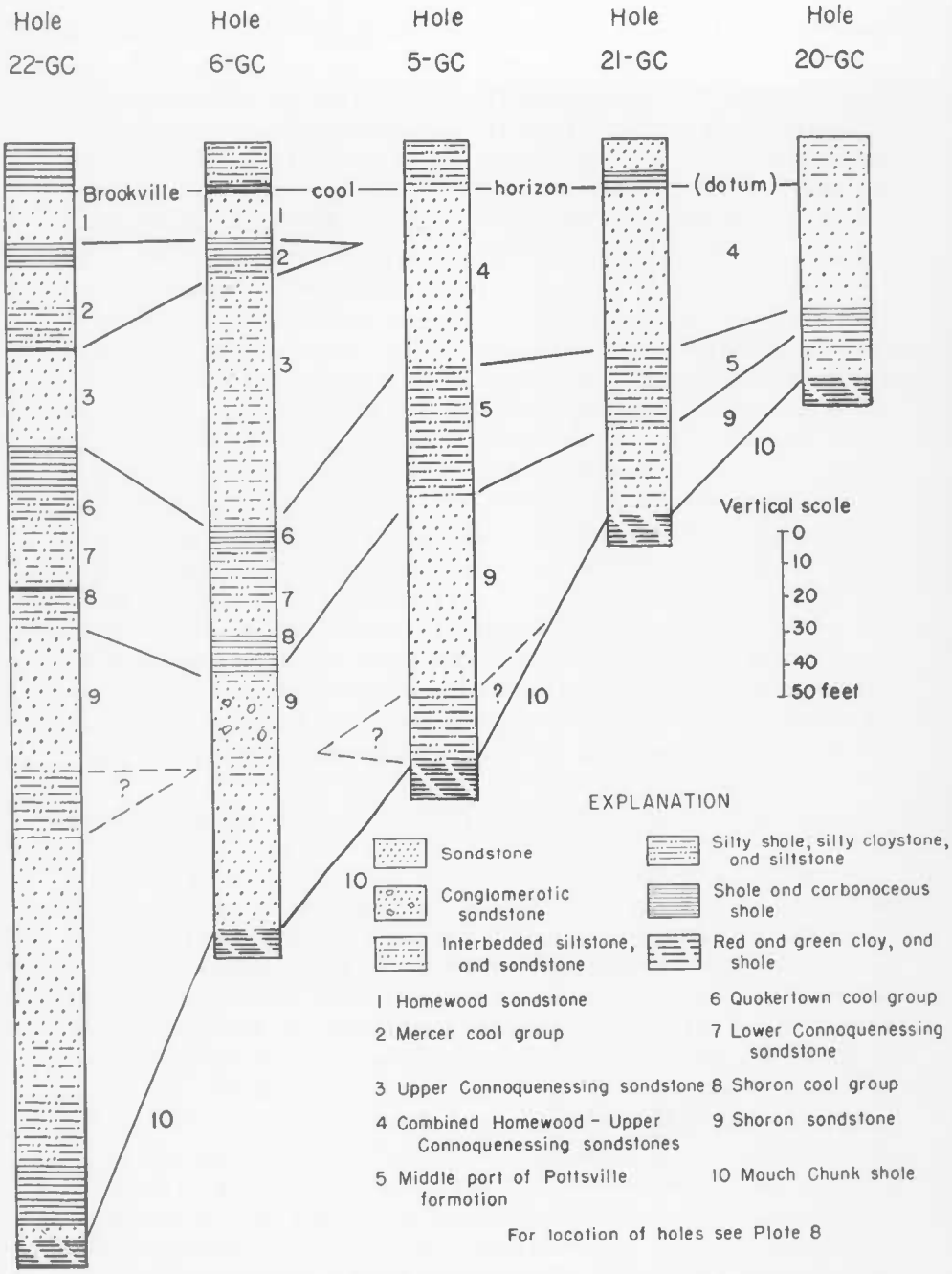


FIGURE 6. Sections of the Pottsville formation from U. S. Bureau of Mines drill holes in the Georges Creek and Upper Potomac basins.

the Pottsville formation of Maryland and West Virginia is a complex problem and not within the scope of this report.

Northeastward from hole 6-GC the Pottsville formation thins rapidly and the thinning is associated with abrupt changes in the subdivisions of the Pottsville formation. In hole 5-GC, 3 miles northwest of hole 6-GC, the Mercer coal group has been excluded by the coalescing of the Homewood and Upper Connoquenessing sandstones and is not known to reappear in the north end of the Georges Creek basin. A second change noticeable in hole 5-GC is the loss of identity of the three units in the middle part of the Pottsville; these units are represented by 40 feet of undifferentiatable silty shale and claystone. The Sharon sandstone is well developed and there is an argillaceous zone at the base of the section that may either be correlative with the unit beneath the Sharon sandstone in hole 22-GC or represent a local pocket of reworked Mauch Chunk shale.

Holes 21-GC and 20-GC in the north end of the Georges Creek basin show three subdivisions—the combined Homewood-Upper Connoquenessing sandstone, the undifferentiable middle part of the Pottsville formation and, at the base, interbedded siltstone and fine-grained sandstone that are considered to represent the Sharon sandstone. These three subdivisions thin progressively to the northeast. The 60-foot section from hole 20-GC, located near the Pennsylvania state line, is the thinnest section of the Pottsville formation recorded for Maryland.

It is apparent from the sections of the Pottsville in the Georges Creek and Upper Potomac basins that the southwestward thickening of the formation is accomplished both by the addition of new units at the base and by the intercalation of additional units within the formation. Previously it has been assumed that the thickening resulted from addition of units at the base of the section alone. This assumption introduces considerable error when applied to the problem of the subdivisions of the Pottsville formation. The usual method of identifying the subdivisions by counting off the alternating sandstone units and argillaceous units from the top down cannot be employed in areas where marked changes of thickness are evident. In hole 20-GC, for example, the units interpreted by the usual method would be, descending, the Homewood sandstone, Mercer coal group, and part of the Upper Connoquenessing sandstone, whereas it has been shown that the upper sandstone is the Homewood and Upper Connoquenessing sandstones combined and that the Mercer beds are absent.

Upper and Lower Youghiogheny Basins.—There is little information on stratigraphic details of the Pottsville formation in the westernmost coal basins of Maryland. No records of drill holes penetrating the Pottsville formation are obtainable for either the Upper or the Lower Youghiogheny basins and no extensive field work has been done in either basin since 1920. Because of the obscure outcrops, sections measured at the surface are incomplete or lack the

necessary detail to permit close comparison with the drill records from the other basins. Certain general stratigraphic features, however, are indicated by the scattered sections available. Sections of the Pottsville formation from the Upper Youghiogheny basin are given in Maryland Geological Survey reports by Swartz and Baker (1922), Martin (1902), and Clark and Martin et al. (1905) and in other sources by Martin (1908) and Swartz, Price and Bassler (1919). Of these reports only Swartz and Baker (1922) include a section of the Pottsville formation from the Lower Youghiogheny basin.

In the Upper Youghiogheny basin the Pottsville formation is between 210 and 260 feet thick and contains a sequence of beds similar to that found in the Castleman basin. Two sandstone units separated by an argillaceous unit are present at the top of the formation and are, presumably, the Homewood and Upper Connoquenessing sandstones and the Mercer coal group. Below these beds is an interval 60 to 90 feet thick that is not persistent in lithologic character and locally contains interbedded siltstone and sandstone, sandstone, and several thin discontinuous coal beds. This is probably the middle part of the Pottsville formation. If three units are present in this interval the descriptions of the sections are too generalized to permit their recognition. A sandstone from 25 to 50 feet thick is present at the base of the section and corresponds in stratigraphic position with the Sharon sandstone.

Less is known of the Pottsville formation in the Lower Youghiogheny basin. Swartz (Swartz and Baker, 1922, p. 111) presents the following generalized section but gives no source for the information on which it is based (Swartz's names for the units are omitted):

	Feet
Pottsville	
Massive conglomeratic sandstone	91
Shale	77
Sandstone	40
Shale	20
Sandstone	25
Total thickness of the Pottsville formation	253

This section is too generalized to permit comparison with the sequence in the Pottsville formation in other basins. The total thickness is similar to that of the Pottsville formation in the other western coal basins.

ALLEGHENY FORMATION

General Character

The Allegheny formation includes the beds lying between the base of the Brookville coal and the top of the Upper Freeport coal. The thickness of this

section in Maryland is relatively uniform, ranging between 275 and 325 feet. The lower two thirds of the Allegheny formation resembles the Pottsville formation in the irregularity of its rock units; the coal beds, though considerably more numerous, are only persistent locally and the lenticular sandstones vary greatly in thickness. The upper part of the section is composed of more regular strata and contains several persistent coal beds. The change from irregularity to regularity of section that takes place in the upper half of the Allegheny formation is gradual and there is no sharp division between the two facies. At some places within the individual coal basins persistent beds occur well down in the middle part of the sequence, whereas in other places the Upper Freeport coal, which marks the top of the Allegheny formation, is the only persistent bed. In general the degree of regularity in the Allegheny formation increases westward and southwestward in the coal basins.

The Allegheny formation of Maryland is similar in most respects to that of Pennsylvania, and correlation of the more persistent units in the two areas is not difficult. The principal units in the Maryland section are shown in the generalized columnar section of the Allegheny formation, Figure 7.

Lithologic Types

The Allegheny formation has a greater diversity of rock types than the Pottsville formation. The most striking difference is the greater number and thickness of coal beds, the feature that was used by Rogers as a basis for defining his "Lower Productive Coal Measures." As many as 12 coal beds are present in some sections of the Allegheny formation, but the number varies considerably from place to place. The Upper Freeport and Upper Kittanning coal beds are the most persistent, the former being the principal bed of the Allegheny formation mined for commercial coal in Maryland. Below the Upper Kittanning coal the coal beds are nonpersistent, and coal groups rather than individual beds are recognized.

The underclays of coal beds are the most varied lithologic units in the Allegheny formation and several types of clay including refractory flint clay are commonly present. Calcareous claystones and argillaceous limestones of freshwater origin are locally present in the underclays of the coal beds in the upper part of the Allegheny formation. They are generally restricted to areas where there is at least local regularity of section and consequently they are more common to the west and southwest in the Maryland coal measures terrain.

As in the Pottsville formation, sandstone is the dominant lithologic type and sandstone units occur between all the coal horizons of the Allegheny formation. The sandstones vary greatly in grain size. Conglomeratic sandstone occurs locally in each of the sandstone units but is most common in the Freeport and Kittanning sandstones. Most of the sandstone beds are massive and show cross-

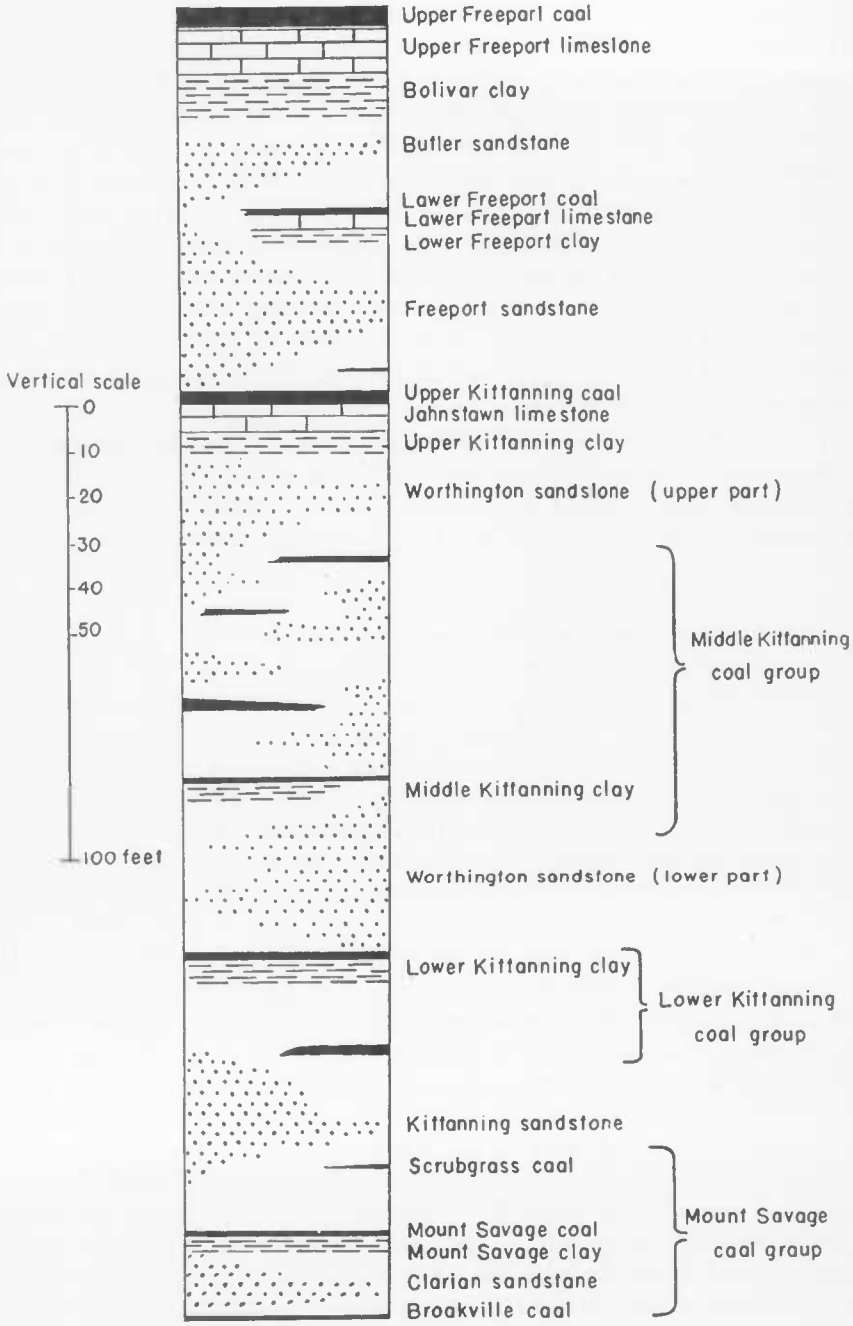


FIGURE 7. Generalized section of the Allegheny formation in Maryland

lamination. Quartzitic zones with stylolites are common in all sandstone units but are best developed in the beds in the lower half of the Allegheny formation.

The massive sandstone units are lenticular in form and grade laterally into interbedded siltstone and fine-grained sandstone, siltstone, and silty claystone. As is true of sandstone beds throughout the coal measures, units of the Allegheny thicken locally at the expense of underlying coal beds and in some places coalesce with adjacent sandstone units to exclude the intervening coal beds. Different sandstone units are dominant in different parts of the coal basins and it is unusual for every sandstone zone of the Allegheny formation to be represented by a thick bed of massive sandstone in any one section. However, a few sections of the Allegheny formation are known in which more than 80 per cent of the thickness of the formation consists of massive sandstones. Allegheny strata can generally be distinguished from overlying Conemaugh strata by the absence of zones of red clay and shale. This helpful factor in correlation is applicable to the entire northern Appalachian bituminous coal field. In Maryland a second feature worthy of note is the absence of marine shales and limestones in the Allegheny formation. The widespread Vanport limestone member of the Allegheny formation of western Pennsylvania is not present in Maryland, where marine beds are confined to the Conemaugh formation.

Subdivisions of the Allegheny Formation

Mount Savage coal group.—A group of irregular strata between 20 and 40 feet thick immediately overlies the Homewood sandstone of the Pottsville formation. These strata comprise the Mount Savage coal group. As many as three coal horizons are present locally in the Mount Savage coal group: a nonpersistent upper bed seldom more than 6 inches thick; a middle bed, the most persistent of the three, commonly about 2 feet thick; and a lower bed seldom more than 1 foot thick. Swartz (Swartz and Baker, 1922, pp. 43–45) called these beds the Upper Mount Savage rider coal, Upper Mount Savage coal, and Lower Mount Savage coal and suggested that they are equivalent to the Scrubgrass, Clarion, and Brookville coals, respectively, of the Pennsylvania section. These correlations are substantiated by the records from the recent drilling programs in Maryland.

The Upper Mount Savage coal contains locally in its underclay a flint clay that has long been the principal source of raw clay for the refractory products industry in Maryland. The coal overlies the clay and is often mined with it. In Maryland this coal and clay are called the Mount Savage; the name Clarion is seldom applied. Because it is firmly entrenched in the literature and has wide usage in the coal and clay-mining industries the name Mount Savage is retained for the Upper Mount Savage coal and its underclay. The other two coals in the group are of no economic value in Maryland and have no popular terminology,

so the better-known names Scrubgrass and Brookville are substituted for the local Maryland names. These changes are shown in the following table.

Terminology of the Mount Savage coal group in Maryland and Pennsylvania

Maryland		Pennsylvania
Swartz and Baker 1922	This Report	Clarion formation of Ashley (1928, pp. 91, 93, 114)
Upper Mount Savage rider coal	Scrubgrass coal	Scrubgrass coal
Upper Mount Savage coal	Mount Savage coal	Clarion coal
Mount Savage fire clay	Mount Savage clay	Clarion clay
Lower Mount Savage coal	Brookville coal	Brookville coal

Other than the coal beds and the local lenses of Mount Savage clay, the Mount Savage coal group consists largely of dark gray siltstones, claystones and shales. In some areas a massive sandstone is present between the Mount Savage and Brookville coals. This is the stratigraphic position of the Clarion sandstone of Pennsylvania as originally defined by Stevenson (1878, p. 43). Where the Clarion sandstone is present the Mount Savage clay is generally absent.

Sandstone lenses are present commonly in the shales above the Mount Savage coal. Almost all of these are small and of limited extent. Similar sandstones are present locally at the horizon of the Scrubgrass coal.

Kittanning sandstone.—A massive sandstone, 25 to 50 feet thick, is present in some places between the Mount Savage and Lower Kittanning coal groups. This sandstone locally replaces a large part of the Mount Savage coal group. In places it joins with the Clarion sandstone, commonly present in the same areas, to exclude the beds between, thus cutting out most of the Mount Savage coal group. Where a massive sandstone is absent, its horizon is marked by interbedded sandstone and siltstone.

Various names have been applied to this unit. Swartz (Swartz, Price, and Bassler, 1919, p. 572) called it the Mount Savage sandstone and noted (Swartz and Baker, 1922, p. 45) that it occupies the stratigraphic position of the Kittanning sandstone of Pennsylvania. In Pennsylvania the name Kittanning has been applied by some geologists to the sandstone above the Lower Kittanning coal group and by others to the sandstone below it, but the accepted definition (Wilmarth, 1938, pp. 1107–1108) follows the latter usage.

Lower Kittanning coal group.—The Lower Kittanning coal group occurs between 175 and 225 feet below the Upper Freeport coal. In sections where the underlying Kittanning sandstone and overlying Worthington sandstone are present the Lower Kittanning group is sharply defined and delimited. When either of these sandstones is absent from the sequence, the coal beds of the Lower Kittanning group may be difficult to distinguish from the nearest coal beds of the adjacent coal groups.

The Lower Kittanning coal group includes as many as four coal beds but

rarely has more than two. A common pattern for the group is two coal beds separated by 5 to 30 feet of argillaceous strata. Usually the coals are too thin to mine but there are a few local occurrences of a single bed of minable thickness at this horizon. Where a thick bed is present it commonly shows three benches of coal separated by shale partings. Minable coals are rare, however, and the Lower Kittanning coal group is far less important in Maryland than in Pennsylvania, where, next to the Upper Freeport, it is the most persistent and valuable coal of the Allegheny formation.

Associated with the Lower Kittanning coals, commonly as the underclay of the upper of two coal beds, is the Lower Kittanning clay. In many places this is a plastic to semiplastic fire clay that carries thin beds and small lenticular bodies of flint clay. A similar clay is present in some places under the lower coal bed. Both clays are included in the term Lower Kittanning clay.

As interpreted in this report the Lower Kittanning coal group includes the Lower Kittanning (Ellerslie) coal of Swartz (Swartz, Price, and Bassler, 1919, p. 572) and probably a part, at least, of his Middle Kittanning (Luke) coal. The Ellerslie sandstone, described by Swartz (Swartz and Baker, 1922, p. 47), is found in very limited areas between the two coal beds that are commonly present in the Lower Kittanning coal group. This sandstone is between 5 and 20 feet thick but grades laterally into dark gray sandy shales and siltstones.

Worthington sandstone (lower part).—In much of the area underlain by the Allegheny formation in Maryland the interval between the Lower and Middle Kittanning coal groups contains a sandstone unit. Locally this is a single massive sandstone bed that clearly separates the two groups, but in other areas it appears to be multiple-bedded and to include some of the Middle Kittanning coals in its upper part. Less commonly the sandstone occupies the entire interval between the Lower Kittanning coals and the Upper Kittanning coal bed.

In Pennsylvania the interval between the Lower and Middle Kittanning coals generally lacks a dominant sandstone unit in the eastern and central parts of the bituminous field, but a sandstone phase appears in the western part of the state. This sandstone, originally named the Worthington sandstone by W. G. Platt (1880, pp. xxi, 319) and J. P. Lesley (1876) has the same irregular character as noted for the sandstone in Maryland, appearing either locally between the Lower and Middle Kittanning coals, associated with the Middle Kittanning coal, or occupying the entire interval between the Upper and Lower Kittanning coals.

Swartz (Swartz, Price, and Bassler, 1919, p. 572) listed the Westernport sandstone of Maryland, named but not stratigraphically delimited by I. C. White in 1882 (Wilmarth, 1938, p. 2306), as lying between his Middle Kittanning (Luke) and Piney Mountain coals, the Lower and Middle Kittanning horizons, respectively, of this report. Whether the Westernport sandstone actually occupies this position in its type area around Westernport, Maryland,

or whether it is actually between the Upper and Middle Kittanning coals is open to question. Considerable local variation is shown in both the drill records and measured sections in the Westernport area, and sandstones are locally recorded in both positions.

Records from the Castleman basin show that a fairly persistent sandstone is present between the Lower and Middle Kittanning groups. In some areas, however, the upper part of this sandstone appears to extend up into and partially replace the Middle Kittanning coal group so that it is not always possible to distinguish between the two units.

According to present usage (Wilmarth, 1938, p. 2374) the term Worthington sandstone is applied to sandstones between the Lower and Upper Kittanning coals. Although intended to be more definite, the name Westernport sandstone, as it has been used in Maryland, is essentially equivalent to the Worthington sandstone but the latter name has priority of usage. As a somewhat flexible terminology is best suited to an irregular sequence of this type, the prefixes upper and lower can be used where the Worthington sandstone is clearly divided by the Middle Kittanning coal group.

Middle Kittanning coal group.—The most irregular coal group of the Allegheny formation in Maryland is the Middle Kittanning. The irregularity is not a continuous lateral change as there is relative regularity in the Middle Kittanning section within local areas. However, there is little resemblance between sections in adjacent areas.

As many as five thin coal beds are present locally in the Middle Kittanning coal group, but commonly the group is characterized by three coal beds. These fall within a 40-foot to 60-foot interval beginning between 115 and 150 feet below the Upper Freeport coal. This interval is thickest in the Georges Creek basin and thins to the west and southwest in the other coal basins.

Where the characteristic sequence of three coal beds is present in the Middle Kittanning coal group, the beds between the coals commonly consist of dark gray and black clay, shale, and siltstone. Thin beds of sandstone are commonly interbedded with the siltstone and grade laterally into massive sandstone in local areas. Sandstones of this type occur most frequently between the upper and middle coal beds. The underclay zone of the middle coal bed locally contains lenses of plastic to semiflint clay. This clay is the equivalent of the Middle Kittanning clay of Pennsylvania and probably of the Oak Hill fire clay of Ohio.

The Middle Kittanning coal group was called the Piney Mountain coal by Swartz, who recognized the threefold character of the group but believed it to be nonpersistent (Swartz and Baker, 1922, p. 48). Swartz mistakenly considered the coal below the Piney Mountain coal, his Luke coal (here included in the Lower Kittanning coal group), correlative with the Middle Kittanning of Pennsylvania, but correctly correlated the next coal above the Piney Mountain

coal with the Upper Kittanning coal. This left the Piney Mountain without an equivalent in the Pennsylvania section, thus strengthening his belief that it was only a local coal bed restricted to the Maryland section.

Worthington sandstone (upper part).—Massive sandstone is only locally present above the Middle Kittanning coal group in Maryland and is most commonly found in areas where the Allegheny formation is generally sandy throughout. Locally it coalesces with the lower part of the Worthington sandstone in and below the Middle Kittanning coal group, excluding or greatly restricting that group. Where no prominent sandstone is present the interval between the Middle Kittanning coal group and the Upper Kittanning coal is usually occupied by silty claystone and siltstone interbedded with thin layers of fine sandstone.

Upper Kittanning coal.—The Upper Kittanning coal is the lowest persistent coal bed in the Allegheny formation in Maryland. In the Georges Creek and Upper Potomac basins it lies between 80 and 105 feet below the Upper Freeport coal. This interval thins somewhat to the west and is usually between 60 and 85 feet thick in the Castleman basin and the other Maryland basins to the west. Locally a "rider" coal is present in the overlying shale between 5 and 20 feet above the main bed. The Upper Kittanning coal is commonly between 2 and 5 feet thick and has been mined commercially from some areas in western Maryland.

Argillaceous limestone of fresh-water origin is locally associated with the coal and lies immediately below it, or is separated from it by only a few inches of impure clay. This limestone is impure and grades both downward and laterally into calcareous claystone and clay with limy pellets. It is as much as 15 feet thick in some areas but averages between 5 and 10 feet. It occupies the same stratigraphic interval as the Johnstown limestone member of the Pennsylvania section. A bed of fire clay is in some places associated with the Upper Kittanning coal. It occurs under the Johnstown limestone member where the latter is present, or beneath the coal where the limestone is absent. Both plastic and flint clay are locally present, but extensive bodies of clay of minable quality are rare. The clay has been called the Hardman clay in West Virginia (Hennen and Reger, 1913, p. 347) and the name has received some usage in Maryland. The local name "Furnace clay" is sometimes used in the Georges Creek basin.

Freeport sandstone.—A massive sandstone that is locally conglomeratic is commonly present in the Allegheny formation above the Upper Kittanning coal, between it and the Lower Freeport coal. The sandstone ranges from 15 to 50 feet in thickness. In some areas it rests directly on the Upper Kittanning coal bed and locally wholly replaces the coal bed. In some localities in exceptionally sandy sections of the Allegheny formation the Freeport sandstone coalesces with the overlying Butler sandstone and underlying Upper Worthington

sandstone and forms a solid sandstone unit between the Upper Freeport and Middle Kittanning coals.

The Freeport sandstone was named by Rogers (1859, p. 476) and the name is accepted throughout most of the northern bituminous coal field. The same unit has been called the Montell sandstone in Maryland by Swartz (Swartz, Price, and Bassler, 1919, p. 572). It has also been called the Lower Freeport sandstone in both Maryland and Pennsylvania.

Lower Freeport coal.—A thin coal is present in some localities between the Upper Kittanning and Upper Freeport coal beds. Its position is variable and it may occur anywhere from 35 to 60 feet below the Upper Freeport coal. Though the Lower Freeport coal is nonpersistent and not commonly present in the Maryland section, the horizon can generally be recognized by the presence of a persistent underclay. Several feet of argillaceous limestone and limy claystone called the Lower Freeport limestone is present in the underclay zone. This unit is not common in the Georges Creek and Upper Potomac basins but is present in many places in the western coal basins. A thin bed of flinty claystone, or rarely flint clay, is locally present immediately below the Lower Freeport limestone and is known as the Lower Freeport clay.

Butler sandstone.—A sandstone unit from 5 to 60 feet thick is commonly present between the Upper and Lower Freeport coal beds. It is highly lenticular and nonpersistent. It commonly coalesces with the Freeport sandstone to exclude the Lower Freeport coal horizon.

Upper Freeport coal.—The Upper Freeport coal marks the top of the Allegheny formation, the boundary being the top of the coal bed. This coal which lies 85 to 120 feet below the Brush Creek coal of the overlying Conemaugh formation, is a persistent bed and is the principal commercial coal of the Allegheny formation in Maryland. In some areas a rider is present 10 to 25 feet above the main bed. The Upper Freeport coal has long been called the Davis coal in adjacent parts of West Virginia and is still called by that name locally in Maryland.

Below the Upper Freeport coal is a thick underclay that commonly contains two units, an upper argillaceous limestone and an underlying clay. The Upper Freeport limestone is similar to the fresh-water limestone described for the Lower Freeport and Upper Kittanning horizons and differs from these only in its greater thickness and continuity. Commonly a thin bed of impure plastic clay separates the coal and the limestone, but in many places the limestone directly underlies the coal. Argillaceous limestone is present in the upper part of the unit but grades downward to a silty clay with limestone pellets. The average thickness of the Upper Freeport limestone is about 10 feet, though locally as much as 25 feet of limestone has been recorded.

The clay unit immediately underlies the limestone. The name Upper Freeport clay has been applied to the unit, but in areas where the clay is of economic

value it is more commonly known as the Bolivar clay. The clay is a lithologically variable unit made up of plastic, semiplastic, and flint clays and impure claystone.

Sandstones in the Allegheny Formation

At some places in the Georges Creek, Upper Potomac, and Castleman basins several successive sandstone units within the Allegheny formation thicken and coalesce to exclude the intervening coal-bearing beds and form a thick body of sandstone. Two such sandstone bodies, one in the north end of the Georges Creek basin and one in the Castleman basin, are fairly well delimited by drill holes; and the presence of a third is indicated in the north end of the Upper Potomac basin. Both of the known bodies are elongate and have a well-defined northwest trend. The sandstone body in the Georges Creek basin is in the lower part of the Allegheny formation and occupies a narrow area trending northwest across the north end of the basin. Here the Worthington, Kittanning, Clarion, and probably the Homewood sandstones locally coalesce and exclude the Mount Savage and Lower Kittanning coal groups. Additional details of this sandstone body and its effect on the local distribution of clay deposits are given in the section on the distribution of the Lower Kittanning clay.

An area in the central part of the Castleman basin, including much of the southern third of the drilling area on U.S.B.M. Project 823 (see Plate 8), contains a thick body of sandstone that occupies the entire upper part of the Allegheny formation above the Middle Kittanning coal group. Four of the drill holes in this area have completely clastic sections above the Middle Kittanning coal group. In drill holes 1-CB and 3-CB, 125 feet of sandstone consisting of the coalesced Upper Worthington, Freeport, and Butler sandstone units overlies the Middle Kittanning coal group. In drill hole 11-CB, 150 feet of strata above the Middle Kittanning group consists predominantly of sandstone with some interbedded siltstone and minor amounts of silty shale. Hole 30-CB has a 200-foot section of sandstone and siltstone overlying the Middle Kittanning coal group. These four holes are at or near the middle of the sandstone body and their pattern indicates that the body trends approximately north-northwest across the basin. A short distance east of the central part of the sandstone body, in drill holes 5-CB, 18-CB, and 7-CB, only the Butler sandstone is abnormally thick, the Upper Kittanning coal is present, and the Lower Freeport coal is present excepting in hole 18-CB. To the southwest of the sandstone body, a similar change to a less sandy section of the Allegheny formation takes place. In hole 28-CB the Upper Kittanning coal is present and only the Butler sandstone is abnormally thick. The sandstone body is, therefore, relatively narrow. It has also been identified in outcrops of upper Allegheny strata along the base of both Negro and Meadow Mountains.

Another sandstone body occupying the entire upper part of the Allegheny

formation above the Middle Kittanning coal group was encountered in hole 13-GC in the north end of the Upper Potomac basin. In this area the pattern of drill holes is not such that a trend can be definitely determined for the sandstone body; however, if it is an elongate body, northwestward is the only way it can extend between known drill-hole sections and outcrops. It is quite possible that this sandstone body is a continuation of the sandstone body in the Castleman basin. Both lie in the same northwest line and both occupy exactly the same stratigraphic position.

Only one explanation seems to satisfy the known facts regarding these sandstone bodies. They apparently were deposited in drainage channels that were more or less continually occupied by streams during the deposition of large parts of the Allegheny formation. Thus the sandstone body in the Castleman basin, and possibly that in the Upper Potomac basin, marks a line of drainage that appears to have been localized soon after deposition of the Middle Kittanning coal group and to have persisted until after deposition of the Upper Freeport coal.

Similar bodies of sandstone are doubtless present in the Pottsville formation but the data on this part of the section are insufficient to permit their recognition. The sandstone bodies have economic significance in that the coal and clay beds are not generally present in and immediately adjacent to them. Thus in the Castleman basin neither coal nor clay beds can be expected at the Upper Kittanning, Lower Freeport, and Upper Freeport horizons over the area occupied by the sandstone body.

CONEMAUGH FORMATION

The Conemaugh formation includes those strata lying between the top of the Upper Freeport coal bed and the base of the Pittsburgh coal bed. In western Maryland and adjoining parts of Somerset County, Pennsylvania, the Conemaugh formation reaches its greatest recorded thickness and is generally between 825 and 925 feet thick. It consists of a variety of lithologic types including claystone, shale, sandstone, fresh-water limestone, red shale, marine shale, and coal beds. The coal beds are mostly thin, and only a few of them are of commercial value.

Lower Member of the Conemaugh Formation

The Conemaugh formation can be subdivided into an upper and lower part on the basis of certain marked lithologic differences. The division is approximately at the horizon of the Barton coal, which occurs from 450 to 500 feet above the base of the Conemaugh formation in Maryland. Between the base of the formation and the Barton coal, several beds of marine shale are present, the coal beds are relatively persistent, and the formation displays a striking regularity over broad areas. Above the Barton coal the sequence is considerably

more irregular, contains no marine beds, and the coal beds are less persistent. These differences are not confined to western Maryland but appear to hold for adjacent parts of bordering states as well. The two subdivisions of the Conemaugh are sufficiently distinct stratigraphically to rank as members. The lower member includes the strata lying between the top of the Upper Freeport coal and the top of the Barton coal, and the upper member extends from the top of the Barton coal to the base of the Pittsburgh coal.

The lower Conemaugh strata were deposited during the maximum extent of the Pennsylvanian seas in Maryland and adjacent areas. Direct evidence for this is the presence of marine shale over certain of the coal beds, a feature found nowhere else in the Maryland coal measures. Indirect evidence is the regularity of much of the lower member of the Conemaugh formation which probably results from the more stable conditions of deposition found in areas adjacent to the sea. In the upper member of the Conemaugh formation the less regular strata and the absence of marine beds indicate a return to conditions of deposition in coastal swamp areas well back from the sea and imply a withdrawal of the sea from adjacent areas.

Within western Maryland there are additional differences of a more local nature between the lower and upper members of the Conemaugh formation. Among them are the predominance of redbeds in the lower member and the greater development of fresh-water limestone in the upper member. For the formation as a whole a greater number of minable coal lenses appears to be present at the coal horizons in Maryland than in adjacent states. These additional coal lenses are the most obvious feature in the general increase in the number and diversity of units in the Conemaugh formation as it attains its maximum thickness.

The lower member of the Conemaugh formation displays a diversity of lithology that is in contrast with the underlying Allegheny formation. Two types of lithology, red clay and shale, and fossiliferous marine shale, make their first appearance in the Pennsylvanian rocks. In addition, claystone and fresh-water limestone are more common, whereas sandstone is less common.

The thickness of the lower member of the Conemaugh formation as encountered in 35 drill holes that penetrated this member ranges from 453 to 504 feet and averages about 480 feet. Variability in thickness is more pronounced in the Georges Creek and Upper Potomac basins, where the difference between maximum and minimum thickness is somewhat more than 50 feet. In the western basins this difference is about 25 feet.

Units that have been identified in the lower member of the Conemaugh formation in Maryland are listed in the generalized section of the lower member of the Conemaugh formation, Figure 8.

Though many units in the lower member of the Conemaugh formation are sufficiently well defined and persistent to be regarded as key beds, few possess

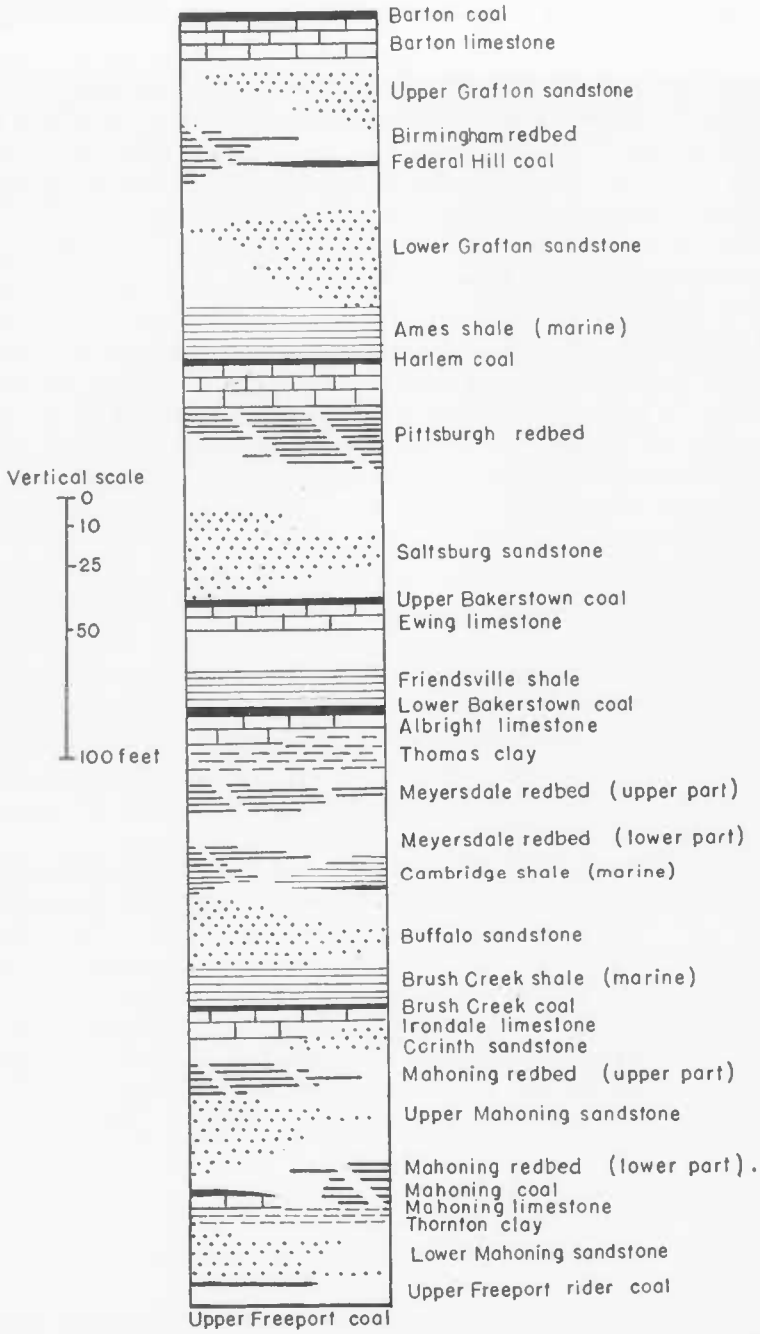


FIGURE 8. Generalized section of the lower member of the Conemaugh formation in Maryland.

distinctive characteristics that can be used to distinguish them from beds of like lithology at other horizons. When the lower member is considered as a whole, however, a striking uniformity in sequence over broad areas is shown by these key beds. Swartz, Price, and Bassler (1919, p. 579) recognized the value of this uniform sequence as the critical part of the Pennsylvanian section for regional correlation in the northern Appalachian coal fields. Using it as their primary control, they corrected previous errors in Maryland coal-bed correlation and demonstrated the relationships of the section in Maryland to that in adjacent states.

The principal key beds in the lower member of the Conemaugh formation are the coal beds, marine shales, and redbeds. The most persistent of these lie within an interval extending from the base of the Brush Creek coal to the top of the Ames marine shale. This is the most uniform part of the lower member of the Conemaugh formation in that the units are quite persistent and the intervals between them show remarkably little variation. From the top of the Ames shale to the horizon of the Barton coal the interval is uniform in thickness, but there is some variation in the character of the intervening beds. Below the Brush Creek coal the lower member of the Conemaugh formation is subject to considerable local variation in thickness and lithologic character. This interval, which is about 100 feet in average thickness, can be considered to be a zone of transition between the Allegheny formation and the regular and lithologically varied beds of the lower member of the Conemaugh formation above the Brush Creek coal.

The Upper Freeport Coal—Brush Creek Coal Interval

This interval ranges from 80 to 135 feet in thickness. Although some of the variation in thickness results from local changes in the individual units, the averages for the total thickness of the interval in the several basins indicate a slight increase to the west. The stratigraphy of the interval is complex and the true relationships of the numerous units that have been given local names are obscure. Ten units are locally present between the Upper Freeport coal and the Brush Creek coal in western Maryland (see Figure 8) but nowhere are all known to occur together in the same section.

Study of more than 60 complete sections penetrated in diamond drill holes in the Georges Creek, Upper Potomac, and Castleman basins indicates that there are two distinct phases of the interval. In one phase the rocks in the interval are predominantly sandy and a coal bed, the Mahoning coal,[3] is present. In the other phase, the interval is characterized by a preponderance of claystone, a double redbed zone is present, sandy zones are poorly developed, and no coal is present. Intermediate stages between these two phases are represented in many of the drill-hole sections. In none of them, however, is the Mahoning coal present in the same section as a redbed.

[3] The Piedmont coal of Swartz (Swartz and Baker, 1922, p. 55).

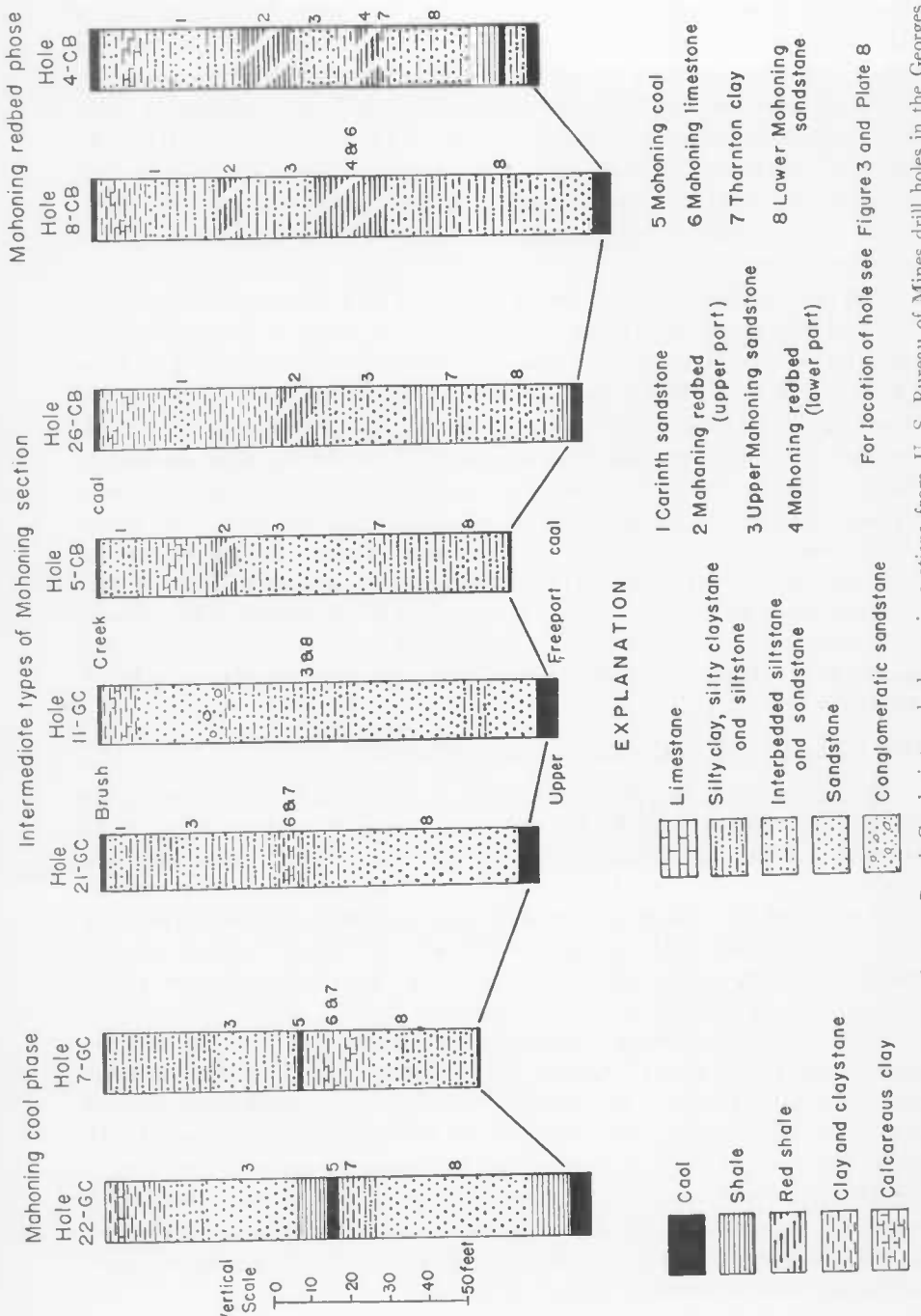


FIGURE 9. Phases of the Upper Freeport-Brush Creek interval shown in sections from U. S. Bureau of Mines drill holes in the Georges Creek, Upper Potomac, and Castleman basins.

In Figure 9 sections illustrating the two phases of the Upper Freeport-Brush Creek interval are shown graphically; other sections, considered to be intermediate between the two, show a few of the stratigraphic variations within the interval. The Mahoning coal phase is largely restricted geographically to the east side and south end of the Georges Creek basin and to the Upper Potomac basin. The coal itself is not known to be present in the Castleman basin but a sandy phase is present locally. The Mahoning redbed phase is well developed in the Castleman basin and is locally present in parts of the Georges Creek basin.

Mahoning coal phase.—The Mahoning coal phase is a sandy phase. The Mahoning sandstone locally occupies the entire interval between the underclay zone of the Brush Creek coal and the roof shales of the Upper Freeport coal, although such a development of this sandstone is not common in western Maryland. More commonly the sandstone is clearly split into an upper and lower part by shale and clay at the horizon of the Mahoning coal bed. Neither the Upper nor the Lower Mahoning sandstones are constant and they show rapid lateral gradation into siltstone and silty claystone.

The Mahoning coal is present locally overlain by black roof shales and underlain by a clay bed that commonly contains siliceous flint clay and "flinty" claystone. Commonly the coal is absent and the horizon is marked by the roof shale-underclay contact, or, more rarely, by shale in contact with fresh-water limestone. The Mahoning underclay, which is also called the Thornton clay, is the most valuable key bed of the Upper Freeport-Brush Creek interval. It commonly contains a characteristic fragmental claystone made up of green and tan fragments. This distinctive bed is the only unit in the interval above the Lower Mahoning sandstone that can be traced with certainty from the Mahoning coal phase laterally into the Mahoning redbed phase.

The interval between the Upper Mahoning sandstone and the Brush Creek coal is occupied by the Brush Creek underclay, which is predominantly an impure calcareous clay. The Irondale limestone, an argillaceous fresh-water limestone, is a local phase of this underclay and occupies part or all of the underclay interval. Commonly a thin calcareous sandstone, the Corinth sandstone, is also present; it ranges from a few inches to 15 feet in thickness and occurs above, within, or immediately below the clay or the limestone.

Mahoning redbed phase.—The average section of the redbed phase of the Upper Freeport-Brush Creek interval has a preponderance of claystone including two zones of mottled green and red claystone. Sandstone is relatively rare and no coal is present. Except at the top and the base, the succession of units is not clearly defined and the individual beds vary in thickness and lateral extent.

The beds at the base of the interval are in most places sandy. The Lower Mahoning sandstone is present locally but more commonly it is represented by

interbedded siltstone and sandstone or by beds of siltstone in gray claystone. The uppermost part of the interval, the Brush Creek underclay zone, differs from that of the Mahoning coal phase only in the greater abundance of freshwater limestone.

Between the Lower Mahoning sandstone and the Brush Creek underclay the strata commonly consist of two zones of green and red claystone beds separated by a zone of siltstone, silty claystone, or interbedded siltstone and fine sandstone. In many places this silty zone is also greenish in color. Each of the redbeds contains a fairly persistent bed of fragmental clay and claystone. The lower redbed locally contains limestone pellets and where these are present the fragmental clay is commonly absent. The upper redbed rarely contains limestone. The clay of the upper redbed zone was called the Thornton clay by Swartz (Swartz and Baker, 1922, p. 57) but this was a misnomer. The Thornton clay as originally defined by I. C. White (1903, p. 322) underlies the Mahoning coal and is equivalent to the Mahoning underclay. The clay of the upper redbed zone is thus nameless.

Correlation of the two phases.—The two phases just described are apparently the extremes of lithologic variation in the Upper Freeport-Brush Creek interval. Most sections do not conform strictly to either of these phases but appear to represent gradations between them. In the sections intermediate in type red claystone is present only in the upper zone, whereas the lower one is commonly represented by green claystone beds that contain either a clay bed or a zone of limestone pellets. In such sections thin sandstone beds or beds of interbedded siltstone and sandstone separate the two redbed zones.

The red-colored claystones lack lateral persistence and are of little value in correlating from the redbed phase to the sandy phase. The change from dominantly red claystone to green claystone is coincident with an increase in the silt content of the claystone. No red-colored claystone is known to occur in any section where either silt or sand is a major constituent of the redbed zone.

The most persistent unit in the sections of intermediate type is the clay bed associated with the lower redbed. It is considered to be equivalent to the Thornton clay of the Mahoning coal phase because it is similar to it in lithologic character, occurs at approximately the same distance above the Upper Freeport coal, and can be demonstrated to lie between the upper and lower splits of the Mahoning sandstone. This correlation suggests that the lower redbed of the redbed phase is equivalent to the Mahoning coal bed and its associated shale and clay of the coal phase. The inferred relationships of the two phases throughout the Upper Freeport-Brush Creek interval of Maryland are summarized diagrammatically in Figure 10.

If the lower Mahoning redbed has a coal-bearing phase the question arises whether or not the upper redbed horizon has a similar phase. In Maryland no coal was found at this horizon in the Bureau of Mines drill holes. Swartz gives

generalized sections (Swartz, Price, and Bassler, 1919, pl. 14) from parts of Maryland showing a coal he calls the Gallitzin at this horizon but in at least one of these sections his correlations are in error. The Gallitzin coal in Pennsylvania has often been said to lie between the Mahoning coal and the Brush Creek coal approximately at the horizon in question. Ashley (1928, p. 109) states that he "has correlated the Gallitzin coal with the Brush Creek coal all through central Pennsylvania." However, no stratigraphic data have been published to support this contention, so the possibility still exists that the coal known as the Gallitzin bed is distinct from the Brush Creek. This possibility is strengthened by the occurrence of the Mason coal, in the Conemaugh formation of Ohio, which was shown by Stout (1947), in his most recent section of the Ohio coal measures, to occur between the Mahoning coal and the Brush Creek coal. More

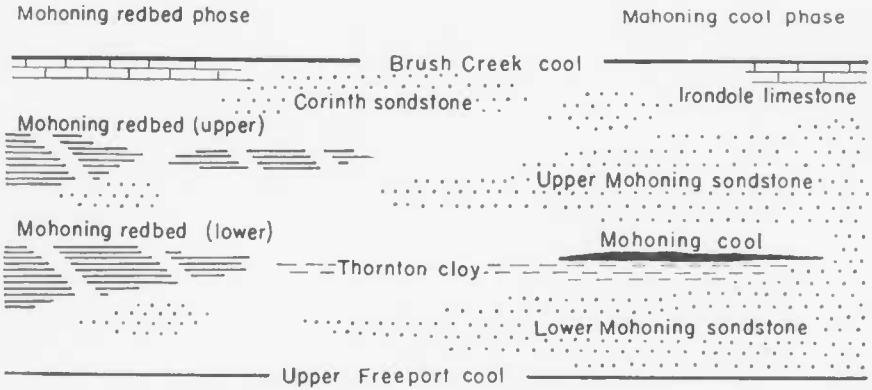


FIGURE 10. Inferred relationships of the lithologic units in the Upper Freeport-Brush Creek interval.

specific reference to the Mason coal and its surrounding lithologies was made by Lamborn (1930, p. 113), who states that in Jefferson County it lies "about 32 feet below the Brush Creek marine shale and 37 feet above the Mahoning coal." Lamborn also noted that the underclay of the Mason coal is "usually gray in color but at some localities is mottled pink or red." The Mason coal and its equivalent in the "Gallitzin" coal beds in Pennsylvania are quite possibly the coal-bearing phase of the upper Mahoning redbed and have the same stratigraphic relationship to it that the Mahoning coal has to the lower Mahoning redbed.

Brush Creek Coal—Ames Shale Interval

The interval between the Brush Creek coal and the Ames shale includes the major part of the lower member of the Conemaugh formation and contains the distinctive sequence of key units. The relatively slight variation in the thick-

ness and lithologic character of the units in this interval follows well-defined patterns of gradation and does not affect the overall regularity of section. The degree of regularity of the lower member of the Conemaugh formation as a whole increases westward. This increase is demonstrated for the Brush Creek-Ames shale interval in the following table in which the persistence of key units in the eastern coal basins is compared with the persistence of the same units in the Castleman basin.

Frequency of occurrence of the principal key units in the Brush Creek coal-Ames shale interval

Units	Percentage of drill holes in which units occur	
	Georges Creek and Upper Potomac Basin	Castleman Basin
Ames marine shale	67	100
Harlem coal	92	100
Pittsburgh redbed	58	65
Upper Bakerstown coal	79	85
Lower Bakerstown coal	90	100
Meyersdale redbed	53	95
Brush Creek marine shale	55	92
Brush Creek coal	81	92

The interval between the Brush Creek coal and the Harlem coal at the base of the Ames shale is 210 to 260 feet in the Georges Creek and Upper Potomac basins. Most of the sections under 230 feet are in the latter basin. The interval is 225 to 250 feet thick in the Castleman basin; in the Upper and Lower Youghiogheny basins it decreases in thickness, averaging between 190 and 220 feet. Individual units within the Brush Creek coal-Ames shale interval are described in the following paragraphs.

Brush Creek coal.—The Brush Creek coal bed is a thin, persistent bed that is relatively uniform in thickness and character throughout western Maryland. It is generally 12 to 18 inches thick. Locally it has been removed by the channeling that preceded the deposition of the Buffalo sandstone.

Brush Creek shale.—Overlying the Brush Creek coal is a persistent unit of fossiliferous black shale which, in some places, is as much as 25 feet thick. Marine fossils occur scattered throughout the shale and are locally concentrated in thin beds. In the Upper and Lower Youghiogheny basins thin beds of fossiliferous limestone are present in the shale but limestone is rarely found in the unit in the other coal basins. At the base the shale is commonly carbonaceous and in the upper part is silty and grades upward into shaly gray siltstone. Lenticular "ironstone" concretions from 1 to 6 inches in their long diameter are scattered throughout the shale.

The Brush Creek shale may not be of marine origin over the entire area now

occupied by the Maryland coal basins. Although the local absence of the marine shale can usually be accounted for by erosion prior to the deposition of the overlying Buffalo sandstone, there are at least two small areas near the juncture of the Upper Potomac and Georges Creek basins where plant-bearing black shales occur between the Buffalo sandstone and the Brush Creek coal and no marine fossils are present.

Buffalo sandstone.—A massive sandstone overlies the Brush Creek shale. Commonly it is fine to medium grained; conglomeratic beds are rarely present. In places where massive sandstone is absent the unit is represented by siltstone with interbedded fine-grained sandstone. The maximum thickness recorded for the Buffalo sandstone in Maryland is 47 feet; thicknesses of 15 to 30 feet are common.

Cambridge shale.—In the northwest corner of the Georges Creek basin, the north half of the Castleman basin, and the greater part of the Lower Youghiogheny basin a thin coal-bearing unit including a marine shale occurs as a lateral phase of the lower redbed of the Meyersdale redbed unit. Where best represented it consists of an inch or two of coal (unnamed) overlain by several feet of black fossiliferous marine shale, the Cambridge shale, and underlain by several feet of calcareous underclay. In areas marginal to those in which the Cambridge shale is present the Cambridge horizon has been recognized in some places by the presence of fossiliferous limestone nodules in the lower red claystone of the Meyersdale redbed.

This unit is equivalent to the Cambridge limestone member in Pennsylvania[4] and eastern Ohio.

Meyersdale redbed.—The Meyersdale redbed is a complex unit similar in many respects to the Mahoning redbed below the Brush Creek coal. Throughout most of the Maryland coal basins the Meyersdale unit consists of two redbeds separated by a fine sandstone or by interbedded siltstone and fine sandstone. Mottled green and red claystones, or commonly only green claystones, are the predominant lithology in both the upper and lower beds of the Meyersdale unit. Locally limestone pellets and ironstone concretions are present. The red color is more persistent in the upper bed.

This threefold unit occupies the interval between the top of the Buffalo sandstone and the base of the Thomas clay (the underclay of the Lower Bakerstown coal); its average thickness is about 50 feet.

Thomas clay and Albright limestone.—The underclay zone of the Lower Bakerstown coal is highly variable in thickness and character throughout the Maryland coal basins. In places it consists of a semiplastic to plastic clay of low grade; elsewhere the same clay contains limestone pellets or is largely re-

[4] According to Wilmarth (1938, p. 1662) the name Pine Creek limestone, proposed by I. C. White in 1878, is still used by the Pennsylvania Geological Survey for this unit although the name Cambridge has priority.

placed laterally by argillaceous fresh-water limestone. Rarely local pockets of semirefractory plastic clay are present.

The name Thomas was applied by Swartz (Swartz and Baker, 1922, Pl. 7) to both the clay and the limestone in the underclay zone of the Lower Bakerstown coal. However, the name Albright limestone was used by Hennen and Reger (1914, p. 140) for a limestone below the "Bakerstown coal" in West Virginia. If the correlation between this latter coal and the Lower Bakerstown coal of Maryland is accepted, the name Albright has precedence. This problem is discussed in somewhat more detail below under the heading Ewing limestone. The name Thomas clay has clear title and has gained some usage in the northern bituminous coal field.

Lower Bakerstown coal.—This is the most important coal bed in the lower member of the Conemaugh formation. It has been mined extensively in the Georges Creek and Upper Potomac basins. Here it locally attains a thickness of 4 feet. It has also been the principal producing bed in the Castleman basin, where its thickness is more constant but averages only about 2½ feet. It occurs between 110 and 140 feet above the Brush Creek coal. In some parts of the Georges Creek and Upper Potomac basins two coals separated by as much as 10 or 15 feet of shale are present at the Lower Bakerstown horizon. Relationships of these two "splits" are obscure.

Friendsville shale.—Swartz (Swartz, Price, and Bassler, 1919, p. 574) named the shale overlying the Lower Bakerstown coal from exposures near Friendsville in the Lower Youghiogheny basin. In this area both he and, previously, Martin (1908) reported marine fossils in the shale. No marine fauna was found in the Friendsville shale in the Castleman, Georges Creek, or Upper Potomac basins. Thin beds of limestone are also locally common in the shale. The Friendsville shale appears to be equivalent to the Woods Run shale of Pennsylvania and the Portersville limestone of Ohio, both of which contain a marine fauna.

Ewing limestone.—Between the Friendsville shale and the Upper Bakerstown coal the predominant rocks are limestone and lime-pellet claystone of fresh-water origin. The calcareous beds are in the Upper Bakerstown underclay zone. In limited areas in the Georges Creek and Upper Potomac basins a thin sandstone separates these limy beds from the Friendsville shale.

Swartz (Swartz and Baker, 1922, p. 6) called the limestone beneath the Upper Bakerstown coal the Albright limestone, considering it to be the equivalent of a limestone of that name described by Hennen and Reger (1914, p. 140) as underlying the Bakerstown coal in Preston County, West Virginia. A careful comparison of the measured section of the type locality at Albright (Hennen and Reger, 1914, p. 93) with drill-hole records from the Maryland coal basins indicates that the Bakerstown coal is the equivalent of the Lower Bakerstown coal of Maryland, not the Upper Bakerstown coal. Thus the name Albright takes precedence

over Swartz's name Thomas for the limestone portion of the Lower Bakerstown underclay.

A further complication is introduced when a name for the limestone beneath the Upper Bakerstown coal is considered. This limestone is doubtless correlative with the Ewing limestone of Ohio, defined by Orton (1878, pp. 889–890) as lying about 40 feet below the Ames marine limestone (above the Harlem coal) and 80 feet above the marine Cambridge limestone member. Reports of the West Virginia and Maryland Geological Surveys and some reports of the Pennsylvania Geological Survey have misapplied the name Ewing using it to denote the fresh-water limestone in the underclay of the Harlem coal. That this interpretation is in error is adequately demonstrated both by Orton's original definition and by subsequent elaboration by Condit (1912, p. 37). Condit demonstrated that the Ewing limestone underlies the Barton coal of Ohio, which is equivalent to the Upper Bakerstown coal of Maryland. Thus, according to definition, the limestone units of the underclays of the Lower Bakerstown and Upper Bakerstown coals are properly called the Albright and Ewing limestones respectively.

Upper Bakerstown coal.—The Upper Bakerstown coal is a characteristically bony coal of little commercial value occurring approximately 40 feet above the Lower Bakerstown coal throughout most of western Maryland. It is persistent and may reach a thickness of 3 or 4 feet.

Saltsburg sandstone.—The Saltsburg sandstone overlies the Upper Bakerstown coal and is ordinarily separated from it by a few feet of shale. It is discontinuous and is represented locally either by a medium-grain sandstone as much as 40 feet thick or by siltstone.

Pittsburgh redbed.—The interval between the Saltsburg sandstone and the limestone beneath the Harlem coal is occupied chiefly by green or red and green clays and claystones locally containing zones of limestone pellets or thin beds of fresh-water limestone. In the Georges Creek and Upper Potomac basins a thin sandstone is commonly present at the top of the redbed.

Unnamed limestone.—A thick, argillaceous, fresh-water limestone or calcareous claystone generally occupies the underclay zone of the Harlem coal. It ordinarily grades downward into clay with limestone pellets and then into the claystones of the Pittsburgh redbed, provided the thin sandstone at the top of the Pittsburgh redbed is not present. The name Ewing can no longer be applied to this limestone for reasons given above; hence the unit is unnamed.

Harlem coal.—A persistent coal bed known as the Harlem coal occurs between 110 and 140 feet above the Lower Bakerstown coal. The Harlem is usually too thin to mine commercially as it averages only about 18 inches in thickness.

Ames shale.—The Ames shale is a marine shale similar to the Brush Creek and is easily confused with it in the field. The Ames shale is usually between 15

and 30 feet thick. In the Lower Youghiogheny basin it locally contains limestone beds, but elsewhere in Maryland the limestone is rare in the unit. The black shale grades upward into lighter silty shale that locally contains plant fossils.

As far as is known, the Ames shale is marine throughout Maryland except for a local area in the Georges Creek basin, where the shale is barren of marine fossils and carries plant fossils.

Ames Shale—Barton Coal interval

The beds in the interval between the Ames shale and the Barton coal, which marks the top of the lower member of the Conemaugh formation, average about 100 feet in thickness. The individual lithologic units in this interval are less regular than those in that part of the Conemaugh just described.

Lower Grafton sandstone.—The Lower Grafton is the dominant sandstone unit of the interval. It is commonly a medium- to coarse-grained, locally conglomeratic sandstone that may be as much as 45 feet thick. In the Georges Creek and Upper Potomac basins it locally lies disconformably on the limestone beneath the Harlem coal, replacing both the coal and the Ames shale.

Federal Hill coal.—The Federal Hill coal is a thin, nonpersistent coal bed that occurs 60 to 80 feet above the Harlem coal. Where the coal itself is absent the horizon is marked by the contact of its roof shale with an underclay zone characterized by claystone with limestone pellets and layers of argillaceous limestone. The Federal Hill coal appears to be equivalent to the Duquesne coal of southwestern Pennsylvania.

Birmingham redbed.—In the Georges Creek basin the Federal Hill coal is fairly common but in the other Maryland basins the coal, its roof shale, and its underclay are in many places replaced by red and green claystone. This redbed is known as the Birmingham redbed.

Upper Grafton sandstone.—A thin sandstone, seldom exceeding 20 feet in thickness, is present in some places above the Federal Hill and Birmingham beds. It is ordinarily fine grained.

Barton limestone.—The Barton underclay zone generally consists of a thick argillaceous limestone. In some coal basins it is used locally as an agricultural limestone.

Barton coal.—The Barton coal occurs between 120 and 150 feet above the Harlem coal. In the Georges Creek and Upper Potomac basins it locally reaches a thickness of 3 to 4 feet and is mined commercially. In the other coal basins it is generally thin and is less persistent.

Upper Member of the Conemaugh Formation

The interval between the Barton coal and the Pittsburgh coal at the base of the Monongahela formation is 400 to 450 feet in western Maryland. Only the

Georges Creek and Upper Potomac basins include complete sections of the upper member of the Conemaugh formation; most of this member has been removed by erosion in the other basins.

This section includes no refractory clays and is not pertinent to the correlation of the underlying beds. A discussion of it is not within the scope of this report.

STRATIGRAPHIC RELATIONS OF THE CLAYS OF THE COAL MEASURES

Clay beds of different types and grades occur throughout the coal measures as the underclays of coal beds and in the zones of red and green shale. The clays of the redbed zones are of low grade and are useful chiefly as brick and tile clays. The underclays of the coal beds are highly variably in character and range in grade from worthless silty clays and argillaceous limestones to refractory clays.

The term "refractory clay" is applied to a clay that has the quality of refractoriness or the ability to withstand high degrees of heat without softening. Clay material that fuses below 1500° C is not considered refractory. Clay workers do not agree unanimously on the precise temperature ranges that define the different grades of refractoriness. Three categories of refractory clay, modified from Ries (1927, p. 335), are used in this report. Refractory clays are those that fuse at and above Cone 30 (about 1650° C); clays fusing between Cone 27 and Cone 30 (about 1600° to 1650° C) are classed as semirefractory clays; and clays fusing between Cones 20 and 26 (about 1500° to 1600° C) are classed as low-grade refractory clays. Because this report is concerned only with refractory clays, all coal measure clays fusing below 1500° C are referred to as low-grade clays.

The term "fire clay" has been used for many years to denote clays with the quality of refractoriness. However, the occurrence of clays of refractory grade under coal beds has prompted the use of the term "fire clay" in another sense and it is commonly applied, as a stratigraphic term, to any clay that underlies a coal bed. As only a very small percentage of the clays under coal beds are of refractory grade the two usages cannot be harmonized and it is considered best to drop the term. Clays under coal beds are properly called underclays; they may or may not be refractory.

CYCLICAL NATURE OF THE SEDIMENTS

The coal beds and other lithologic units of the coal measures occur together in a definite sequence that is repeated again and again throughout the section. This cyclical distribution of beds has been the subject of considerable study, particularly in the Interior coal fields of Illinois, where the individual sequences, termed cyclothems, are treated as subdivisions of the Pennsylvanian series.

A typical cyclothem, according to Wanless and Weller (1932, p. 1004), is

composed of at least eight members that occur in the following order (numbered from bottom to top):

8 Shale with ironstone nodules
7 Limestone with marine fossils
6 Black shale with large concretions
5 Coal
4 Underclay
3 Fresh-water limestone
2 Sandy shale
1 Sandstone (unconformable on next cyclothem below)

It is recognized that this sequence is commonly incomplete. Wanless (1939, p. 8) reports that members 1, 4, 5, 7, and 8 are the most common members in the Interior coal fields.

Cyclothems can be identified in the strata of the northern Appalachian coal fields but the eight subdivisions recognized in the Interior coal fields very rarely occur in any one cyclothem. The cyclothems of the northern Appalachian coal measures all have four parts in common—the sandstone, the underclay, the coal, and the shale above the coal: members 1, 4, 5, and 8 of the Wanless and Weller cyclothem section. Detailed studies of the cyclothems in the Maryland coal measures indicate that these four lithologic zones are the basic parts of the cyclothem and that all the other rock types common in the coal measures occur as lateral variants within one or another of the four zones. The rock types in each of the four zones of the cyclothems in the Pottsville, Allegheny, and lower Conemaugh strata of Maryland are described below.

Shale zone: Shales, gray to black, of fresh-water, brackish-water, marine, or mixed origin. Some of the fresh- and brackish-water shales are silty, sandy, or have laminae of siltstone and sandstone. Some are carbonaceous and pyritic, or carry ironstone concretions. The marine shales locally contain limestone concretions or, rarely, thin beds of fossiliferous limestone.

Coal zone: Coal, cannel coal, "bone," and carbonaceous shale.

Underclay zone: Varies from a simple zone of dark gray silty clay to a complex zone that commonly contains plastic and semiplastic clays; claystones of several types, including high-alumina flint clay; fresh-water argillaceous limestone and marl. Both clays and claystones are locally carbonaceous. Fragmental claystones are common. The underclay zone is gradational with the sandstone zone below through silty to sandy clay and claystone.

Sandstone zone: Clastic beds whose textures range from siltstone to conglomerate. Sandstones are often quartzitic and stylolitic. Pebbles of the

conglomerates are largely quartz. An unconformity is usually present at the base.

The principal difference between the cyclothems in the northern Appalachian coal fields and those of the Interior coal fields is the lack of marine shale and limestone in most of the cyclothems in the northern Appalachian fields. In the latter region the sandstone, underclay, and coal zones of the cyclothem are of fresh-water origin and the shale zone is of fresh-water, brackish-water, or marine origin. In western Maryland and adjacent areas only two coal beds,—the Brush Creek and the Harlem—commonly have marine beds overlying the coal. In western Pennsylvania a few additional marine zones occur in the section and more appear as the coal measures are traced westward. In the Interior coal fields marine shale and limestone are generally present over the coal beds; farther to the west in Kansas and Nebraska most of the cyclothem is represented by marine deposits.

Interpretations of the Pennsylvanian cycles are concerned primarily with the nature of the sequence of environments responsible for the different parts of the cyclothem and with the mechanism by which this sequence was repeated many times during the deposition of the coal measures. No review of the hypotheses that attempt to solve the problems involved will be given here; with a few exceptions these hypotheses are in fairly close agreement regarding the principal environments represented by the individual parts of a cyclothem. The following interpretation, modified after Weller (1930) and Wanless (Wanless and Shepard, 1936), applies to regions, such as Maryland, that were on the margin of the basin of Pennsylvanian sedimentation. The cycle was initiated by a relative lowering of sea level. This resulted in some erosion that was followed by the deposition of sands in a continental environment. The finer sediments of the underclay zone were deposited next under relatively stable conditions probably in shallow bodies of fresh water. As these bodies of water became filled with sediment, extensive swamps developed, and peat, the antecedent of the coal beds, was formed. Peat formation was brought to a close by a relative rise of sea level. In some cycles the sea invaded the area and marine shales were deposited; in other cycles brackish- and fresh-water shales accumulated in marginal areas probably under estuarine and coastal-swamp environments. The beginning of the succeeding cycle is indicated in some sections by silt and sand in the upper part of the shale interval; but more commonly the new cycle begins abruptly with sandstone resting with local unconformity on the shale.

THE REDBEDS

Practically all of the clays in the coal measures are restricted to the underclay zone of the cyclothem and can therefore be considered to have been de-

posited during the process of swamp formation. Possible exceptions to this generalization are the clays associated with redbeds of the Conemaugh formation.

In the lower member of the Conemaugh formation of Maryland as many as four redbeds are present locally—Mahoning, Meyersdale, Pittsburgh and Birmingham; of these the Mahoning and Meyersdale beds are double, containing an upper and a lower split. The lower splits of the Mahoning and Meyersdale redbeds and the Birmingham redbed are known to grade laterally into nearly complete cyclothems consisting of the underclay, the coal, and the shale over the coal. Sections that show stages in the lateral gradation from the redbed phase to the coal-bearing phase indicate that the redbeds replace at least the entire nonclastic portion of the cyclothem. Near the transition from one phase to the other it is common to find redbeds with rather complex sections in which the underclay and shale portions of the cyclothem can be distinguished. An example is the Birmingham redbed, which, in areas of the Castleman basin adjacent to its coal phase (Federal Hill coal), has a section consisting of red clay and claystone overlain by a smut streak that is in turn overlain by a red and green shale. It is not always possible to demonstrate that the clays and claystones of a redbed zone are restricted to its basal part, but this was found to be the case in all sections where the rock types within the redbed were sufficiently distinct to permit zonation. It seems likely, therefore, that the clays of the redbed zones occupy the same stratigraphic position relative to the cyclothem as the clays of the underclay zone and that they are genetically related to this part of the cycle.

THE UNDERCLAY ZONE

The underclay zone of the cyclothem is considered to include all the beds lying between the base of the coal and the top of the basal sandstone of the cycle. This interpretation of the term "underclay" is justified by the following facts:

1. The lithologic types generally found in this interval include clay, claystone, and argillaceous limestone.
2. Each of these have been observed in direct contact with the coal.
3. The limestone, which many geologists separate from the underclay, grades both laterally and vertically into the clay.

In the Maryland coal measures four principal lithologic types occur in the underclay zone. These seldom occur together in any one section but, where they do, they appear in a definite stratigraphic sequence. They are described briefly in the following generalized section.

Coal zone.

Underclay zone:

1. Clay, plastic and semiplastic, generally silty and in many places carbonaceous; the "bastard clay" of miners.

2. Calcareous clay and/or argillaceous limestone. Limestone commonly occurs as irregular pellets in semiplastic or plastic clay or as beds of pellet aggregates.
3. Claystone. "Hard" clays such as flint and semiflint clays, and impure claystones. Commonly fragmental.
4. Clay, silty to sandy, or argillaceous siltstone; transitional between the underclay phase and the sandstone below.

Sandstone zone.

The silty unit at the base of the underclay zone includes the beds gradational between the sandstone and the clays above. It is merely a silty or sandy phase of any of the other three lithologic types in the underclay zone, depending on which overlies the sandstone at any given place. Where the calcareous clays overlie the sandstone, the sandstone is commonly calcareous in its upper part.

Claystone

Indurated clays possessing a conchoidal, subconchoidal, or splintery fracture are called claystone. They include the "hard" clays and "semihard" clays of coal field terminology. Several varieties of claystone are recognizable in a gradation from relatively pure claystone, whose chemical composition approaches that of the clay mineral kaolinite, to siliceous claystone with an appreciable amount of fluxible impurities. The terms "flint clay" and "semiflint clay" have long been applied to two varieties of more or less pure claystone by workers in the ceramics and refractories industries. Other varieties of claystone are not commonly distinguished by name.

Flint Clay.—Dense, homogeneous claystone with a well-developed conchoidal fracture (see Plate 1) is called flint clay. The breaks are smooth, and fresh surfaces have a waxy feel and take a polish easily. Flint clay lacks plasticity and on weathering breaks down into fine shards.

Flint clay is composed largely of the clay mineral kaolinite. Selected Maryland flint clays were examined petrographically by J. M. Axelrod of the U. S. Geological Survey who reports kaolinite as the predominant clay mineral. Foose (1944, p. 572) reports flint clays of the Mercer horizon in Pennsylvania as consisting "entirely of kaolinite" except for "rare anhedral grains of zircon." The famous flint clays of Missouri, on the other hand, have been shown by Allen (1935, pp. 7–9) to contain halloysite as their principal clay mineral.

Flint clays are highly refractory, with a fusion point from Cone 32 to Cone 34 (1700° to 1760° C). The chemical composition of some Maryland flint clays is given in columns 1 and 2 of Table 1.

Semiflint Clay.—Claystone of the semiflint variety differs from flint clay chiefly in being somewhat less dense. The two types are gradational and there is no sharp line of distinction between them. However, the semiflint clay is in

general softer than the flint clay, has a subconchoidal to splintery fracture, and breaks down on weathering into a powder that shows slight plasticity.

Semiflint clays have the same mineral composition as the flint clays, and some have equally high fusion points and similar chemical analyses. However, most semiflint clays are less refractory than flint clays and show a lower alumina content and higher silica content. Analyses of Maryland semiflint clays are given in Table 1.

Other Varieties of Claystone.—Several other types of indurated clay material are covered by the term "claystone." Nearest in purity to the flint and semiflint clays are the claystones that are actually siliceous varieties of flint and

TABLE 1

Partial ultimate analyses and fusion points of hard clays from the Maryland coal measures

[For location of all samples, see Appendix]

		SiO_2	Fe_2O_3	Al_2O_3	TiO_2	Ignition Loss	Total	Fusion Point Cone
Flint Clay	1	43.8	2.5	36.4	2.6	14.9	100.2	34+
	2	48.7	1.8	34.3	1.6	13.0	99.4	34
Semiflint Clay	3	51.3	1.3	32.7	1.3	12.4	99.0	32
	4	51.1	2.5	33.0	1.5	9.9	98.0	32
Claystone	5	55.4	2.2	28.0	2.1	9.5	97.2	31
	6	56.5	4.1	26.5	1.3	10.2	98.6	30
	7	55.1	2.9	27.7	1.5	9.6	96.8	28

1. Flint clay, Mount Savage bed, analysis 65
2. Flint clay, Upper Kittanning bed, analysis 4.
3. Semiflint clay, Lower Kittanning bed, analysis 41.
4. Semiflint clay, Bolivar bed, analysis 13.
5. Flinty claystone, Lower Kittanning bed, analysis 12.
6. Flinty claystone, Thornton bed, analysis 27.
7. Mixed claystone and semiflint clay, Middle Kittanning bed, analysis 35.

semiflint clay. These claystones are commonly brittle, are as hard or even harder than flint clay, have a splintery to almost shaly fracture, and the fragments do not readily break down in weathering.

The chemical analyses of claystones (see Table 1) show that the silica content is somewhat higher, the fluxible impurities, chiefly iron, are higher, and the alumina content is lower than in flint and semiflint clays. Siliceous claystones, where free of fluxible impurities, are similar in their refractoriness to semiflint clays.

Another variety of claystone with less well-defined characteristics is borderline between the claystones and the semiplastic clays and can be considered as a gradational type. It is sometimes called a semihard clay as it shows considerable

induration but is softer than the other claystones. The fracture is irregular and it breaks into blocky fragments. On weathering it breaks down into a mealy, powdery mass. Chemical analyses show that it is similar in composition to siliceous claystone.

Fragmental Structure.—Fragmental structure is a very common feature of the claystones. It occurs in all the varieties and was found at every horizon in the Maryland coal measures that has claystone as an integral part of the underclay zone. It was also found, though less commonly, in the silty and sandy beds transitional between the claystones and the basal sandstone unit of the cyclothem.

The fragmental claystones vary considerably in character (see Plate 2). As a rule the harder claystone types have fragmental zones typified by angular fragments, whereas some of the softer claystones, the semiflint and semihard clays, show pelletlike structure, with the individual fragments molded against one another. The fragments are uniform in character or are mixed and include several varieties of claystone and argillaceous siltstone. The interstitial material also shows diversity of character. It consists of very fine fragments of the same lithology as the larger claystone fragments, of claystone showing no fragmental structure, or of claystone with a high content of visible impurities such as silt, sand, iron minerals, and carbonaceous matter.

Color.—Claystones occur in a variety of colors. The pure varieties, such as flint and semiflint clays, generally show shades of brown, light gray, or blue gray. Color is not everywhere evenly distributed through the claystone and even some of the homogeneous material shows mottling. Many of the less pure claystones are tan, olive, green, and shades of gray. Green claystones are in general confined to redbeds or to the underclays of cyclothems known to grade laterally into redbeds. Black color, resulting from concentration of organic material, is not common in the purer claystone types but is frequently found in silty claystones.

Plastic and Semiplastic Clays

The dominant clay types of the underclay zone are the soft clays with irregular fracture that break down into a plastic mass on weathering. Two types, plastic and semiplastic clay, are distinguished. Semiplastic clays are waxy in appearance and in general tougher than the plastic clays. Both are characterized by the presence of numerous slickensided surfaces lying in diverse positions throughout the clay.

The predominant clay mineral of the soft clays of the coal measures is either kaolinite or illite (Grim and Allen, 1938). Pure clays appear to be much less common among the soft clays than among the claystones. The average soft underclay of the Maryland coal measures is silty and hence is generally low grade. Even where free of silt the clays contain a relatively high percentage of fluxible impurities and are seldom of value in the fresh state as refractory clays.

However, some of these clays are considerably improved by weathering and may be of semirefractory or even refractory grade on the outcrop.

The best soft clays are usually found in underclays that also have local bodies of semiflint and flint clay. Soft clays of these horizons in the fresh state are only rarely of semirefractory or refractory grade but in the weathered state can be used locally as refractory bonding clays. Analyses of various soft clays from the Maryland coal measures are given in Table 2.

The structure and color in the soft clays are less variable than in the claystones. Soft clays rarely show fragmental structure but they contain dikelike bodies and other evidences of flowage in the plastic state. Slickensides are the most typical structural feature of the soft clays.

TABLE 2

Partial ultimate analyses and fusion points of soft clays from the Maryland coal measures

[For location of all samples, see Appendix]

	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	CaO	Ignition Loss	Total	Fusion Point Cone
1	52.1	1.7	31.9	2.9		9.5	98.2	31
2	57.0	1.9	27.3	1.6		8.6	96.4	30
3	58.5	3.6	25.1	1.1	0.7	8.4	97.4	19
4	57.8	7.4	21.9	1.3		7.6	96.0	16 to 18
5	52.1	3.3	22.8	1.3	5.1	10.6	95.2	14

1. Dark brown semiplastic clay, Lower Kittanning bed, analysis 44.
2. Light gray semiplastic clay, Lower Freeport bed, analysis 37.
3. Mottled light gray semiplastic clay, Thomas bed, analysis 40.
4. Mottled red and green plastic clay, Meyersdale bed, analysis 26.
5. Dark gray plastic clay, Brush Creek bed, analysis 19.

Shades of gray are the predominant colors of fresh soft clays. Clays associated with the redbeds are gray, red, and green. Some of the weathered soft clay retains the color of its fresh state but it is more commonly bleached to dirty white and is stained various colors by impurities.

Calcareous Clays

Calcareous clays and claystones and argillaceous limestones are common in the underclay zone (see Plates 3 and 4). The most characteristic type of calcareous matter is a fine-grained limestone that occurs as light gray to gray-white pellets scattered throughout a matrix of soft clay or claystone. The pellets vary in number and size; as a rule they are small and widely scattered at the top and the base of a calcareous zone and are larger and more closely spaced within the zone. The size range of most pellets is from about 2 to 10 mm in diameter. The pellets in many places are closely packed together to form irregular nodules of

limestone. The matrix of clay or claystone that surrounds them is in most places calcareous.

A second mode of occurrence of the calcareous material is as beds of argillaceous limestone. Some of these beds are as much as 20 feet thick but beds from 6 inches to about 2 feet thick interspersed with lime-pellet clays are more characteristic. Some of these limestones have a discernible pellet structure and are obviously the result of close packing of the pellets described above. Pellet structure is not everywhere obvious and there are argillaceous limestones that appear to be uniformly fine grained.

The fresh-water origin of the limestones and calcareous clays of the underclay zone is generally accepted. They are not known to contain marine fossils and they are quite different lithologically from the harder, denser, less argillaceous marine limestones that are present at some places in the shales above the coal beds.

Interrelations of the Rock Types in the Underclay Zone

The Sequence of Rock Types.—The gross lithologic character of the individual underclay zones of the Maryland coal measures is determined largely by combinations of the three lithologic types just described—the claystones, plastic and semiplastic clays, and calcareous clays. Each of these types is restricted to the underclay zone and all show a pattern of distribution with respect to one another. Where the claystone is present it occurs in the lower part of the underclay and commonly grades upward into either the soft clay or the calcareous clay. Where both of these latter types are absent the claystone is directly overlain by the coal. In some places transition beds are present between the claystone and either of the other types; elsewhere the contact is sharp and suggests local disconformity.

Relations between the soft clays and the calcareous clays are not as well defined. In places a limestone or calcareous clay directly underlies a coal but more commonly is separated from it by a thin bed of lime-free clay. In the latter case the limestone, whether it is in beds or pellets in the clay, has usually been considered to be distinct from the clay and to lie stratigraphically below it in the section. Where a fresh-water limestone is consistently present this is the obvious interpretation but in areas where limestone occurs in lenses of limited lateral extent a different interpretation is indicated.

In the discussion of the stratigraphy it was shown that the fresh-water calcareous clays and limestones have a peculiar stratigraphic distribution, being absent in that part of the section below the Upper Kittanning coal, sporadically present between the Upper Kittanning coal and Lower Bakerstown coal, and almost everywhere present in the Conemaugh formation above the Lower Bakerstown coal. Relations of the limy clays and the lime-free plastic and semiplastic clays were studied in that part of the section where the calcareous beds

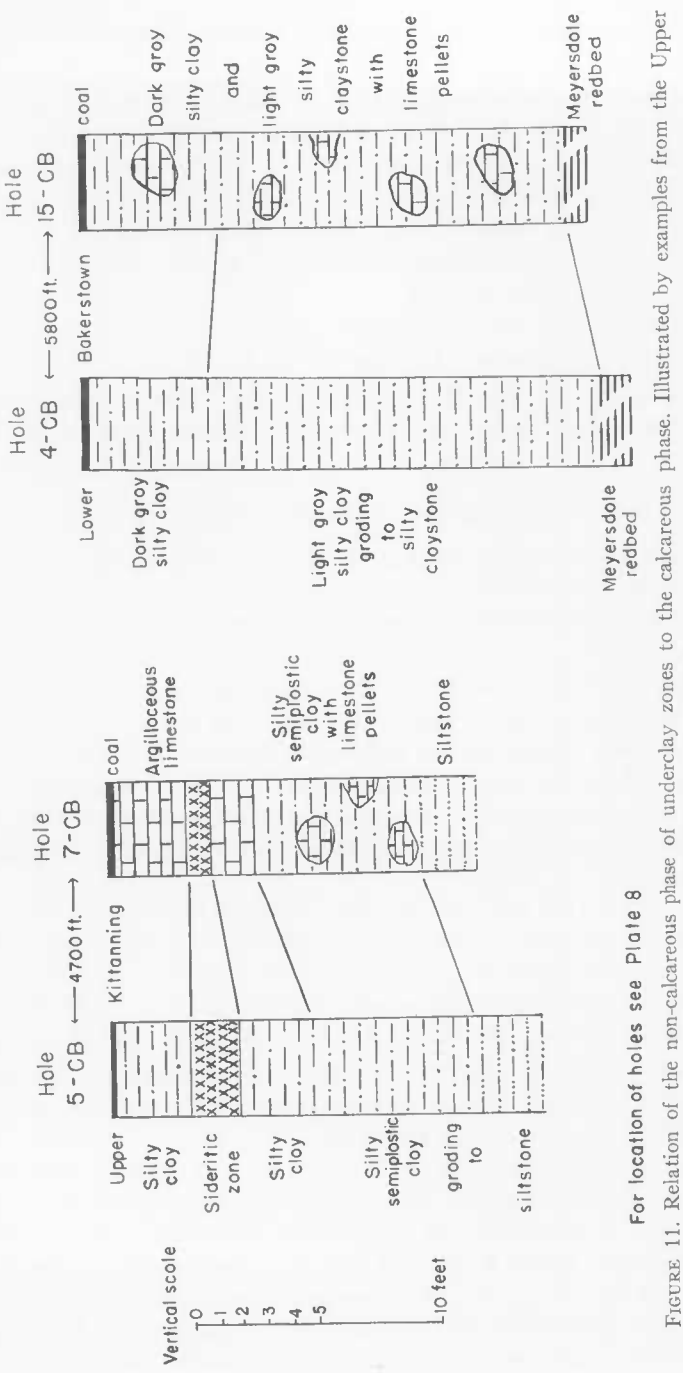


FIGURE 11. Relation of the non-calcareous phase of underclay zones to the calcareous phase. Illustrated by examples from the Upper Kittanning and Lower Bakerstown underclay zones in the Castleman basin.

are only sporadically present. Here the limy beds tend to be present in the underclay over irregular areas of varying size. Except for the presence of the limestone beds or pellets, the sections of the underclay zones along the margins of these areas are similar in lithologic detail to nonlimy sections lying outside the areas. Two of many examples illustrating this are given in Figure 11. The relationship suggests that in the Maryland coal measures the calcareous clays and argillaceous limestones are a lateral phase of the plastic and semiplastic clays that underlie the coal rather than a lithologic unit distinct from them.

Compound Underclay Zones.—Underclay zones that consist of a repetition of several partial underclay sections instead of the usual simple succession from claystone to plastic clay and, locally, argillaceous limestone are said to be compound. Compound underclay zones are generally thicker than simple underclay zones and appear to contain an indiscriminate mixture of the rock types common to the zone. At some places the claystones in the lower part of the underclay zone give way upward to soft plastic clays that are overlain in turn by more claystone, apparently reversing the usual order of occurrence. This and other combinations of rock types in compound underclay zones can, for the most part, be attributed to interruptions in the deposition of clay sediment during swamp formation and the subsequent repetition of part or all of the underclay cycle of sedimentation.

The principal evidence for repetition in an underclay zone is the sharp unconformable contact that separates the rock type that is repeated from the one next below it. Where the repetition is completely within the claystone portion of the underclay zone the claystone appears as a single unit but shows local disconformities in its section; examples of these are shown on Plate 5. The underclay zone of the Upper Freeport coal is compound and in the Castleman basin several distinct repetitions of partial underclay sections are evident. Figure 25 is a graphic section showing the details of this phenomenon in the drill core from hole 26-CB. Here the basal claystone and the upper part of the sandstone zone below it are repeated and three distinct repetitions are evident in the upper claystone bed.

In addition to the repetition of rock types that marks a true compound underclay zone, other factors are responsible for disrupting the simple basic pattern of the underclay section. Some clay beds show an unstratified mixture of clay types and in addition contain much clastic material. Most mixtures of this kind are confined to small lenses and were probably the result of local erosion and redeposition of the clay during the cycle of swamp formation. They are essentially similar in origin to the fragmental clays but are a feature of larger scale.

Local induration of a soft clay type by impurities gives it the gross characteristics of a claystone. Many of the lime-pellet clays are fairly well indurated by calcium carbonate and resemble claystones. Iron carbonate disseminated through a soft clay has the same effect. Claystones of this type are fairly simple

to recognize and are not likely to be mistaken for the kaolinitic claystones common to the lower parts of underclay zones.

Summarizing the relationships of the rocks within a simple underclay unit the soft clay or the calcareous clay, or, since they are laterally gradational, a combination of the two types underlies the coal. The claystone consistently underlies these rock types and is in contact with the coal only where they are absent. In compound underclay zones the normal sequence of clay types is broken and the clay bed is complex in character. The transition from the underclay unit to the sandstone unit below it consists of a sandy phase of whichever one of the three types of underclay material overlies the sandstone.

Visible Impurities in the Underclays

Different kinds and amounts of impurities contribute to the complexity of the underclay unit. Some of these impurities are microscopic and their presence is detectable only by detailed petrographic study or by chemical analysis. However, the principal impurities, and those that commonly lower the quality and grade of the clays, are either visible to the naked eye or can be detected with a hand lens.

Silt and Sand.—Silt and sand are not confined to the transition zone between the underclay and sandstone units, but may occur in any part of the underclay zone. Where silt is present in an underclay zone it commonly occurs as irregular bodies or is scattered throughout the matrix. It also occurs as the interstitial material in fragmental claystones. Sand is present in much the same fashion, as scattered grains, in streaks and pockets, but rarely in well defined beds. Grain size is variable; some of the clays in the lower part of the Allegheny formation have coarse sand grains scattered throughout and in a few places pebbles as large as $\frac{1}{4}$ inch in diameter have been found.

Siltstone and rarely fine-grained argillaceous sandstone occur as fragments in some of the fragmental claystone. These clastic materials have no doubt been derived from underlying beds of the transition zone.

Calcareous Matter.—The principal mode of occurrence of calcareous matter in the underclay zone is in the form of pellets, nodules, and beds of argillaceous limestone. These calcareous rocks are a lateral variant of the plastic clay portion of the underclay zone and are thus in a sense impure soft clays.

Calcareous matter also occurs as films of calcite in fractures and on slickensided surfaces, or as veinlets of limestone. The latter are common in claystones under calcareous soft clays and are also present in the redbed clays. Finely disseminated calcareous matter not discernible in the hand specimen is seldom present outside of the calcareous soft clay phase.

Carbonaceous Matter.—Carbonaceous matter is easily detected by its color. Black clays and claystones as a rule occur directly under a coal or are even interbedded with it. Few clays of this type are very thick and most of them

are silty. The carbonaceous matter is very finely disseminated. Another mode of occurrence of carbonaceous matter in the underclay zone is in the form of plant rootlets, stigmaria, or similar rootlike structures. Where finely divided carbonaceous matter is the only visible impurity, it appears to have no effect on the refractoriness of the clay.

Iron Minerals.—Fresh clays and claystones contain two principal iron minerals as impurities—pyrite (FeS_2) and siderite ($FeCO_3$). Pyrite occurs as scattered crystals and small crystalline masses in clays and claystones; it also commonly forms a thin film on slickensides and fractures in the clay. In most of the underclay zones studied, however, pyrite is second in importance to siderite among the iron impurities.

Siderite in the underclay zone occurs either as ironstone concretionary masses or as grains (see Plate 6). The grains vary in size but commonly are between 0.2 and 0.8 mm in diameter. They are present in all parts of the underclay zone but are most common in the claystones. Commonly the grains are scattered throughout the clay but in some places they are concentrated and form irregular tabular bodies from a few inches to as much as 2 feet thick.

The concretionary ironstone occurs in all units of the cyclothem except the coal. In the underclay the concretions range in size from an inch or two up to 2 feet or more in their long diameter. Many of the ironstone concretions are septarian, that is, they have cracks cutting across them that are filled with secondary mineral matter. In Maryland the septarian ironstone concretions most commonly occur in the Mount Savage clay. Barite, calcite, selenite, pyrite, marcasite, and siderite have been identified in the fillings of these concretions.

Other iron minerals are undoubtedly present in the fresh clays but siderite and pyrite are the principal impurities in most of the high-iron clays. Where the clays have been weathered iron oxide is the common impurity and usually replaces the crystalline siderite. The ironstone concretions commonly have an external coating of iron oxide and in some of them this is as much as an inch thick. Iron oxide is also present as films on fractures and slickensides in clays and claystones at and near the outcrop.

Gypsum.—Gypsum is not a common impurity in the Maryland underclay zones but it has been found at several localities in the Bolivar clay. It is associated as a rule with limy clays and occurs in thin beds or as coatings on partings and fractures in the clay.

STRATIGRAPHIC DISTRIBUTION OF THE CLAY TYPES

Many of the rock types and impurities in the underclay zone have a restricted stratigraphic range and are confined to one part or another of the coal measures. As a result different parts of the section possess characteristic associations of rock types in the underclay zones. From an economic standpoint

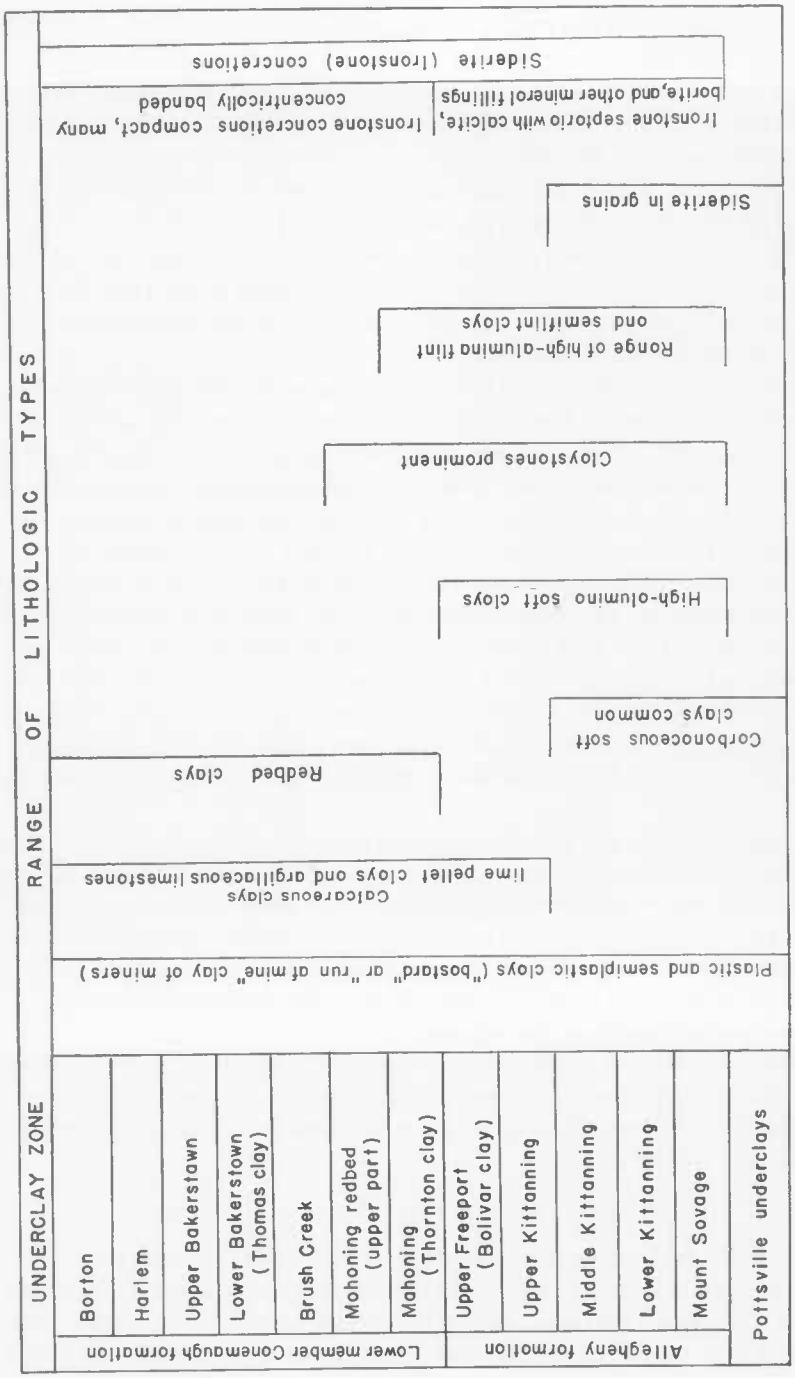


FIGURE 12. Stratigraphic distribution of the principal lithologic types found in Maryland underclays.

the most important aspect of this distribution of rock types is the restriction of high-alumina refractory and semirefractory clay to the Pottsville and Allegheny formations, and lower member of the Conemaugh formation throughout the Appalachian bituminous coal fields. The upper limit for refractory-grade clays fluctuates somewhat from place to place within the lower member of the Conemaugh but no exception is known to the restriction of these clays below a horizon approximately in the middle of the formation.

In Figure 12 the stratigraphic distribution of the principal rock types and impurities in the underclay zones of the Maryland coal measures is summarized.

Of the principal clay types in the underclay zone only the soft clays appear to have an unlimited range throughout the section. The calcareous clay and limestone are not present in the underclay zones of Maryland coals below the Upper Kittanning coal. In the Upper Kittanning and Lower Freeport underclays limestone is locally present, and it is common in the Upper Freeport underclay and in underclay zones throughout the Conemaugh formation.

The claystones are represented by one or more varieties in all the underclay zones in the Pottsville and Allegheny formations and in the lower member of the Conemaugh formation. However, only in the Allegheny formation and in that part of the lower member of the Conemaugh formation below the Brush Creek coal is the claystone sufficiently thick and persistent to be a prominent member of the underclay zone.

The distribution of lithologic types within the soft clay and calcareous clay phases of the underclay zone is relatively unrestricted. Limestone beds, nodules, and pellets occur at any horizon where the calcareous phase is developed. With one exception the soft clay types are also common at all horizons. The exception is the tan-colored soft clay which, where uncontaminated by visible impurities, has an alumina content greater than 29 per cent in the fresh state; this clay appears to be restricted to the Allegheny formation and is especially common in the Middle and Lower Kittanning underclays.

In the claystone portion of the underclay zone the flint clays have a limited distribution. They are present locally in the Allegheny formation and in a few places in the lower member of the Conemaugh formation below the Brush Creek coal. The flint clays and associated semiflint clays and claystones tend to range in color from shades of brown and dark brown in the lower part of the Allegheny formation to shades of gray and lighter brown in the upper part. Where the claystones are fragmental the composition of the fragments is generally uniform in the clay beds of the lower part of the Allegheny formation; but in the upper part flint clay, siliceous claystone, silty claystone and even siltstone fragments are locally mixed together in the same clay bed.

Visible impurities in the underclays are not limited to any particular part of the section, and silt and sand, carbonaceous matter, and iron minerals occur locally in all the underclays. However, the mode of occurrence of some of these

impurities differs in different parts of the section. Carbonaceous matter is a dominant constituent of the soft clays in the Pottsville formation and in the lower half of the Allegheny formation, where clays and claystones are commonly dark gray or black. Above the middle part of the Allegheny formation the carbon content of the clays is generally less and light gray colors predominate.

Among the iron minerals pyrite is present throughout the coal measures, but siderite, in the form of grains or small subrounded pellets, appears to be restricted to the underclays of the Allegheny formation below the horizon of the Upper Kittanning coal. Siderite grains are only rarely found in the Pottsville formation of Maryland but this is probably because the underclay units are poorly developed in this part of the Maryland coal measures. In Pennsylvania siderite in the form of grains is a common impurity in the Mercer clay of the Pottsville formation. It is also commonly present in both states at the contact of the Pottsville formation and the Mauch Chunk shale in areas where clay or claystone forms the base of the Pottsville.

The sideritic concretions, generally referred to as ironstone, occur throughout the coal measures. They are not confined to the underclay zone but are most numerous in it. Two varieties of ironstone concretion, septarian and concentrically banded concretions, occur in different parts of the coal measures. Septarian concretions with various mineral fillings are present principally in the Allegheny formation, within which they are far more common and also larger in the Mount Savage clay than in any other underclay. Concentrically layered ironstone concretions that range between $\frac{1}{2}$ inch and 3 inches in their long diameter are common in claystones of the Conemaugh formation.

In Maryland the underclay zones containing the high-alumina clay types, which are the potential refractory clays, are limited to the Allegheny formation and the lower part of the lower member of the Conemaugh formation. Even the lower-grade soft clays that are potential semirefractory-grade clays where they have been leached are largely restricted to the Allegheny formation. Therefore prospecting for refractory-grade clays in Maryland can be limited to the outcrop areas of the Allegheny formation and the basal portion of the overlying Conemaugh formation. This section contains six principal underclay zones; in ascending order these are Mount Savage, Lower Kittanning, Middle Kittanning, Upper Kittanning, Upper Freeport (Bolivar), and Mahoning (Thornton) underclay zones. One other zone in the lower member of the Conemaugh formation—the Lower Bakerstown underclay zone—commonly is free of calcareous matter and should also be considered a possible source of soft clay.

CLAYS OF THE POTTSVILLE FORMATION

No clays of commercial importance have been discovered in the Pottsville formation in Maryland. The underclays of the several coal horizons are in

general thin, carbonaceous, silty clays and claystones that grade abruptly downward into gray siltstones. Particular attention has been paid to underclays in the interval that includes the Mercer coal beds because of the occurrence of high-grade flint and diaspore clays at this horizon in the northeastern part of the bituminous coal field in Pennsylvania. However, no variation from the worthless clay described above was found at this or any other underclay horizon of the Pottsville formation.

The flint clay under the Mount Savage coal in Maryland was at one time considered (Clark and Martin et al., 1905, and Martin, 1902, 1908) to be equivalent to the Mercer clay of Pennsylvania and many clay workers still hold this view. This correlation was doubtless influenced by the fact that the classic area for the Mount Savage clay is in the the north end of the Georges Creek basin where the Pottsville is abnormally thin and the Mercer coal group has lensed out between the Homewood and Upper Connoquenessing sandstones. Thus the Mount Savage clay was found at a distance above the Mauch Chunk shale comparable to the position of the Mercer clay farther north in Pennsylvania. Swartz (Swartz, Price and Bassler, 1919, and Swartz and Baker, 1922) correctly correlated the Mount Savage horizon with the Clarion horizon of Pennsylvania, using as his primary basis intervals from easily recognizable persistent horizons higher in the section. Data from the drill records of the Georges Creek, Castleman, and Upper Potomac basins substantiate this correlation.

Lack of thick, silt-free clays in the Maryland Pottsville formation perhaps can be attributed in part to the fact that the Maryland coal basins lie athwart what must have been an unstable area of irregular sedimentation between the great basin of Pottsville deposition to the south and the comparatively shallow area of deposition in western Pennsylvania and Ohio. In addition the high percentage of clastic material in the Pottsville of the eastern coal basins of Maryland suggests that these coal basins were near the source of sediment in areas unfavorable to the accumulation of thick underclays. The percentage of clastic material in the Pottsville formation of the other Maryland coal basins is also high but local lenses of argillaceous beds increase in number westward. None of these is known to contain clay of refractory grade.

CLAYS OF THE ALLEGHENY FORMATION

UNDERCLAYS

Of the five principal underclays in the Allegheny formation, two—the Bolivar clay and the Upper Kittanning clay—occur in the upper part of the Allegheny formation and underlie persistent coal beds. As a result they are relatively easy to identify both on the outcrop and in drill cores. Such is not the case with the other important underclays of this formation—the Mount Savage clay, Lower Kittanning clay, and Middle Kittanning clay. These three zones are

in a part of the Allegheny formation that is characterized by marked irregularity of strata and nonpersistent coal beds. It is difficult to identify these three clay zones on the outcrop because they are somewhat similar to one another in character and relatively close together. In addition, the clay lenses that occur at the three horizons are generally less extensive and fewer in number than those in the underclays of the coal beds in the more regular strata higher in the formation. Consequently all three clays are rarely found together in any one section.

Satisfactory identification of the Mount Savage, Lower Kittanning, and Middle Kittanning clays is possible only where these beds can be located in a measured section and their respective distance below a persistent coal bed, such as the Upper Kittanning or Upper Freeport coals, can be determined. Even this means of identification may not be conclusive as there is considerable variation in the intervals between the three clays, owing to the irregular development of the sandstones that separate the three coal groups in which they occur.

The numerous drill-hole sections have made it possible to recognize local stratigraphic variations and thereby to establish control for the correlation of the clay beds. Descriptions of the individual zones are based only on clay deposits whose stratigraphic position has been determined through the control sections of the drill-core records.

MOUNT SAVAGE CLAY

Stratigraphic Relations

Lenses of high-grade refractory flint and plastic clay are only rarely present in the underclay of the Mount Savage coal bed. Details of the succession of beds in the coal group, discussed in the section on stratigraphy, show that the clay, where present, is commonly underlain by a coal—the Brookville bed. At many places a thin argillaceous sandstone (Clarion sandstone) is present between the Mount Savage and Brookville coals and forms the floor of the clay.

The Mount Savage clay deposits occur as widely scattered, irregular, lenticular bodies. From a few of these deposits the Maryland refractories industry has obtained most of its refractory-grade flint clay and a large part of its soft clay, a circumstance that has led to the belief that the Mount Savage clay is a relatively persistent bed of uniformly high-grade clay. Unfortunately this is not the case, and all the Mount Savage clay mined to date in Maryland has come from two clay bodies. One other body has been mined in West Virginia but its extension into Maryland near Westernport has not been worked. In addition to these three occurrences two other bodies are indicated by drill-hole records. The distribution of these deposits is shown in Figure 13.

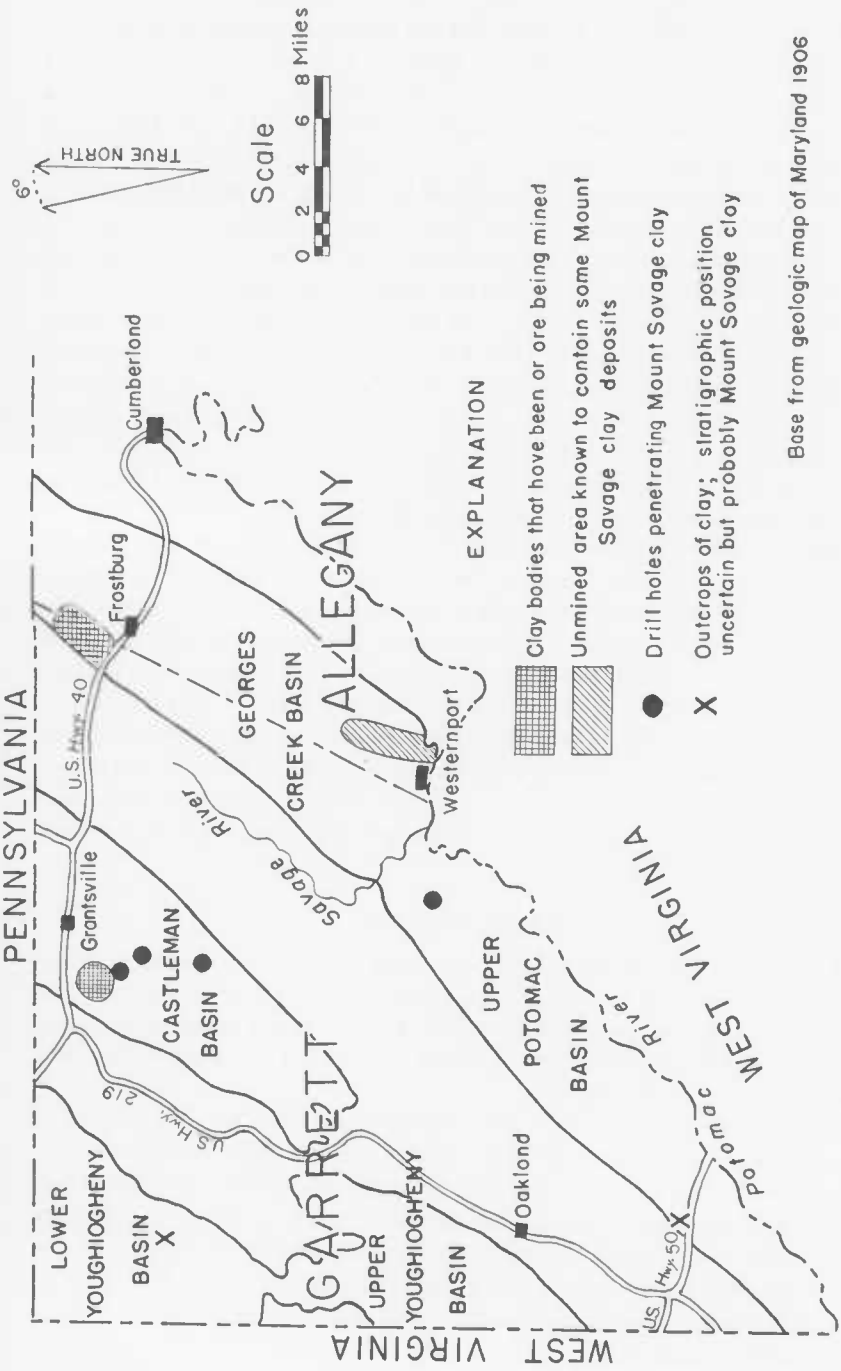


FIGURE 13. Known occurrences of Mount Savage clay of refractory grade in Maryland

In the area covered by the Bureau of Mines drilling programs in the Georges Creek, Upper Potomac, and Castleman basins, a total of 37 holes penetrated the Mount Savage horizon. Only seven of the holes showed flint clay and in only two of these was the clay of a minable quality and thickness. Although a large part of the coal measures terrain in western Maryland has yet to be prospected for refractory clays, the results of the drilling are probably representative of what can be expected at the Mount Savage horizon.

The drill-core records and the known exposures of the Mount Savage coal group show clearly that the clay bodies are isolated lenses occurring only within areas where the coal group is thick, coal-bearing, and relatively free of sandstone. Outside of these areas the Mount Savage coal group is either composed of interbedded siltstones, sandstones, thin shales, and coal streaks or is restricted by the thickening of sandstone units above and below to a thin zone of silty strata. A part or all of the Mount Savage coal group is known to have been removed by channeling prior to the deposition of the overlying Kittanning sandstone, but such removal is only a local feature.

Apparently the optimum development of the Mount Savage coal group is restricted to certain areas. The distribution of these areas follows no discernible pattern; they appear to be widely scattered but there is insufficient subsurface evidence to estimate what percentage of the total area they occupy in comparison with the intervening sandy phase. The clay bodies within the coal group also have an erratic distribution. Although the Mount Savage underclay is commonly present throughout the areas of maximum development of the Mount Savage coal group it varies considerably in character and does not everywhere contain bodies of high-alumina flint clay. Thus a well-developed Mount Savage coal group is a good indication for prospecting but it is not an infallible guide to flint clay bodies.

Character of the Clay

The sections of the Mount Savage coal group in the separate areas of development differ from one another in minor respects and have certain lithologic variations that appear to be characteristic. In their major features, however, they are essentially similar and all show the sequence of major units described in the paragraphs on stratigraphy.

The Mount Savage underclay consists of soft clay, flint clay, and claystone. Where all three materials are present together the soft clay underlies the coal and overlies the flint clay and the latter generally grades downward into claystone or silty claystone. These generalized relationships of the clay types are seldom found in this simplified order in the field. Variation is imposed on the sequence chiefly by the unequal local development of one of the clay types to the partial or complete exclusion of one or both of the other two. In some places the underclay is compound.

Flint clay is the most characteristic clay type of the Mount Savage underclay zone; it is typically brown to gray-brown, rarely gray in color with dark brown to black clay as interstitial filling in the fragmental portions or as a network of veinlets throughout much of the nonfragmental clay. The veinlets are presumably fillings of cracks developed in clay that somehow escaped disruption to form a fragmental layer. Fragmental structure is present in most of the flint clay and claystone beds in other parts of the section but Mount Savage fragmental flint clays show a greater uniformity in the composition of the fragments and the interstitial material. As a rule all the fragments are of the same kind of clay or are at least of the same degree of purity. In addition the interstitial filling, though darker, is commonly similar in quality to the fragments. This homogeneity accounts in large part for the uniformly high grade of the Mount Savage flint clays. There is some local variation in flint clay types within the Mount Savage; the extremes are a hard, conchoidally fracturing, lustrous flint clay, and a brittle, soapy type of clay with a more splintery fracture that approaches a semiflint clay in character. Both types are usually high grade.

The soft clays in the Mount Savage underclay are generally tough and mealy when fresh but readily break down to plastic and semiplastic clay on exposure. Locally they are of refractory grade in the fresh state but more commonly are silty and of low grade. Weathering has raised some of the soft clays to at least semirefractory grade. Where the underclay zone is compound, soft clay locally occurs below the flint clay as well as above it. The flint clay commonly grades into siliceous claystone that can be easily recognized by its stony appearance and its content of silt and detrital quartz grains. The siliceous claystone may appear anywhere in the flint clay bed but it is most common at the base, where it is gradational between the flint clay and the sandy strata below. Flint clay grades laterally into claystone, silty claystone, and argillaceous siltstone. As a rule this easily recognized gradation signifies that the limit of the clay body has been reached. In some places narrow, elongate bodies of silty claystone and siltstone occur within the flint clay body.

The chief impurity in the Mount Savage clays, other than siliceous material, is siderite. This mineral occurs both as grains scattered through the clay and as the principal component of large septarian ironstone concretions that are characteristic of the Mount Savage clay. The concretions are easily removed in mining but the scattered grains cannot be separated economically and where present render the clay worthless.

The Big Savage Mountain Area

The type area of the Mount Savage clay is northwest of Frostburg along Big Savage Mountain between U. S. Highway 40 and the latitude of Mount Savage. In this area the clay has been mined, for over 100 years, from a num-

ber of different properties. It cannot be satisfactorily demonstrated that more than one clay body underlies this area. On the contrary, descriptions of the old mine workings by Maryland clay workers and the nature of the clay beds in the active mines suggest that the entire area contains a single clay body cut up by channeling that took place shortly after the deposition of the clay. The channels, filled either by the overlying Kittanning sandstone or a locally developed sandstone lens between the Mount Savage coal and the clay, range from a few feet to several hundred feet in width.

The following section of the Mount Savage clay and adjacent beds was taken in the crop stripping of the Big Savage Refractories Corporation near the old North American mine on Big Savage Mountain northwest of Frostburg.

Section in Stripping of Big Savage Refractories Corporation, on Big Savage Mountain

	Feet
Massive conglomeratic sandstone (Kittanning)	15 to ?
Interbedded sandstone and siltstone	10 to 15
Coal and bone with shale partings (Mount Savage)	3
Soft plastic clay, somewhat silty	4
Sandstone	2 to 3
Interbedded siltstone and silty claystone	4 to 6
Clay, variable amounts of plastic and flint clay, latter at base of bed	12
Soft silty clay (only top exposed).	

The relative amounts of flint clay and plastic clay vary markedly in the stripping. The thickest section of flint clay recorded in Maryland occurs in a narrow "rib" that occupies the entire 12-foot underclay zone. Elsewhere in the stripping the flint clay is from 4 to 6 feet thick and is overlain by a weathered plastic clay reported to have a fusion point of Cone 31 or 32. The flint clay is constant in grade and fuses at Cone 33 to 34.

All other recorded sections of the Mount Savage clay from the Big Savage Mountain area are mine sections and show only the clay and the beds immediately adjacent to it. Hall (Watts et al., 1922, pp. 351–357) gives numerous sections and tests on samples from the Mount Savage bed in the mines along Big Savage Mountain. The mines west and northwest of Mount Savage have since been abandoned and only the Benson mine and the old North American mine northwest of Frostburg are still worked. The sections are generally similar from mine to mine; two examples are given below.

Section in the Benson Mine of Big Savage Refractories Corporation

	Feet	Inches
Roof; siltstone and silty claystone.		
Silty gray clay	1	4
Gray to brown-gray, locally fragmental flint clay	5	4
Gray to dark gray silty plastic clay	1	8
Floor; siltstone.		

Section in Union Mine No. 6, 2¼ miles N. 60° W. of Mount Savage. After Hall (in Watts et al., 1922, p. 352)

	Feet	Inches
Coal streak.		
Brown to gray plastic clay (Cone 30)	3	8
Brownish flint clay (Cone 33)	3	6
Gray plastic clay, carbonaceous streaks (Cone 22)	1	0
Coaly streak	0	2
Sandy shale floor.		

Most of the sections from the Big Savage Mountain area show a plastic clay immediately underlying the Mount Savage flint clay and some even show a coal streak in this part of the section. These features are evidence of the compound nature of the Mount Savage underclay zone. Additional evidence of this is the local complexity in the interval between the Mount Savage coal and the flint clay. Here channels of sandstone are present that locally restrict or completely replace the flint clay bed.

Hall's account of the clays along Big Savage Mountain is the most complete record available for this classic area. Unfortunately it is little more than a listing of sections and tests of spot samples and no map is given showing the location of the sections or even of the mines from which the samples are taken. A great amount of detailed information on the area is now available but it applies only to the part that is mined out.

Other Areas with Mount Savage Clay

A clay usually considered to be the Mount Savage clay is locally present east and northeast of the town of Westernport in the south end of the Georges Creek basin. The clay crops out on both sides of the Potomac River gap and was once mined on the West Virginia side of the gap. In the talus on the steep north side of the gap are both siliceous and relatively pure flint clay associated with ironstone, but no crop face is exposed sufficiently well to afford a good section of the clay bed.

Bureau of Mines drill hole 8-GC located on the east end of Hampshire Hill, about 2 miles northeast of Westernport, penetrated an impure bed of flint clay at what is believed to be the Mount Savage horizon. The lower part of the Allegheny formation in this hole is atypical because the sandstones that usually separate the Mount Savage, Lower Kittanning, and Middle Kittanning coal groups are lacking. As a result the coal beds and clay beds of the different coal groups are difficult to distinguish from one another. The lowermost clay in this section is possibly the Mount Savage, although the evidence is equivocal. It resembles the clay on the crop in the Potomac gap and is in a section similar to that of the clay mined across the river in West Virginia.

Section of Mount Savage (?) clay in Drill Hole 8-GC

	Feet	Inches
Coal, shale and bone (Mount Savage?).		
Siltstone	1	0
Siltstone with angular fragments of silty claystone	2	11
Interbedded fragmental claystone, flint clay, and some siltstone, with interstitial siderite	5	1
Fragmental flint and siliceous flint clay with interstitial silt and ironstone	1	0
Ironstone, scattered fragments of flint clay	1	0
Siltstone	4	0
Dark gray to carbonaceous shale and silty shale	7	1
Siltstone grading to sandstone.		

A similar section was cut at the Mount Savage horizon in hole 2-GC on Moores Run, about 2.2 miles north-northeast of hole 8-GC, suggesting that the clay body extends at least this far north. No other holes either to the north or to the west of this area encountered clay at the Mount Savage horizon.

Section of Mount Savage clay in Drill Hole 2-GC

	Feet	Inches
Coal sludge, no recovery (Mount Savage coal).		
Dark gray siltstone	0	6
Fragmental flint clay with minor siltstone and interstitial ironstone (Cone 29, Analysis 5)*	5	3
Gray siltstone	1	4
Fine sandstone; some interbeds of silty flint clay	3	10
Flint and semiflint clay, siderite pellets and nodules throughout (Cone 23, Analysis 6)	1	3
Carbonaceous semiplastic to semiflint clay (Cone 28, Analysis 7)	4	3
Siltstone and silty clay.		

* All analyses listed in the sections in the text are given in the Appendix.

Sections similar to those given above are recorded by Hall (Watts et al., 1922, pp. 364–365) from the mines of the Potomac Fire Brick Company and the Faraday Property prospects across the Potomac River in West Virginia. Points of similarity to be noted are the high iron content of the flint clay and the tendency for the clay bed to be split into two benches by a thin siltstone or sandstone, a condition similar to that in the Big Savage Mountain area. A part of one of Hall's sections is given below for comparison.

Fourth Prospect East from Old Plane, Faraday Property, Condensed from Hall (Watts et al., 1922, p. 365)

	Feet
Black shale	0.6
Impure gray iron-stained soft clay with a few nodules of flint clay at base	2.1
Sandstone	2.0
Flint clay, gray, iron-stained, hard, and tough (Cone 32)	1.9
Very ferruginous sandy clay	0.3
Black shale	0.6
Sandy clay.	

Elsewhere in the Georges Creek and Upper Potomac basins only one drill hole penetrated flint clay at the Mount Savage horizon. This was hole 17-GC in the Upper Potomac basin about 5½ miles southwest of Westernport. In this hole considerable core was lost in the Mount Savage interval and neither the thickness of the clay nor the sequence of rock types could be determined. High-grade flint clay, semiflint clay, and dark gray claystone were recovered from the interval; no siderite or other ferruginous impurity was present in the recovered core.

In the Castleman basin one deposit of Mount Savage clay is exposed along Tarkiln Run on Negro Mountain and is mined as a source of raw clay for the Union Fire Brick Company plant near Jennings. In addition one drill hole, 7-CB, adjacent to Meadow Mountain east of Bittinger, penetrated a good bed of clay at the Mount Savage horizon; and there is some evidence of flint clay on the nearby crop. Some flint clay float that could have come only from the Mount Savage bed was also found along the north end of Meadow Mountain just north of U. S. Highway 40. These three occurrences are the only clays known at the Mount Savage horizon in the Castleman basin; they are described in detail in Part II.

All the known sections of the Mount Savage clay in the Castleman basin show it as a simple underclay that directly underlies the Mount Savage coal. This feature is in marked contrast to the compound Mount Savage underclay zone in the Georges Creek basin. The change in character follows the familiar pattern of increasing complexity in the coal measures as they are traced eastward through the Maryland basins.

Evaluation of the Mount Savage Clay

In the Georges Creek and Upper Potomac basins the only area of Mount Savage clay ever mined commercially is still being worked. Two mines, the Benson and North American mines of the Big Savage Refractories Corporation, are being operated at the south end of the Big Savage Mountain area northwest of Frostburg. Both mines are old and have extensive workings. No exploration is done ahead of the mining so that it is not possible to evaluate the properties in terms of reserve clay. The other mines in the Big Savage Mountain area have been abandoned for some time. The old Union Mining Company worked the area for many years and did extensive diamond drilling between their several properties. Evidence from the old workings and the drill holes show that all the clay body northeast of the working mines is mined out except for some deep clay in areas where flooding makes it impractical to mine.

The Mount Savage clay is only rarely present in the northern end of the Georges Creek basin. Along Little Allegheny Mountain it is apparently absent and a drill hole, 20-GC in the central part of the basin just south of the State line, shows only impure claystones in the Mount Savage interval. Along Big

Savage Mountain the Mount Savage coal group lenses out within 2 or 3 miles of the State line, thereby limiting the northeastward extent of the clay body in Big Savage Mountain. The eastward limit of mining has been determined by the practical depth of mining and by the problem of flooding. However, there is also evidence from deep drill holes along the foot of Big Savage Mountain that the clay pinches out downdip. To the south less is known about the clay body; two deep drill holes down the flank of Big Savage Mountain, hole 21-GC along U. S. Highway 40 and hole 10-GC north of the town of Midlothian, show no clay at the Mount Savage horizon, nor has any crop clay been reported along the mountain south of U. S. Highway 40.

Although the evidence on the southwestward extension of the Big Savage clay body is spotty and little is known of the reserves in the active mining area, the body appears to have passed its most productive stage. Possibly enough clay lies within reach of the two working mines to keep the plant they feed active for years. On the other hand, the clay may be nearly worked out. Only exploratory drilling can determine how much clay is still available for mining. Indications are that the limits of the body have been reached in nearly all directions but the northern and eastern limits are the only ones determined with certainty.

The clay body in the Westernport area appears to be extensive but relatively impure because of its high content of iron. Prospecting in this area has been spotty, however, and it is quite possible that iron-free bodies of high-grade clay are present. As it is the only other Mount Savage clay deposit known in the Georges Creek basin, it deserves further and more thorough exploration.

In the Castleman basin the Tarkiln Run clay body is the only Mount Savage clay body worked. Its minable portion is relatively small and most of the clay available for strip mining has been taken. Other bodies of Mount Savage clay in the Castleman basin are too poorly known to permit generalization.

The outlook for Mount Savage clay production is a serious one for the Maryland refractories industry. Erroneous belief that clay beds are continuous and that the Mount Savage bed in particular contains high-grade clays in more than half of its area of distribution has discouraged systematic prospecting. With only three bodies of Mount Savage clay worked or prospected and with one of these containing ferruginous clay and another reaching its probable limits, the outlook for future production of the high-grade Mount Savage clay is not good; and this clay is the chief source of clay for the refractories industry of western Maryland.

Systematic prospecting in the Westernport area and the south end of the Big Savage area in the Georges Creek basin and in areas in the Castleman basin, noted in Part II of this report, is recommended. Reconnaissance prospecting on the crop, while not generally satisfactory, might produce results in the Upper and Lower Youghiogheny basins; favorable areas could then be explored in

more detail. To assure an adequate supply of high-grade refractory clay for the future, the producing companies should explore their present clay bodies to their minable limits. If this procedure indicates a limited supply an active exploratory program should be undertaken in the other areas, where there is some indication of clay at the Mount Savage horizon.

LOWER KITTANNING CLAY

Stratigraphic Relations

Plastic and flint clays are in many places associated with the coals of the Lower Kittanning coal group. This coal group lies between the Kittanning sandstone and the overlying Worthington (Westernport) sandstone. Two coal horizons are commonly present; the lower one as a rule has the thicker, more persistent coal. Clay of refractory grade is present locally in the underclay of both coal beds.

Sections of the Lower Kittanning coal group showing the stratigraphic distribution of the clays are given in Figure 14. Although the coal group and its included clay bodies commonly show sequences that follow a characteristic pattern in a given area they do not appear to be sharply segregated into barren and clay-bearing areas as is the case with the Mount Savage coal group and its clay. Clay-bearing Lower Kittanning strata are considerably more common than clay-bearing Mount Savage strata, but the clay is of lower grade.

Character of the Clay

Plastic and semiplastic clays and claystone are the predominant clay types in the Lower Kittanning clay bodies. Flint clay is a common type only in local areas and is usually subordinate in amount to the plastic clay. Though the character of the clay beds varies greatly from area to area, the character of the clay types is fairly consistent. Plastic clays, where free of macroscopic impurities, are the best-grade refractory soft clays found outside the Mount Savage beds. In the fresh state they are generally gray to tan, fairly compact, and tough. On weathering they break down into plastic white clay. The flint clays and claystones are commonly fragmental, and are colored shades of brown and gray. The flint and semiflint clays are somewhat siliceous, or stony, and consequently not as high grade as the Mount Savage flint clay.

Silt and sand are common in both the soft and hard clays. In the hard clays isolated sand grains are characteristically scattered through the flint clay and claystone or are concentrated in the base of the fragmental zones (see Plate 5). Silt is locally present in thin layers, giving the claystones a banded appearance. In the plastic clays the silt is generally dispersed throughout the clay.

Siderite is a common impurity and occurs chiefly as crystalline pellets scattered through the clay. Ironstone concretions are not common but many irregular masses of siderite are present.

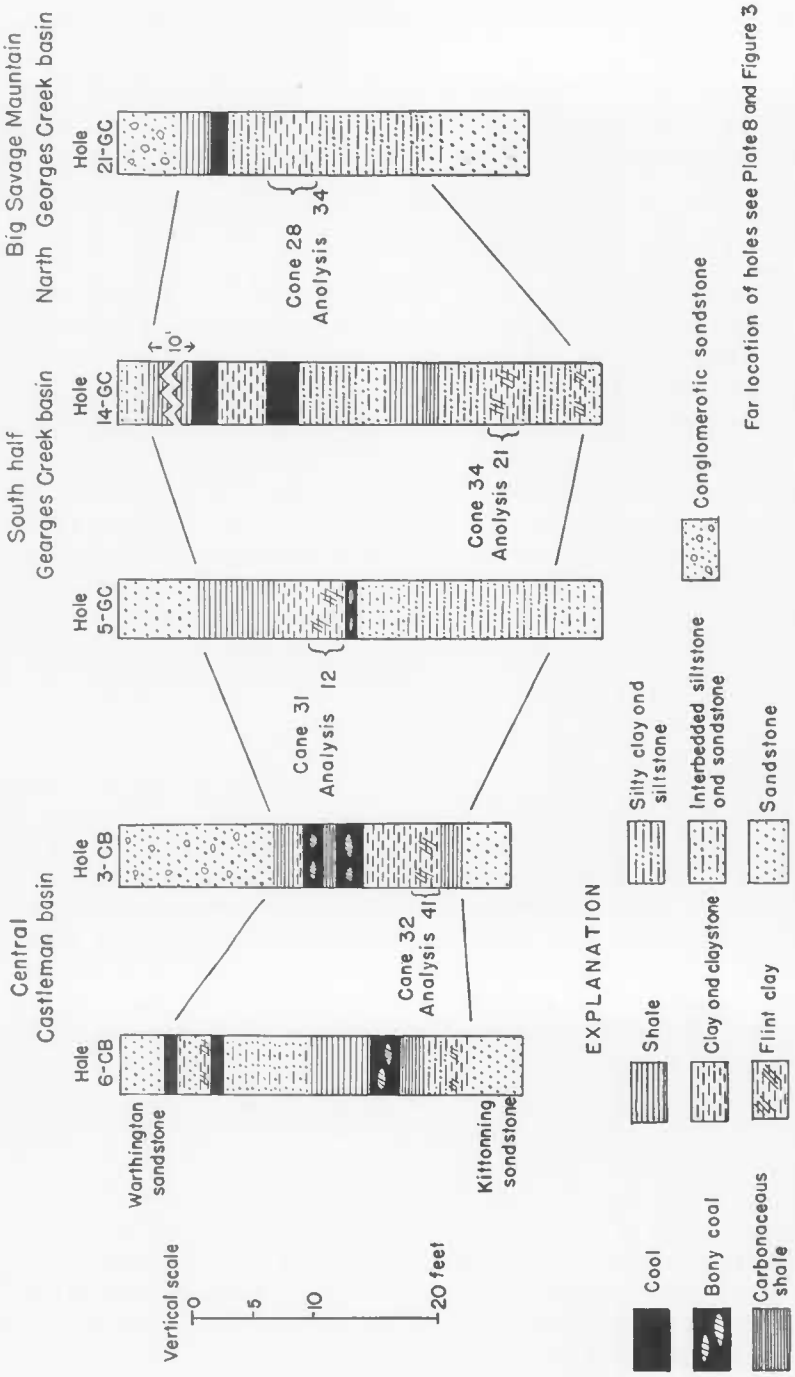


FIGURE 14. Sections of the Lower Kittanning coal group showing the stratigraphic position of its included clays.

Distribution

Lower Kittanning clay bodies of economic value have been mined in the north end of the Georges Creek basin. Here two areas of the clay are recognizable, one along Little Allegany Mountain, north of Jennings Creek, and one along Big Savage Mountain, northwest of Frostburg. The Lower Kittanning clay was once mined extensively along the top of Little Allegany Mountain west and southwest of Ellerslie, in Maryland, and northwest of Cooks Mills and southwest of Hyndman in Pennsylvania. Hall (Watts et al., 1922, p. 359) gives the following section from the Ellerslie Fire Clay Mine of the Andrew Ramsay Company. This mine had its entrance just across the Pennsylvania line but the workings were on the Maryland side.

Ellerslie Fire Clay Mine

	Feet
Massive sandstone roof.	
Heavy brown shale	1.5
Coal	1.9
Soft clay and coal smut	.5
Soft clay	.3
Brown flint clay	1.0
Soft gray clay	.9
Coal smut	.7
Soft clay	.5
Flint clay	1.5

Among other results of tests run on the clays in this section the following fusion points are given by Schurecht (Watts et al., 1922, p. 433):

	Cone
Brown flint clay	33
Soft gray clay	30
Flint clay	34

Leighton (1941, p. 209) reports that the clay in the old Ramsay mine "ranges from 4 to 14 feet thick and is in places all soft gray clay and in other entries is part soft and part brown flint clay." Hall (Watts et al., 1922, p. 359) mentions that both the Lower Kittanning and Mount Savage clays are present in the Ellerslie mine, the flint clay at the base of the section above presumably being taken as the Mount Savage. However, both the coals given in the section are in the Lower Kittanning group as are both the clays. A similar section of coal and clay, in an interval that is unmistakably the Lower Kittanning coal group, was encountered in a drill hole about 2½ miles west of the Ellerslie mine.

Section from Drill Hole 20-GC

	Feet	Inches
Medium grained quartzitic sandstone (Worthington).		
Lower Kittanning coal group:		
Carbonaceous claystone, pyritic	1	0
Fragmental flint clay and clay and claystone, sandy	2	6
Tan semiplastic clay with siderite pellets and irregular ironstone concretions	2	0
Carbonaceous sandy claystone and shale	8	9
Silty fragmental semiflint clay	1	0
Coal	2	0
Coaly claystone, scattered sand grains	0	2
Siliceous semiflint clay and claystone	1	7
Dark gray siltstone, sandy layers	8	6

The Lower Kittanning coal group in this section is thicker than that in the Ellerslie mine but is otherwise similar to it. The additional thickness is due to the local presence of a sandy zone in the middle part of the coal group.

At the south end of Little Allegany Mountain the Mount Savage Refractories Company was still operating the Barrelville mine of the old Union Fire Brick Company in 1948. There is some question as to whether the clay in this mine is the Mount Savage or Lower Kittanning. The working face in the mine shows too little of the section to help in solving this problem and outcrops at the surface are poor. In general character it resembles the Lower Kittanning clay from the old Ramsey mine north along the Mountain. In addition the regional trend toward a sandy, clayless phase of the Mount Savage coal group and a thick, clay-bearing Lower Kittanning coal group in this area favors the interpretation that the Barrelville mine is in the Lower Kittanning.

Throughout the Little Allegany Mountain area north of Jennings Run the Lower Kittanning clay body appears to carry a relatively large proportion of flint clay, a factor that has probably led to its misidentification as the Mount Savage clay. In contrast to this the Lower Kittanning clay along Big Savage Mountain is almost exclusively plastic clay. Adjacent to the mines in the Mount Savage clay on Big Savage Mountain, the Lower Kittanning soft clay has been mined for use with the Mount Savage flint clay in the manufacture of high-grade refractory products. The soft clay is called the "Baker and Clink" clay by the clay workers in the Savage Mountain area. A small open pit is being operated by the Big Savage Refractories Corporation on the outcrop of the Lower Kittanning clay in the vicinity of their Benson mine. The soft clay is of good quality, with a fusion point of about Cone 30.

The extent of the Lower Kittanning plastic clay along Big Savage Mountain is not definitely known. It is present in drill hole 20-GC along U. S. Highway 40 west of Frostburg but is absent in drill hole 10-GC 1½ miles farther south. It has also been found in drill holes and outcrops west of the town of Mount

Savage. The following section shows details of the Lower Kittanning clay from the drill hole along U. S. Highway 40.

Section from Drill Hole 21-GC

	Feet	Inches
Coal (Lower Kittanning).		
Tan plastic clay and claystone, silty to sandy	2	8
Tan and gray fragmental semiplastic clay (Cone 28, Analysis 34)	3	11
Tan claystone grading to siltstone.		

West of Mount Savage a drill hole at the foot of Big Savage Mountain revealed the following Lower Kittanning section.

Section from Drill Hole 25-GC

	Feet	Inches
Coal and carbonaceous shale.		
Silty to sandy brown claystone with fine siderite pellets	0	6
Gray and tan fragmental semiflint clay, locally silty	0	8
Dark brown and gray siliceous flint clay with ironstone concretions	0	8
Carbonaceous claystone with siderite pellets and pyrite crystals	0	9
Silty semiplastic clay	2	0
Siltstone grading to sandstone (Kittanning).		

In this section the carbonaceous claystone marks the position of the lower coal bed. Between the coals no soft clay is present and the hard clay types dominate. Presumably the lens of the so-called "Baker and Clink" clay is restricted to the Big Savage Refractories Corporation property. Two drill holes of the old Union Fire Brick Company, 1 mile and 1½ miles north of drill hole 25-GC from which the section above was taken, show the Lower Kittanning coal group to be restricted to a 15-foot interval of dark gray sandy shale and siltstone between massive quartzitic sandstones. Apparently excessive development of sandstones and related restriction of clay beds characterizes the lower part of the Allegheny formation at the north end of Big Savage Mountain in Maryland. A sandstone body formed by the coalescing of the Worthington, Kittanning, and Clarion sandstones accounts for the absence of both the Mount Savage and Lower Kittanning clays in this area. Farther southeast, approximately in the center of the basin, a similar section of predominantly sandy strata of the lower Allegheny formation was cut in hole 19-GC about half a mile south of Jennings Run midway between Mount Savage and Barrelville. Still farther to the southwest where the strata in question crop out in the south end of Piney Mountain the lower part of the Allegheny formation also appears to consist predominantly of sandstone. An elongate sandstone body apparently extends northwestward approximately through the town of Mount Savage and effectively isolates the clay deposits of the lower part of the Allegheny formation in the Big Savage Mountain area from those in the Little Allegany Mountain area.

The Lower Kittanning clay has never been mined elsewhere in the Georges Creek basin, owing in part to the fact that it is generally too low grade and erratic to be of interest except in areas where it can be mined for mixture with the higher-grade Mount Savage clays. The drill hole records for the east flank of the Georges Creek basin from hole 16-GC east of Eckhart mines to hole 8-GC northeast of Westernport show no clay of economic value at the Lower Kittanning horizon. Instead silty to sandy fragmental claystone and silty semiplastic clay are consistently present. A typical development of the Lower Kittanning coal group illustrative of its character along the east flank of the basin is in hole 8-GC.

Section from Drill Hole 8-GC

	Feet	Inches
Lower Kittanning coal group:		
Coal.		
Gray siltstone	9	4
Fragmental argillaceous siltstone	1	5
Fragmental gray and brown claystone and flint clay, some ironstone concretions	1	10
Brown silty claystone	0	9
Carbonaceous shale	4	6
Dark gray fragmental claystone and siliceous flint clay	2	2
Kittanning sandstone equivalent:		
Interbedded siltstone and fine sandstone.		

An unusual section of Lower Kittanning clay was penetrated in hole 14-GC in the center of the basin about 1½ miles northwest of hole 8-GC on the north bluff above Mill Run less than 1 mile southwest of the town of Barton. Here the predominant clay type is a flint clay similar to the type in the Mount Savage clay bed. Unfortunately, practically the entire flint clay zone is peppered with clear siderite grains (see Plate 6). Relations of this clay bed within the Lower Kittanning coal group are shown in the section in Figure 14. The part of the section including the clay is:

Section from Drill Hole 14-GC

	Feet	Inches
Lower Kittanning coal group:		
Dark gray to carbonaceous shale	3	7
Gray soft clay grading to claystone with black ferruginous pellets	3	3
Gray silty claystone grading to flint clay	0	7
Light brown-gray flint clay locally fragmental with dark interstitial flint; clear siderite pellets scattered throughout (Cone 30, Analysis 21)	2	6
Brown siltstone.		

None of the other drill holes in the vicinity of hole 14-GC show a similar section and it is presumed that this body is of limited extent.

Along the west flank of the basin two holes penetrated clay of fair quality at the Lower Kittanning horizon; the others showed silty and sandy clay types similar to the clays along the east flank of the basin. A drill hole on Koontz Run, 2 miles northwest of Lonaconing, penetrated the following section of clay.

Section from Drill Hole 5-GC

	Feet	Inches
Lower Kittanning coal group (upper part only):		
Coal.		
Dark gray shaly clay	3	0
Fragmental semiflint clay, light gray fragments, dark gray interstitial clay (Cone 31, Analysis 12)	3	0
Coal.		

Relationship of the clay to the remainder of the Lower Kittanning beds is shown in the section from hole 5-GC in Figure 14. Except for the clay of the Little Allegany Mountain area this is the best grade of raw clay found at the Lower Kittanning horizon in the Georges Creek basin. Ironically it is found in a drill hole within 100 feet of the ruins of the Maryland Coal Company clay plant that failed for lack of raw clay (see page 105).

A soft clay similar in character to the "Baker and Clink" clay of the Big Savage Mountain area was penetrated in the Lower Kittanning interval in hole 9-GC, about 2½ miles northwest of Westernport. The clay bed consists of about 7 feet of fairly uniform dark gray semiplastic clay containing a few silty zones. It directly underlies the upper of the two coal beds in the Lower Kittanning section. The fusion point for this clay was Cone 26 and its analysis (Analysis 15) indicates the presence of more than 4 per cent of fluxible impurities. It is inferior to the clay of similar type from hole 21-GC at the south end of the "Baker and Clink" clay area.

South of hole 9-GC the lower part of the Allegheny formation passes gradually into a sandy phase that appears to reach a maximum in the northern extremity of the Upper Potomac basin just south of Savage River gap, west of Bloomington. Although the lower part of the Allegheny formation becomes abruptly less sandy to the south, no clay was cut in the Lower Kittanning interval in any of the five holes drilled in the north end of the Upper Potomac basin. In the area from the Savage River to the latitude of Kitzmiller, only the lower of the two principal coals in the Lower Kittanning coal group is generally present and in most instances this coal bed is overlain by dark gray silty claystone and siltstone rather than more typical clay types of the Lower Kittanning.

In the Castleman basin the Lower Kittanning coal group is generally well developed and locally clay-bearing; its character and distribution are discussed in Part II.

Evaluation of the Lower Kittanning Clay

In the north end of the Georges Creek basin the Lower Kittanning clays have been exploited along with the Mount Savage clay. The Little Allegany Mountain area is mined out, for all practical purposes, and can be eliminated from consideration. The limited area of "Baker and Clink" clay on Big Savage Mountain is not very well known but indications are that a considerable quantity of good grade plastic clay may be present on the crop. The amount of mining in this crop clay to date has been negligible. The only sample of fresh "Baker and Clink" clay available (Analysis 34 from hole 21-GC) indicates that it would not qualify as a soft clay for high-grade refractory products without having some of its impurities leached by weathering.

Elsewhere in the Georges Creek basin the Lower Kittanning clay is relatively unexplored. The area around the headwaters of Koontz Run was prospected in 1916 in connection with the building of the Maryland Coal Company clay plant. From what can be learned of this exploration it was concentrated around a few obvious exposures and was not done systematically.

The drill hole records show no clays of sufficient value to warrant any large-scale exploration for Lower Kittanning clay bodies along the nearby outcrop areas. Since no extensive deposits similar to those in Little Allegany Mountain are indicated elsewhere in the basin, the Lower Kittanning clay does not appear to warrant much consideration as a potential source of high-grade clay. However, it has been of value in furnishing plastic clay in the Mount Savage area and there are probably other areas in which it contains sufficiently high grade material to serve as a bond clay for mixture with high-grade flint clay. The headwater area of Koontz Run is the best potential prospecting area for Lower Kittanning plastic clay of this type.

MIDDLE KITTANNING CLAY

Stratigraphic Relations

Notwithstanding the fact that the Middle Kittanning coal group contains the most irregular strata of any coal group in the Allegheny formation, a fairly persistent pattern is recognizable in its sequence within certain areas. The Castleman basin is such an area and its section of the Middle Kittanning coal group can be used as a basis for comparison with other areas. Three coal beds are commonly present in the Middle Kittanning interval in the Castleman basin; the uppermost coal is at least 25 feet below the Upper Kittanning coal horizon and the lowest of the three coals lies 40 to 60 feet below the upper coal. In most places sandstones are absent between the coal beds; where sandstones are present they are thin and nonpersistent. The Middle Kittanning coal group is usually separated from the Lower Kittanning coal group by a sandstone; but even where the sandstone is absent or poorly developed the two coal groups

are fairly distinct. Clay is most commonly present between the lower two coals of the Middle Kittanning group.

In the Georges Creek basin the pattern of the Middle Kittanning interval is not as clearly defined as in the Castleman basin because of the more pro-

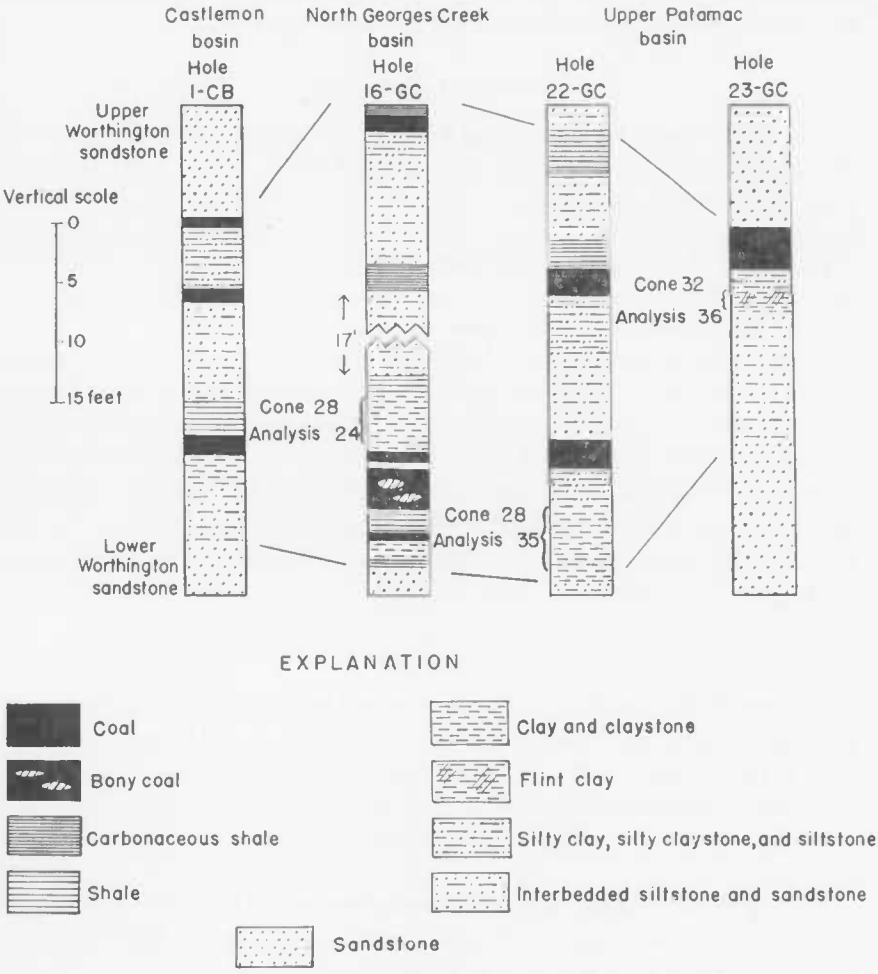


FIGURE 15. Sections of the Middle Kittanning coal group

nounced irregularity of the strata. The number of coal beds varies from place to place, although three is the most common number in the north half of the basin. The uppermost coal appears anywhere from 20 to 70 feet below the Upper Kittanning coal. In some sections sandstones locally separate the several

Middle Kittanning coal beds. Locally no sandstone is present between the Middle and Lower Kittanning coal groups; consequently the boundary between the coal groups in some places is difficult or impossible to locate. Where there is more than one coal bed, the Middle Kittanning clay is locally present and is associated with the lower coal beds in the group. Representative sections of the Middle Kittanning coal group are given in Figure 15.

Character of the Clay

Clays associated with the Middle Kittanning coal group include claystones, flint and semiflint clays, and soft clays, most of which are generally too low in grade or too thin to be of commercial value. Good grade flint clay is rare and is present only in minor quantities as small lenses or as fragments in the claystones. Some of the siliceous claystones and flint clays are brown but more are dark gray. Most of the fragmental clays have both gray and brown fragments but the interstitial clay is dark gray to black.

In only one section did the Middle Kittanning clays contain the siderite pellets so common in the lower clay horizons. Some of the clays contain a few yellowish ironstone concretions about half an inch in diameter, and irregular masses of sideritic clay occur locally as lenses or as the interstitial material of some of the fragmental claystones. Silt and sand are the principal impurities in the flint clays. Flint clay in thin lenses is generally silty; thicker flint clay beds are silty and sandy in their basal parts but in some places contain relatively pure flint clay at the top.

Distribution

The Middle Kittanning clay has been mined only in three short-lived stripping operations in the Castleman basin. It appears to be of better grade there than in the Georges Creek and Upper Potomac basins. The clay in the Castleman basin is predominantly soft clay but thin lenses of flint clay occur locally in the basal part of the clay bed; the deposits are described in Part II of this report.

Drilling records furnish the only information available on the Middle Kittanning clays of the Georges Creek and Upper Potomac basins. A lens of plastic to semiflint clay with iron as a common impurity is present in the Middle Kittanning interval over a large part of the north half of the Georges Creek basin. The southern limit of this large lens appears to trend northwestward across the basin, passing south of drill holes 11-GC and 10-GC through the settlements of Ocean and Carlos. Representative sections of the Middle Kittanning coal group in this area are:

Section of Middle Kittanning clay in Drill Hole 11-GC

	Feet	Inches
Middle Kittanning coal group:		
Coal	1	0
Dark gray shaly clay	4	6
Sandstone with some interbeds of dark siltstone	24	2
Dark gray shale	3	9
Coal and carbonaceous shale	2	5
Gray semiplastic clay with somewhat shaly fracture (Cone 30, Analysis 18)	2	3
Coal and bone	1	10

Section of Middle Kittanning clay in Drill Hole 15-GC

	Feet	Inches
Middle Kittanning coal group:		
Coal and pyritic, coaly shale	2	2
Shaly siltstone	14	8
Fine-grained sandstone with shaly partings	10	0
Carbonaceous shale, sandy at top	13	0
Dark gray fragmental semiplastic to semiflint clay, sideritic in lower part (Cone 30, Analysis 22)	2	0
Silty to sandy claystone	4	8
Dark gray shale	2	4
Coal and claystone	1	7

Section of Middle Kittanning clay in Drill Hole 25-GC

	Feet	Inches
Middle Kittanning coal group (in part):		
Medium-grained sandstone	25	6
Gray to black shale, coal at base	3	0
Fine sandstone	0	8
Carbonaceous claystone	4	2
Fragmental claystone, minor siliceous flint clay	1	0
Siltstone and silty claystone	7	6
Gray semiplastic clay (Cone 28, Analysis 38)	2	6
Siliceous, sideritic flint clay	0	8
Silty claystone grading to siltstone and sandstone.		

In these three sections the Middle Kittanning interval shows the same pattern. An upper coal horizon is underlain by a sandstone that is in turn followed by two coal horizons with the clay between them. In the section of hole 25-GC the upper coal horizon is not shown and the lower one is absent. Except for the local absence of the sandstone unit this sequence is typical for the Middle Kittanning interval in the north end of the Georges Creek basin. Where no prominent sandstone is present in this area, its horizon is commonly marked by interbedded siltstone and fine sandstone.

Another area in which the drills penetrated Middle Kittanning clay is in

the Upper Potomac basin between Elklick Run and the longitude of Kitzmiller. The position of the clay in the section is shown in Figure 15 in the partial sections of drill holes 22-GC and 23-GC, the two holes drilled in the area. Details of the clays are given below.

Section of Middle Kittanning clay, Drill Hole 22-GC

	Feet	Inches
Coal.		
Gray and dark gray finely silty plastic clay	2	0
Fragmental semiplastic clay	0	9
Fragmental semihard to semiflint clay, scattered ironstone concretions (Cone 28, Analysis 35)	6	3
Interbedded siltstone and sandstone.		

Section of Middle Kittanning clay, Drill Hole 23-GC

	Feet	Inches
Coal.		
Silty gray-brown claystone grading to silty flint clay	1	5
Dark brown, locally fragmental semiflint and flint clay (Cone 32, Analysis 36)	2	0
Interbedded siltstone and sandstone.		

In drill cores from other parts of the Georges Creek and Upper Potomac basins the Middle Kittanning underclay consists of impure silty to sandy clay and claystone.

Evaluation of the Middle Kittanning Clay

The Middle Kittanning clay has some potential value as a source of soft clay. This clay generally requires weathering to bring it up to a grade satisfactory for use as a refractory clay and therefore is of value only on the crop. Associated flint clays are thin or, where thick enough to mine, are in very small bodies. They are rarely equal in purity to the Mount Savage flint clays and are somewhat siliceous or stony. At best the Middle Kittanning clay of Maryland is a substitute for the soft clays of the Mount Savage and Lower Kittanning underclays.

UPPER KITTANNING CLAY

Stratigraphic Relations

The Upper Kittanning underclay can be readily identified in drill cores because of its position below the persistent Upper Kittanning coal. Even where this coal is absent the clay can be identified from its position relative to the Upper Freeport coal, which is probably the most persistent coal bed in the northern Appalachian coal fields.

The Upper Kittanning underclay zone is the lowest underclay zone in the Allegheny formation in which fresh-water limestone is a common constituent.

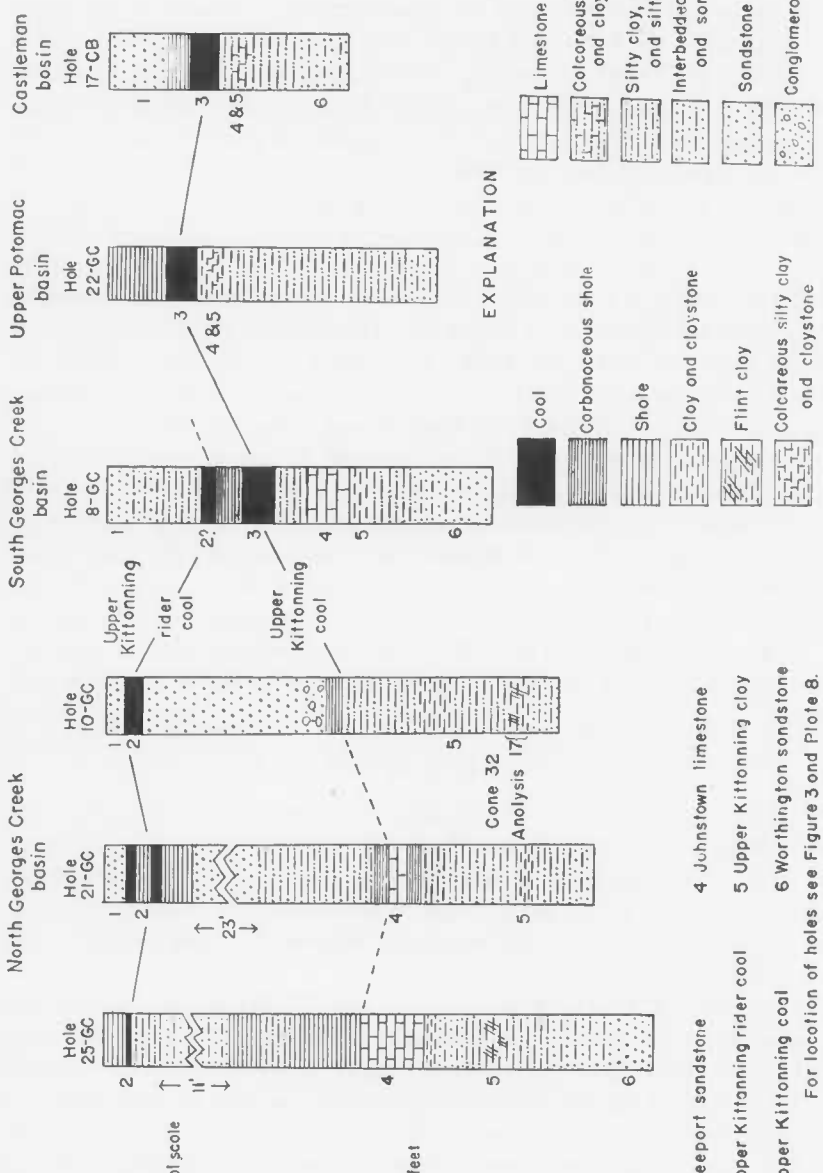


FIGURE 16. Sections of the Upper Kittanning coal and its underclay

Although such limestone has been recorded from the underclay unit of the uppermost coal of the Middle Kittanning coal group its occurrence at this horizon is exceedingly rare. A thin bed of argillaceous limestone was cut at this horizon in hole 6-GC, and a second occurrence is recorded in the log of a hole drilled by the Manor Mining and Manufacturing Company in the Upper Potomac basin in the Kitzmiller-Vindex area. Limestone or limy claystone is present under the Upper Kittanning coal in slightly more than 50 per cent of the drill holes in the Georges Creek, Upper Potomac, and Castleman basins.

Throughout most of the area the clay, or limestone and clay, of the Upper Kittanning underclay zone lies directly below the Upper Kittanning coal. However, in the Big Savage Mountain area of the Georges Creek basin the rider to the Upper Kittanning coal appears to be abnormally thick and the Upper Kittanning bed is either very thin or absent. The interval between the rider and the Upper Kittanning coal horizon is thick and contains a sandstone bed. (See first three sections in Figure 16.) This atypical relationship, coming in one of the areas where the Upper Kittanning clay has been worked led Swartz (Swartz and Baker, 1922, pp. 48–49) to consider the clay as underlying a thin coal, which he calls the Little Montell coal, some feet below the thicker bed he interpreted as the Upper Kittanning coal. Although the drill holes are not closely enough spaced to disprove Swartz's interpretation, the fact that the Upper Kittanning clay elsewhere directly underlies the Upper Kittanning coal bed is a strong argument in favor of the interpretation suggesting a local excessive development of the rider coal. In addition, if Swartz's Little Montell coal is indeed an additional bed and not poorly developed Upper Kittanning coal, sections showing three rather than two coal horizons could be expected in the Upper Kittanning interval. No such sections were cut in any of the drill holes.

Character of the Clay

The Upper Kittanning clay types range from soft clay to flint clay, are typically impure, and rarely include bodies of refractory-grade clay. In many of the places where limestone or limy claystone is present the clays beneath it are limy throughout. In the sections lacking limestone, silty, plastic, and semiplastic clays predominate and claystone and siliceous flint and semiflint clays are less common.

Iron in several different forms is a common impurity in the Upper Kittanning clay, generally in concretionary masses or in the interstitial areas of the fragmental claystone and flint clay. Siderite pellets, a typical form of impurity in the lower clays of the Allegheny formation, were not seen in the Upper Kittaning clays but these clays commonly contain ironstone bands and irregular crystalline masses of siderite. The siderite masses weather to limonite and were at one time a source of iron. According to Swartz (Swartz and Baker, 1922,

p. 48) the iron in the Upper Kittanning underclay was mined by the Union Mining Company in the neighborhood of Mount Savage in 1846 and smelted in that town.

High-grade clay bodies occur at only a few places in the Upper Kittanning underclay. Bodies of mahogany-brown flint clay, similar in appearance to the Mount Savage clay, and plastic clays of refractory grade are present in some of these places. However, most of the lime-free Upper Kittanning clay that has been observed is silty or even sandy and while it locally shows thin lenses of good quality the bed as a whole is too silty or has too much sideritic material to be of value.

Distribution

Few deposits of good clay occur in the Upper Kittanning underclay in the Georges Creek basin. The best bed penetrated by the drills was in hole 2-GC on Moores Run about 1.1 miles east of Barton at a depth greater than 600 feet.

Section of Upper Kittanning underclay, Drill Hole 2-GC

	Feet	Inches
Coal (Upper Kittanning).		
Silty clay and siltstone, pyritic	2	7
Interbedded claystone, semiflint clay, and flint clay, locally fragmental, with zones of siltstone and some interstitial siderite (Cone 29, Analysis 3)	2	8
Mahogany-brown flint clay, fragmental zones (Cone 34, Analysis 4)	3	6
Siltstone.		

The only mining of the Upper Kittanning bed was done in the vicinity of Mount Savage. The clay mined here was predominantly a soft clay, although some siliceous flint clay was associated with it. Hall (Watts et al., 1922, p. 351) gives the following section for clays considered to be Upper Kittanning in an abandoned mine of the Union Mining Company.

Union Mine Number Five

2¼ Miles N. 70° W. of Mount Savage

	Feet
Iron-stained sandstone roof.	
Yellow, iron-stained plastic clay (Cone 13)	0.6
Black, carbonaceous clay (Cone 16)	1.1
Gray soft plastic clay (Cone 18)	5.3
Hard tough flint clay	0.4
Soft plastic gray clay (Cone 15)	2.5

Flint clays listed by Watts from the same area are siliceous and generally low grade. The following hard-clay section was penetrated in the Upper Kit-

tanning underclay zone in a drill hole 1.75 miles west-southwest of Mount Savage; the clays were too impure to warrant testing.

Section of Upper Kittanning clay, Drill Hole 25-GC

	Feet	Inches
Dark silty shale, plant remains (Upper Kittanning horizon at base of this unit).		
Limestone	6	2
Claystone with interbeds of siltstone and sandstone	5	10
Gray siliceous claystone with siltstone and ironstone inclusions	0	9
Mottled brown and blue-gray claystone and semiflint clay, ferruginous stringers	1	0
Silty claystone and siltstone.		

The record from another drill hole about 4 miles southwest of this hole and less than a mile north of the town of Midlothian shows the following Upper Kittanning section:

Section of Upper Kittanning clay, Drill Hole 10-GC

	Feet	Inches
Coal (Upper Kittanning rider).		
Quartzitic sandstone	16	10
Carbonaceous shale (Upper Kittanning horizon)	1	2
Irregular-interbedded light gray claystone, silty claystone, and siltstone	7	11
Fragmental siliceous flint clay (Cone 32, Analysis 17)	1	6
Silty plastic and semihard clay grading to claystone.		

No other Upper Kittanning clays penetrated by the drills in the north end of the Georges Creek basin were considered worth testing. In most of the holes in this area highly siliceous claystone overlain by a bed of argillaceous limestone represent the Upper Kittanning underclay zone. Similar sections were found in the other two areas where limestone was present in the underclay zone. A typical section from the south end of the drilling area northwest of Kitzmiller in the Upper Potomac basin is given below.

Section of the Upper Kittanning underclay, Drill Hole 22-GC

	Feet	Inches
Coal (Upper Kittanning).		
Gray shale	0	7
Argillaceous limestone	2	0
Silty claystone and silty semiplastic clay	9	4
Siltstone and silty claystone.		

Between the areas in which limestone is present, the Upper Kittanning clay is generally a silty, plastic to semiplastic clay with local lenses of impure claystone.

Evaluation of the Upper Kittanning Clay

The Upper Kittanning clay has not proved to be of value in Maryland. Although the bed is far more persistent than the lower clay beds in the Allegheny formation, the presence of calcareous material in the underclay greatly limits the areas where high-grade refractory clays could be present. With the single exception of the excellent bed of flint clay cut in hole 2-GC on Moores Run in the Georges Creek basin no deposits of minable Upper Kittanning clay are known in this basin. Actually the area represented by the good flint clay in hole 2-GC is small as other drill records from surrounding holes show no comparable bed at the Upper Kittanning horizon. Nevertheless, this single known lens of refractory clay marks the Upper Kittanning clay as a potential producing bed.

BOLIVAR (UPPER FREEPORT) CLAY

Named Units in the Upper Freeport Underclay Zone

Three names are commonly applied to different parts of the Upper Freeport underclay zone. Argillaceous limestone in the upper calcareous part is locally designated the Upper Freeport limestone. This unit was originally defined as the Freeport limestone by Rogers (1859, p. 492) and was later renamed the Upper Freeport limestone (F. and W. G. Platt, 1877, p. 316); the U. S. Geological Survey has adopted the latter name as a member of the Allegheny formation (Wilmarth, 1938, p. 778 and 2220). The name Upper Freeport clay was applied by Stevenson (1878, p. 34) to the clay that underlies the Upper Freeport limestone. Subsequently the term has been applied to clay between the Upper Freeport coal and Upper Freeport limestone as well as to the clay below the limestone. In Westmoreland County, Pennsylvania, near the town of Bolivar, clay from the Upper Freeport underclay zone has been mined for many years and the name Bolivar fire clay, formally introduced by I. C. White (1891, pp. 159–160), has gained wide usage in the northern bituminous coal fields. The name Bolivar has consistently been applied to the semirefractory- and refractory-grade clays beneath the Upper Freeport limestone.

As the three subdivisions of the Upper Freeport underclay were named at a time when the relations of the different lithologic types in the underclay zone were not as clearly understood as they now are, it is necessary to give the the exact connotation of the three terms as they apply to the Upper Freeport underclay zone in Maryland.

Briefly summarized, the Upper Freeport underclay zone in Maryland commonly consists of (1) an upper part of plastic and semiplastic clay that commonly contains limestone pellets and in many places is replaced in whole or in part by argillaceous limestone and (2) a lower part that commonly consists of two claystone beds separated by a zone of clastic material. The name Upper

Freeport limestone applies to the lenticular beds of argillaceous limestone in the upper part of the underclay zone; it does not apply to the soft clays or lime-pellet clays with which it is both laterally and vertically gradational. The name Bolivar applies to the two claystone beds and intervening clastic bed in the lower part of the underclay section. The name Upper Freeport clay has been used in the past for any clay in the Upper Freeport underclay zone and thus in its broadest sense includes the entire underclay zone except the bodies of Upper Freeport limestone. Because of this latitude of meaning the name Upper Freeport clay has little value in detailed descriptions of the underclay zone; it is not used in the present study.

Stratigraphic Relations of the Upper Freeport Underclay Zone

The underclay of the Upper Freeport coal is thicker and more consistently compound than any other underclay zone in the Allegheny formation. It lies between the Upper Freeport coal and the locally developed Butler sandstone, which overlies the Lower Freeport coal. The interval thus defined ranges from 15 to more than 50 feet in thickness. Although no prominent sandstone is generally present at the Butler horizon in Maryland, a zone of interbedded siltstone and fine sandstone marks its position in most places.

Sections showing the stratigraphic relationships in the interval between the Upper Freeport coal and the Upper Kittanning coal are given in Figure 17. The interval shows gradual westward thinning throughout western Maryland and the Upper Freeport underclay thins in the same direction. In the Georges Creek and Upper Potomac basins the average distance between the Upper Kittanning and Upper Freeport coals is between 90 and 100 feet. To the west in the Castleman basin, the average is between 60 and 70 feet. The Upper Freeport underclay zone in the eastern basins is commonly about 35 feet thick and locally, in the north half of the Upper Potomac basin, increases to 50 feet where no sandstones are present in the Upper Kittanning-Upper Freeport interval. In the Castleman basin the Upper Freeport underclay is seldom more than 25 feet thick and averages about 20 feet.

More important, from an economic standpoint, than the variation in thickness is the variation in the lithologic character of the underclay section. In the areas of its greatest thickness in the eastern coal basins the Upper Freeport underclay zone is generally a highly complex unit made up of interbedded clay, claystone, argillaceous limestone, and siltstone. The clays are impure and silty for the most part and where high-grade they occur as thin lenses with the impure claystones. Although the limestone predominates only in the upper part of the underclay zone, in many places in the eastern coal basins it is distributed as pellets and stringers throughout the entire interval. In most parts of the eastern coal basins the sequence of rock types in the underclay zone is too irregular to permit recognition of its subdivisions, the Upper Freeport limestone and Bolivar clay.

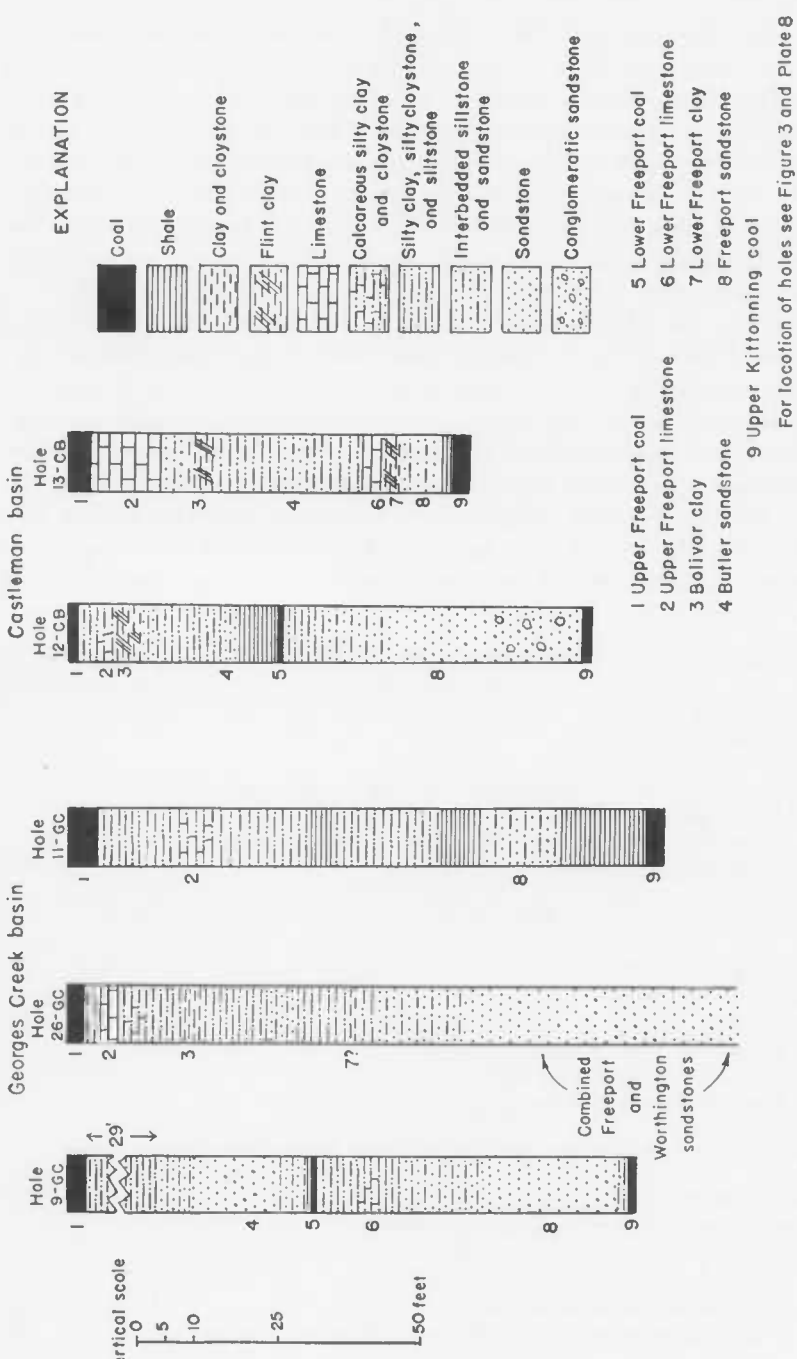


FIGURE 17. Variations in the distribution of beds in the Upper Kittanning-Upper Freeport interval.

The Upper Freeport underclay zone in the Castleman basin is thinner and shows less lateral variation in lithologic character than in the eastern coal basins. The Upper Freeport limestone, which in most places consists of argillaceous limestone, occupies the upper part of the underclay zone and the Bolivar clay, in the lower part of the underclay zone, is generally free of limy impurities. The Bolivar clay is compound and contains a complex section of alternating clay types. As a rule this part of the zone is much better sorted than the corresponding beds in the eastern coal basins, and high-grade clays occur locally without intermixture with low-grade clays.

Throughout the Maryland coal basins the lower, generally noncalcareous part of the Upper Freeport underclay zone that constitutes the Bolivar clay, commonly consists of two clay beds separated by a clastic unit of siltstone, interbedded siltstone and sandstone, or, in a few sections, of sandstone only. This clastic unit is not generally recognizable where the entire lower part of the underclay zone itself is largely silty claystone and siltstone or where the lower of the two clay beds is highly silty. In sections where the Bolivar clay is well-developed, however, the clastic unit within it ranges from 6 inches to 12 feet in thickness. Sections are given below that show the relationships of the clays and the clastic unit in each of the three coal basins.

Section of the Upper Freeport underclay, Drill Hole 13-CB (Castleman Basin)

	Feet	Inches
Coal (Upper Freeport).		
Gray argillaceous limestone	8	3
Bolivar clay:		
Fragmental tan and blue-gray flint clay, silty in upper part	3	7
Gray argillaceous siltstone	2	0
Fragmental brown flint clay with interstitial sideritic claystone	0	8
Silty claystone grading to siltstone.		

Section of the Upper Freeport underclay, Drill Hole 26-CB (Castleman Basin)

	Feet	Inches
Coal (Upper Freeport).		
Argillaceous limestone	9	0
Bolivar clay:		
Fragmental "flinty" claystone	3	6
Siltstone with zones of fine sandstone	6	1
Fragmental semiplastic clay grading to silty claystone	4	0

Section of the Upper Freeport underclay, Drill Hole 23-GC (Upper Potomac Basin)

	Feet	Inches
Coal (Upper Freeport).		
Claystone and silty claystone, locally calcareous	2	0
Bolivar clay:		
Silty claystone with calcareous stringers	12	0
Irregular-bedded fine sandstone	4	2
Fragmental semihard clay with thin beds of limestone in upper part	6	10
Claystone grading to siltstone.		

Section of Upper Freeport underclay, Drill Hole 2-GC (Georges Creek Basin)

	Feet	Inches
Coal (Upper Freeport).		
Interbedded argillaceous limestone and claystone	15	5
Bolivar clay:		
Fragmental semiflint clay and claystone, some interstitial limestone	2	3
Siltstone with thin interbeds of sandstone in upper part	16	3
Fragmental siliceous flint clay and claystone and clay, some limestone fragments and scattered pyrite	0	8
Dark gray semiplastic, finely silty clay	2	6

Character of the Clay

The clay types in the upper part of the Upper Freeport underclay zone are in most places plastic and semiplastic calcareous clay and lime-pellet clay that grade laterally into the argillaceous limestone beds of the Upper Freeport limestone. In a very few places the soft clay of the upper part of the underclay zone is lime-free but in such places it is low-grade refractory clay at best and is not found in commercial quantity.

In the Bolivar clay both soft and hard clay are locally present but the hard clay, in the form of claystone, flint clay, or semiflint clay, is more common. Mixture of clay types and the frequent occurrence of limestone, siderite, and gypsum as impurities are typical of the Bolivar clay in the Georges Creek basin. The flint and semiflint clay are in many places interbedded and intermixed with siliceous flint clay, claystone, and argillaceous siltstone. In the Castleman basin, as has already been noted, the lithologic character of the Upper Freeport underclay zone is less variable and bodies of relatively pure flint and semiflint clay are locally present. The best flint clay of the Bolivar clay is similar to that in the Mount Savage clay; it is colored shades of brown and gray and in most places is fragmental, with the interstitial material equal in grade to the fragments. Such clay is rare in comparison to more siliceous flint clay, which is fragmental and in many places consists of light brown to light gray fragments in a dark blue to blue-gray matrix. Fragmental semiflint clay is also common.

Impurity is one of the most distinctive characters of the Bolivar clay. No other clay in the Allegheny formation contains such complex mixtures of clay, siltstone, limestone, ironstone, and gypsum. Silt is the predominant clastic impurity; sand is generally restricted to the bed that separates the two parts of the clay. Limestone is locally present as stringers or veinlets in the clay or, more rarely, as pellets and small lenses. The pellets and lenses occur locally in the lower bed of the Bolivar clay; the thicker lime-pellet clay and limestone of the Upper Freeport limestone locally grade downward into the upper bed of the Bolivar clay.

Iron is in the form of irregular masses of siderite, ironstone concretions, and veinlike stringers of ferruginous material. The concretions vary in type from

small concentrically layered forms to the larger septarian concretions with calcite and barite fillings. Concretions of the latter type are similar to those in the Mount Savage clay but are less common and smaller.

Gypsum occurs as a fibrous fracture filling or as thin coatings on slickensided surfaces and on partings. It has also been found in thin layers, seldom exceeding $\frac{1}{4}$ of an inch, roughly parallel to the bedding (see Plate 3, b). Although not one of the principal impurities, it occurs anywhere in the Upper Freeport underclay zone and is commonly associated with the limy beds in the upper part.

Distribution

Three principal types of section are recognized in the Upper Freeport underclay zone in the Georges Creek basin. In one type the entire underclay zone is silty and little or no clay is present. A second type, the most common, is a complex underclay zone characterized by the presence of limestone. A third type is also a complex underclay consisting of various lithologic types but lacking limestone. All three types are intergradational.

The silty phase of the Upper Freeport underclay zone occurs in several areas in the Georges Creek and Upper Potomac basins. One narrow northeast-trending belt of silty material, delimited by the drill-hole records, crosses through the south half of the Georges Creek basin. The presence of a similar belt is suggested by a few scattered drill-hole records from the north end of the basin. The record of only one hole outside these two areas, that of hole 13-GC from the north end of the Upper Potomac basin, shows the silty phase. A typical section of the Upper Freeport underclay zone in the silty phase is given below.

Section below the Upper Freeport coal in Drill Hole 6-GC

	Feet	Inches
Coal (Upper Freeport).		
Dark gray siltstone with interbeds of silty claystone	6	1
Interbedded light gray silty claystone and siltstone; minor zones of fine sandstone	31	8
Medium-grained sandstone (Butler sandstone).		

Sections in areas marginal to the silty-phase, like the one below, show transitional features.

Section of Upper Freeport underclay in Drill Hole 14-GC

	Feet	Inches
Coal (Upper Freeport).		
Dark gray slightly calcareous siltstone with a few interbeds of argillaceous limestone	18	2
Fragmental silty claystone with interstitial siltstone	9	0
Siltstone with sandy streaks (Butler sandstone equivalent).		

Calcareous underclay zones in the Upper Freeport of the Georges Creek and Upper Potomac basins are variable in the details of their sequence of rock types. Even within relatively small areas there is no apparent uniformity either in the amount of limestone or in its mode of occurrence, whether in beds, pellets, irregular masses, or veinlike stringers. The stratigraphic distribution of calcareous material within the underclay zone is also variable but in most sections in the two eastern coal basins limestone is present throughout the underclay zone both above and below (and in many places within) the clastic bed dividing the Bolivar clay. (In sections of this type it is not generally possible to distinguish the Upper Freeport limestone and Bolivar clay as distinct units.) Representative sections are given below.

Section of Upper Freeport underclay in Drill Hole 16-GC

	Feet	Inches
Coal (Upper Freeport).		
Fragmental claystone with interbeds of argillaceous limestone	3	6
Silty claystone	4	3
Calcareous siltstone with interbeds of argillaceous limestone	5	8
Fragmental claystone interbedded with argillaceous limestone	8	4
Argillaceous, gypsiferous limestone	2	4
Calcareous semiplastic silty clay grading to claystone	8	0
Fine sandstone (Butler).		

Section of Upper Freeport underclay in Drill Hole 17-GC

	Feet	Inches
Coal (Upper Freeport).		
Dark gray claystone with limestone pellets in lower 4 feet	9	11
Gray calcareous silty clay	4	0
Light gray plastic clay with calcareous film on slickensided surfaces (Cone 28, Analysis 25)	4	0
Interbedded sandstone and siltstone.		

Section of Upper Freeport underclay in Drill Hole 18-GC

	Feet	Inches
Coal (Upper Freeport).		
Gray siltstone	6	3
Plastic clay grading to silty, pyritic claystone; limestone pellets in lower part	5	0
Bolivar clay:		
Dark sideritic claystone grading to light gray fragmental claystone with scattered pyrite	0	10
Fragmental siliceous flint clay (Cone 30, Analysis 28)	1	5
Plastic to semiplastic gray clay, minor pyrite (Cone 30, Analysis 29)	1	4
Silty claystone and siltstone	10	3
Calcareous silty claystone with stringers of siderite	6	0
Shaly semihard clay with 2 inches of flint clay at base	1	5
Interbedded sandstone and siltstone (Butler).		

One small area in the Georges Creek basin contains a body of Bolivar clay that is free of limestone and is not in the silty phase although it probably is marginal in position to the latter. The clay was penetrated by three drill holes between Mill Run and the Savage River. In these holes a relatively thin clay underlies the coal and does not contain any bed of clastic material. This suggests that the lower bed in the Bolivar clay, from below the clastic unit, is in the silty phase and only the upper portion of the clay is represented. Two of the drill-core sections are given below.

Section of Upper Freeport underclay, Drill Hole 1-GC

	Feet	Inches
Coal (Upper Freeport).		
Silty semihard clay	6	3
Plastic clay, light gray (Cone 19, Analysis 1)	5	9
Dark gray siltstone and sandstone.		

Section of Upper Freeport underclay, Drill Hole 9-GC

	Feet	Inches
Coal (Upper Freeport).		
Dark silty semiplastic clay	8	1
Light gray flint clay, fragmental	0	7
Dark gray silty claystone	0	3
Silty claystone grading to siltstone.		

The three major phases of Upper Freeport underclay can also be recognized in the Castleman basin. The silty phase is similar to that found in the eastern basins and the few lime-free sections appear to be associated with it. The predominant underclay type contains limestone but the underclay section as a whole is much less variable in lithologic character than equivalent sections in the eastern basins and the limestone is restricted to that part of the section above the clastic bed. Bodies of high-grade Bolivar clay, not known to occur in the Upper Freeport underclay zone of the eastern basins, are present in the Castleman basin. They are described in detail in the second part of this report.

Evaluation of the Bolivar Clay

The Bolivar clay in the eastern coal basins appears to be worthless. There is a possibility that local clay bodies are present in the Upper Freeport underclay zone in the south end of the Upper Potomac basin but none have been reported from either Maryland or West Virginia. The variable lithologic character and the large amount of siliceous and calcareous impurities account for the sparsity of high-grade clays.

In the Castleman basin the Bolivar clay is one of the potential producing horizons. Lenses of high-grade clay are present in areas where the silt content is low. Although little is known of the clay in the two western basins, the fact

that the Bolivar clay becomes less variable in character westward suggests that they are favorable areas for prospecting.

CLAYS OF THE LOWER MEMBER OF THE CONEMAUGH FORMATION

CLAY BEDS

The rarity of refractory-grade clay in the lower member of the Conemaugh formation of Maryland has already been mentioned. Refractory- or semi-refractory-grade clay occurs only in small lenses and pockets except in the underclays of the Mahoning and Lower Bakerstown coal beds. Of these two beds only the Mahoning underclay zone commonly has local bodies of semi-flint, and, more rarely, flint clay. The Lower Bakerstown or Thomas clay is chiefly a plastic clay.

Most other underclays of the lower member of the Conemaugh formation are ruled out as possible sources of high-grade clay because they consist only of impure soft clays that are in the limy phase. Some of these underclays include pellets and lenses of argillaceous limestone and some of them consist of argillaceous limestone through most of the underclay section. In general the amount of argillaceous limestone in the underclay zones increases upward in the lower member of the Conemaugh formation. Thus at the lower underclay zones in the formation the limy phase is only locally developed, whereas at the upper underclay zones it is widespread.

In the following list the lithologic character and other noteworthy features of the underclay zones in the lower member of the Conemaugh formation are given. The underclays are named for their overlying coal beds; names applied to specific underclay units are given in parentheses.

Underclay Zone	General character
Barton (Barton limestone)	Argillaceous limestone grading to clay and claystone with limestone pellets. A persistent underclay zone 15 to 40 feet thick. The limestone has been quarried in some areas for local agricultural use.
Federal Hill	This underclay consists of about 10 feet of clay and claystone with limestone pellets.
Harlem	Argillaceous limestone grading to clay and claystone with limestone pellets. A persistent underclay zone that is in most places 20 to 30 feet thick. In some areas it grades imperceptibly into the underlying Pittsburgh redbed, which also locally contains limestone.
Upper Bakerstown (Ewing limestone)	Argillaceous limestone grading to clay and claystone with limestone pellets. A persistent underclay 10 to 20 feet thick.
Lower Bakerstown (Thomas clay, Albright limestone)	Usually has a relatively lime-free plastic clay in upper 1 to 4 feet that grades downward into clay or claystone with limestone pellets and lenses. Locally the entire underclay zone is in the limy phase.

Brush Creek (Irondale limestone, Corinth sandstone)	A lithologically variable underclay that frequently contains an abundance of siltstone and sandstone, both of which are, in part, calcareous. Clays and claystones in the limy phase are also common and argillaceous limestone is locally present.
Mahoning (Thornton clay, Mahoning limestone)	A complex underclay that frequently contains fragmental clays and claystones. These are commonly siliceous and contain iron as their chief impurity. Clay with limestone pellets locally takes the place of the claystones. In some areas the clay is associated with the Mahoning coal, in other areas with the lower Mahoning redbed.

CLAYS ASSOCIATED WITH REDBEDS

Redbed zones in the lower member of the Conemaugh formation in many places include low-grade plastic and semiplastic clays. The common clay type is a fine silty plastic clay that weathers to light shades of gray, green, buff, or red, rarely to white. Some redbed clays can be utilized for making brick and tile but no clays of semirefractory or refractory grade have been found in the redbed zones.

In the section on the stratigraphy of the lower member of the Conemaugh formation it was shown that the redbed zones appear to be lateral phases of coal beds, their underclays, and their overlying shales. Three of the redbed zones are known to grade laterally into coal-bearing strata within western Maryland and others can be correlated with coal horizons in neighboring states. The redbed zones of the lower member of the Conemaugh formation in Maryland are listed below in descending order, opposite their coal-bearing phases.

Redbed Zones in Lower Member of the Conemaugh Formation	Equivalent Coal-Bearing Phases
Birmingham	Federal Hill coal horizon.
Pittsburgh	No known equivalent.
Meyersdale (upper zone)	Relationships obscure; may be closely related to a rare split of the Lower Bakerstown coal.
Meyersdale (Cambridge red bed)	Cambridge marine horizon, unnamed coal in Maryland, Wilgus coal of Ohio.
Mahoning (upper zone)	Probably the Mason coal of Ohio.
Mahoning (lower zone)	Mahoning coal, Thornton clay.

Lithologic types are similar in the different redbed zones. The color green predominates, and red mottling or intervals of solid red color, though conspicuous, are only intermittently present. Gray clay is also present in many places. The clays are sparsely to highly silty plastic and semiplastic clays and, more rarely, claystones. Locally they grade imperceptibly into shale. Where shale or shaly clay is present it commonly occupies the upper part of the redbed zone, indicating a local carry-over of the shale lithology from the shale of the coal-bearing phase.

Although fragmental clays and claystones are common in the Mahoning redbed zones they are relatively rare in the higher redbeds. No red clay fragments have been observed in the fragmental beds but fragments of green claystone are common.

Representative sections showing the nature of redbed zones of the lower member of the Conemaugh formation are:

Meyersdale redbed (lower part), Drill Hole 19-GC

	Feet	Inches
Interbedded siltstone and sandstone.		
Silty clay shale, sandy zones in upper part, predominantly green and gray; two zones of red color near top and base	13	6
Mottled red and green fine silty semiplastic clay (Cones 16 to 18, Analysis 26)	4	0
Calcareous sandstone (Buffalo).		

Meyersdale redbed, Drill Hole 20-GC

	Feet	Inches
Siltstone and silty claystone.		
Irregular-bedded greenish-gray clay shale, ferruginous partings, sandy at base	4	6
Gray semiplastic clay, streaks of fine silt (Cone 20, Analysis 31)	5	0
Mottled red and green semiplastic clay and claystone	5	4
Sandstone (Buffalo).		

Section of Harlem underclay and Pittsburgh redbed, Drill Hole 17-GC

	Feet	Inches
Coal (Harlem).		
Interbedded argillaceous limestone and claystone with limestone pellets	22	10
Gray, silty plastic clay, limestone pellets	3	0
Mottled red and green silty plastic clay, limestone pellets	7	0
Gray, silty plastic clay, limestone pellets	12	0
Siltstone and silty claystone.		

No clays of refractory grade are known to occur in the redbed zones with the exception of some fragmental clays in the Mahoning horizons. Many redbed zones, however, are good brick clays where they have been leached to some extent by weathering. Redbed clays of several horizons of the Conemaugh formation are mined for this purpose in adjacent parts of Pennsylvania but none of the beds have been exploited in Maryland.

THORNTON CLAY

The Thornton clay is commonly present near the base of the lower member of the Conemaugh formation, 25 to 50 feet above the Upper Freeport coal. The clay appears in both the Mahoning coal phase and the lower Mahoning

redbed phase and in sections of the interval that are intermediate between the two phases. The clay bed is absent only in those sections of the Upper Freeport-Brush Creek interval that have an unusually high sandstone content.

The Thornton clay can easily be confused with a clay of similar character that is present locally within the upper part of the Mahoning redbed. In the Georges Creek and Upper Potomac basins the upper Mahoning redbed and its clay are only locally present and are usually thin, whereas the Thornton bed is persistent and well developed. To the west the relationship changes somewhat as the upper part of the Mahoning bed thickens and becomes more persistent. The Thornton clay is not as extensively developed as it was in the eastern basins. In parts of the western basins the two zones are separated by 10 or 15 feet of intervening siltstones. This local proximity has led to the belief that the Thornton clay is a double bed. The evidence from the drill holes, however, shows that only the lower bed belongs to the Thornton clay as originally defined by White (1903, p. 322).

Character of the clay

Fragmental claystone is the dominant clay type in the Thornton clay. Silty soft clays are present in some places but these are consistently impure, with either silt or lime in the form of limestone pellets as the common impurity. The fragmental claystones are highly variable in character and in this respect resemble those of the Bolivar clay. However, the Thornton clay contains a considerably greater proportion of light green, greenish-gray, and blue-gray claystones, is consistently more siliceous, and is not known to contain beds of high-grade flint clay.

The outstanding feature of the Thornton fragmental clays is the heterogeneity of the fragments, which include all gradations in lithology between argillaceous sandstone and siliceous flint clay. The matrix is also variable and commonly highly ferruginous. The fragments are not constant in shape; some are angular, some have highly irregular borders, and others show a certain amount of rounding and are molded against one another. In most of the Thornton clay sections the principal impurities of the clay bed are in the fragments of silty claystones and other siliceous clay types that are mixed with the better clay types and in siderite and other iron minerals in the interstitial material.

Distribution

The graphic sections of the Upper Freeport-Brush Creek interval given in Figure 9 illustrate the variable relationships of the Thornton clay. Sections illustrating the details of the Mahoning underclay, including the Thornton clay bed in some of its various phases, are given below. These sections are included in abbreviated sections of the Upper Freeport-Brush Creek interval in

order to show the local development of the clay at the upper Mahoning redbed horizon as well.

Section of Upper Freeport-Brush Creek interval in Drill Hole 2-GC

	Feet	Inches
Coal (Brush Creek).		
Silty clay and claystone, limestone pellets in middle part	9	2
Siltstone	10	8
Semiplastic gray to dark gray, fine silty clay (upper Mahoning clay)	3	0
Siltstone grading to interbedded siltstone and sandstone	13	8
Sandstone (Upper Mahoning)	16	0
Semiplastic to semihard gray to dark gray fine silty clay (Thornton clay) (Cone 29, Analysis 2)	5	4
Siltstone	20	0
Sandstone (Lower Mahoning)	38	4
Dark gray shale	3	1
Coal (Upper Freeport).		

This section is in the Mahoning coal phase and shows both the lower and upper beds of the Mahoning sandstone. The absence of the Mahoning coal is probably the result of erosion prior to the deposition of the overlying sandstone. Both the Thornton and upper Mahoning clay beds show the common type of clay found in the Upper Freeport-Brush Creek interval when the interval is in the Mahoning coal phase. The following section of the Mahoning underclay is from a drill hole in the central part of the Georges Creek basin.

Section of Mahoning horizon in Drill Hole 7-GC

	Feet	Inches
Coal (Mahoning).		
Gray to dark gray silty clay	2	10
Fragmental claystone and silty claystone. Coarse and fine fragments of various shades of gray. Matrix dark blue-gray; slightly calcareous at top and pyritic near base	2	3
Argillaceous siltstone	11	9
Sandstone (Lower Mahoning).		

Except for the south end of the Georges Creek basin and the north end of the Upper Potomac basin the Mahoning coal bed is rarely present in Maryland. Sections in the north end of the Georges Creek basin show great variation in the character of the Upper Freeport-Brush Creek interval. In the drill holes south of the latitude of Frostburg, between it and the latitude of Midland, the Upper and Lower Mahoning sandstones commonly appear as a single unit and the Mahoning coal and underclay are entirely absent. In this area the upper part of the Mahoning redbed makes its only recorded appearance in the Georges Creek and northern Upper Potomac basins. Between the latitude of Frostburg and the Pennsylvania state line the Mahoning horizon reappears

as the Mahoning sandstone becomes double again and its two parts thin out rapidly to the north and northwest. The following two sections are from this area.

Upper Freeport-Brush Creek interval in Drill Hole 19-GC

	Feet	Inches
Coal (Brush Creek).		
Silty claystone and silty plastic clay	7	0
Interbedded siltstone and silty claystone; 1 foot of sandstone at top	12	7
Semiplastic clay and claystone grading to siltstone (upper part of Mahoning redbed equivalent)	9	0
Sandstone (Upper Mahoning)	3	0
Silty clay shale and shaly claystone	4	0
Siliceous green shaly claystone with scattered blebs of siderite	4	0
Fragmental claystone, tan and green fragments in uniform gray matrix. Upper few inches carbonaceous and shaly (Thornton clay) (Cone 30, Analysis 29)	2	2
Interbedded silty claystone and siltstone	18	10
Sandstone (Lower Mahoning)	17	0
Dark gray silty shale	4	0
Upper Freeport coal horizon.		

Upper Freeport-Brush Creek interval in Drill Hole 20-GC

	Feet	Inches
Coal (Brush Creek).		
Carbonaceous claystone grading to light gray claystone and semiplastic clay with limestone lenses and pellets	8	6
Interbedded siltstone and fine sandstone	7	8
Gray claystone (upper Mahoning redbed equivalent)	5	10
Sandstone, minor amounts of siltstone (Upper Mahoning)	5	0
Siltstone, silty claystone, and silty shale	14	1
Coal (Mahoning)	0	10
Gray and dark gray silty shale, coaly partings	5	8
Interbedded claystone, limestone, and clay with limestone pellets	3	9
Fragmental flint clay and siliceous claystone with some interstitial siderite (Thornton clay) (Cone 26, Analysis 30)	2	3
Interbedded silty claystone and siltstone, locally fragmental	4	9
Interbedded argillaceous limestone, silty clay, and silty claystone	7	6
Siltstone, sandstone, and silty claystone (Lower Mahoning sandstone?)	10	9
Upper Freeport coal horizon.		

Both of these sections show less than the average thickness for the Upper Freeport-Brush Creek interval and both are abnormal in that the Upper Freeport coal is lacking, although its horizon is indicated by a thin carbonaceous shale underlain by the Bolivar clay. The upper part of the Mahoning redbed zone is represented by impure gray claystones between the sandy beds at the base of the Brush Creek underclay and the Upper Mahoning sandstone. The Mahoning beds are in a transitional phase, the sandstones are thinning out,

fresh-water limestones are common, and the green claystones, the principal element of the redbed phase, are locally present.

The Thornton clay in hole 19-GC includes a 2-foot bed of siliceous flint clay fusing at Cone 30, which is the best-grade clay found at this horizon in Maryland. It represents probably the expectable optimum grade for the Thornton clay. The grade of the clay in hole 20-GC is obviously impaired by siderite, a common impurity in the clay, and by other fluxible impurities not accounted for in the partial analysis.

The Thornton clay and the clay of the upper part of the Mahoning redbed are both present throughout a large part of the Castleman basin and both are commonly in the redbed phase. Locally, however, relationships are obscured and in many places it is difficult to determine whether only one bed is present or whether both are present but continuous with one another. The following is a typical Castleman basin section of the Upper Freeport-Brush Creek interval showing a sequence of units similar to that of the Georges Creek basin.

Upper Freeport-Brush Creek interval, Drill Hole 4-GC

	Feet	Inches
Coal (Brush Creek).		
Interbedded siltstone and fine sandstone	7	5
Semiplastic clay and claystone, limestone lenses and pellets	13	7
Sandstone	6	7
(Upper part of Mahoning redbed).		
Greenish-gray, silty to sandy fragmental claystone	11	3
Mottled red and green silty semiplastic clay	11	4
Silty claystone, limy stringers and inclusions	4	6
Interbedded siltstone and sandstone (Upper Mahoning sandstone)	7	10
(Lower part of Mahoning redbed and Thornton clay)		
Gray claystone, locally fragmental	4	8
Red and green silty claystone	6	0
Green and gray silty claystone, including zones of fragmental semiflint clay	3	6
Interbedded siltstone and sandstone (Lower Mahoning sandstone)	20	0
Dark gray to black silty shale	7	10
Coal (Upper Freeport rider).		

In this section the two redbed zones are distinctly separated by the interbedded siltstone and sandstone that represents the upper part of the Mahoning sandstone. The fragmental clays of the upper part of the Mahoning redbed are highly silty and sandy. The two zones of fragmental clay in the Thornton clay bed contain a mixture of semiflint clay and claystone that would qualify as a low-grade refractory clay but each is only a few inches thick.

The Thornton clay seldom seems to have both minable thickness and minable grade. The common thick clay beds are most heterogeneous and as a rule include lenses of highly sandy or ferruginous fragmental clay. Less common lenses of semirefractory-grade fragmental clay are in most places thin and in-

terbedded with undesirable clay types. Beds with high-grade fragments in a ferruginous matrix are also common in the Thornton bed. Both the iron content and the fluxible impurities in the fragmental flint and semiflint clays average higher than in similar clay types in the Allegheny formation.

Little is known about the Thornton clay of the western coal basins of Maryland, but it is reported by Hennen and Reger (1914, p. 373) to be persistent and of relatively good quality in Preston County, West Virginia, which borders Garrett County to the west. It is probable, therefore, that both the Upper and Lower Youghiogheny basins have the Thornton clay. The counties in West Virginia that border the Maryland panhandle to the south and southeast (Tucker, Grant, and Mineral Counties) are not reported to have clay deposits of value at the Thornton horizon. In eastern Ohio the Thornton clay is intermittently present and according to Stout (Stout et al., 1923, p. 444) is more persistent than the overlying coal. However, it is everywhere a nonrefractory plastic clay. As in Maryland, the presence of iron and lime as impurities detracts appreciably from its value.

The strata of the lower member of the Conemaugh formation in Pennsylvania are difficult to identify because the coals are poorly developed and the member has no persistent key beds other than the few marine shales and limestones and even these appear to be locally discontinuous. In some areas clays generally referred to as the Mahoning clays are present between the Upper Freeport coal and Brush Creek marine shale. These are dominantly low-grade clays useful only in the manufacture of brick. In Indiana County a bed of semiflint clay called the Wehrum clay is present locally below the Brush Creek horizon. Its exact position in the Upper Freeport-Brush Creek interval has not been reported; it may be in the Brush Creek underclay or it may be correlative with either the upper Mahoning redbed clay or the Thornton clay.

Evaluation of the Thornton clay

The Thornton clay has never been mined in Maryland but it has been worked for many years in neighboring parts of West Virginia. Actually there has been little investigation of the Thornton clay in Maryland. From the several core samples tested on the Bureau of Mines projects it is evident that semirefractory-grade clays exist at the Thornton horizon in the basins drilled. It is therefore a potential producing horizon and merits prospecting.

THOMAS CLAY

The underclay of the Lower Bakerstown coal, unlike most of the underclay zones in the upper part of the lower member of the Conemaugh formation, commonly contains a bed of relatively lime-free clay that locally approaches semirefractory grade. However, calcareous clays and argillaceous limestones are also common at this horizon and most of these are more persistent. Swartz

named the non-calcareous and calcareous phases of the Lower Bakerstown underclay the Thomas clay (Swartz and Baker, 1922, pl. 7) and the Thomas limestone (Swartz and Baker, 1922, p. 60) respectively. The latter term is discarded in favor of the name Albright limestone, which has precedence (see page 42).

Character and Distribution

The clays in the Thomas bed are dominantly plastic and semiplastic. Claystones are not common but a few localities have yielded semiflint clay of low grade. The soft clay types are gray to dark gray mealy clays and are commonly silty. These weather to sticky gray-white and yellowish-white plastic clay.

The two underclay phases (Thomas clay and Albright limestone) are gradational and as a result the Thomas clay is in many places somewhat calcareous. Iron, in the form of irregular stringers of siderite or scattered grains of pyrite, is also a common impurity.

There appears to be no areal pattern to the presence or absence of either the Albright limestone or the Thomas clay. There is, however, an indication that the rare occurrences of hard clay types are restricted to the Georges Creek and Upper Potomac basins. Claystones and semiflint clays were encountered at the Thomas horizon in several drill holes on the east flank of the Georges Creek basin. Sections from two of these holes are given below.

Section of Lower Bakerstown underclay, Drill Hole 5-GC

	Feet	Inches
Coal and black shale (Lower Bakerstown).		
Gray silty semiplastic clay, limy pellets	5	6
Gray silty semiplastic clay grading to claystone	0	6
Fragmental semiflint clay and claystone, gray fragments in darker matrix (Cone 28, Analysis 23)	1	0
Interbedded silty claystone and sandstone.		

Section of Lower Bakerstown underclay, Drill Hole 6-GC

	Feet	Inches
Coal and black shale (Lower Bakerstown).		
Gray silty semiplastic clay	0	10
Gray semiflint clay, locally fragmental with dark ferruginous interstitial material (Cone 18, Analysis 13)	2	0
Fragmental claystones, silty claystone, and siliceous flint clay. Gray and blue-gray fragments in highly ferruginous matrix	1	10
Gray silty claystone.		

Similar sections have been encountered in one or two other drill holes in the Georges Creek and northern Upper Potomac basins. In these holes the purer clay types do not exceed a foot in thickness and are closely associated with clays that have lime or iron as impurities.

The predominant type of soft clay in the Thomas bed of the Georges Creek and Upper Potomac basins is a silty, dark gray mealy clay that is not refractory. Clay of this type appears to grade laterally into the calcareous clays and claystones of the limy phase.

In the Castleman basin hard clay does not occur at the Thomas horizon except as very small lenses or inclusions. The clay in this area is plastic and semiplastic and is of little value when fresh. The section of the only Thomas clay tested from the drill cores in the Castleman basin is that in the following section.

Section of the Lower Bakerstown underclay zone, Drill Hole 3-CB

	Feet	Inches
Coal (Lower Bakerstown).		
Dark gray silty semiplastic clay	1	10
Dark gray argillaceous limestone with light gray limestone pellets (Albright limestone)	5	4
Gray, mealy, semiplastic clay (Cone 19, Analysis 40) (Thomas clay).	3	8
Red and green plastic clay (Upper split of Meyersdale redbed).		

This clay was selected for testing because it was considered typical for Thomas clay in the fresh state in the Castleman basin area. A sample of this inferior clay would not have been tested had not surface deposits of higher grade been found. Apparently the Thomas clay under the proper conditions of exposure and topographic position is locally sufficiently improved by weathering to qualify as a low-grade refractory bond clay.

The character of the Thomas clay in the western coal basins is not known. In adjoining counties of West Virginia and Pennsylvania its use has not been reported. In eastern Ohio the Anderson clay, which is the equivalent of the Thomas clay, is a low-grade clay and has not been used in the manufacture of refractory products.

Evaluation of the Thomas Clay

Although clay of semirefractory grade was encountered in the Thomas clay in one of the drill holes in the Georges Creek basin and clays of similar type were found in other drill holes the deposits of this clay are not of commercial value. It is doubtful that lenses of the semirefractory clay sufficiently large and pure to warrant the cost of underground mining exist at the Thomas horizon. However, bodies of shallow clay that could be strip mined may locally be of value as low-grade plastic bond clays provided they have been leached of some of their impurities by weathering. No bodies of this type are known in the Georges Creek or Upper Potomac basins. Because of the steeper dip of the strata in these basins there is little likelihood of finding areas of strippable clay. With the gentler dips in the Castleman basin and Upper and Lower Youghiogheny basins there is more opportunity for stripping. Shallow bodies

of Thomas clay should be prospected and tested where strip mining is a possibility. In general, however, the clay does not warrant detailed prospecting on its own potentialities but should be considered in an overall program of clay prospecting. Notwithstanding its lack of promise it remains a possible local source of plastic bond clay.

THE REFRACTORY PRODUCTS INDUSTRY IN WESTERN MARYLAND

HISTORICAL SUMMARY

Since the year 1841, when the first brick plant was opened at Mount Savage in Allegany County, the clays of the coal measures have been the chief source of high-grade clays for Maryland's refractory products industry. Refractory flint clay was discovered in 1837 on Big Savage Mountain, just west of the town of Mount Savage. It was first used locally to line two blast furnaces operated by the Maryland and New York Coal and Iron Company, the same plant that produced (Singewald, 1911, p. 140), in 1844, the first iron rails, other than strip rails, in the United States.

In 1841 the Union Mining Company opened Maryland's first refractory brick plant at Mount Savage, taking their clay from mines on Big Savage Mountain about 2½ miles west of the town. Subsequently mines were opened about 2½ miles north of Frostburg on Big Savage Mountain and along Little Allegany Mountain west of Ellerslie. Until 1946, more than 100 years after mining of the refractory clay was begun, commercial production of raw refractory clay in western Maryland was limited to these three localities. The clay was made into various high-grade refractory products in plants at Frostburg, Zihlman (formerly Allegany), and Ellerslie as well as at Mount Savage. Thus the industry has, until recently, been restricted to a small area in the Georges Creek basin north of the latitude of Frostburg.

Two major attempts have been made to operate refractory products plants utilizing clays of the coal measures elsewhere in western Maryland. In 1916 and 1917 the Maryland Coal Company constructed a large plant along Koontz Run about 2 miles northwest of Lonaconing in the Georges Creek basin. An electric tram road was built from the plant to exposures of clay at the head of Koontz Run. All this was done on the basis of a superficial examination of the clay bed that was to be the source of the raw material. Only a small area of clay that had been improved by leaching was tested. After the plant was constructed and entry was made into the clay body it was found to be a small pocket of impure material not of refractory grade. No other adequate source of clay was found nearby and the venture failed without realizing production. Adequate prospecting prior to construction of the plant would have cost an insignificant amount in comparison to the investment lost.

The second venture away from the north end of the Georges Creek basin came during 1945 and 1946 and was instigated by the boom in clay products

brought on by World War II just as the Koontz Run venture was instigated by the production boom of World War I. The presence of a high-grade flint clay near Tarkiln Run on the North Branch of the Casselman River in Garrett County had been known for some time. Ries (1902, pp. 503–505) made the first public report of the locality in an addenda to his "Report on the Clays of Maryland," in which he gives the location and observed thickness of the clay bed and an analysis of a sample of the clay. The locality was mentioned in many subsequent reports, particularly those by G. C. Martin (1902, pp. 215–216; and 1908) and G. M. Hall (in Watts et al., 1922, p. 370). In 1945 and 1946 a large, modern plant was constructed by the Union Fire Brick Company (formerly the Garrett Refractories Company) on the South Branch of the Casselman River about 3 miles south of Grantsville. This was done after diamond drilling the Tarkiln Run deposit had proved some tonnage of high-grade flint clay at a depth sufficiently shallow to permit stripping. The plant has been producing high-grade refractory products since 1947.

PRESENT CLAY PRODUCTION

There are now three plants manufacturing refractory products in western Maryland—the Big Savage Refractories Corporation and the Mount Savage Refractories Company in the north end of the Georges Creek basin and the Union Fire Brick Company in the Castleman basin.

The Big Savage Refractories Corporation has its plant at Zihlman,[5] Maryland, about a mile northeast of Frostburg. It is a modern plant with a tunnel kiln and numerous beehive kilns. Ninety-five percent of its production is first-quality firebrick; the remainder is second-quality firebrick. Capacity production is 1,250,000 bricks per month. In terms of raw clay this amounts annually to between 60,000 and 70,000 tons, of which 30 percent is plastic clay, the remainder flint clay. The raw clay is obtained from some of the original operations on Big Savage Mountain north and northwest of Frostburg. It is transported to the plant by tram on a gravity plane and by truck. Two underground mines, opened many years ago, are working in the Mount Savage clay bed, and a smaller operation is supplying plastic clay from a bed about 60 feet above the Mount Savage clay. Locally referred to as the "Baker and Clink" clay, it is probably the Lower Kittanning clay. Recently some strip mining has been done along the crop of the Mount Savage bed.

The Mount Savage Refractories Company is the only brick plant now in operation at Mount Savage, Maryland. Its principal product is face brick. Not more than 25 percent of its production is refractory products, which include both first- and second-quality firebrick, ground clay, and calcined clay. The plant, formerly that of the old Union Mining Company, is said to have a max-

[5] Formerly the town of Allegany. Railroads have retained the old name; the U. S. Post Office uses Zihlman.

imum production capacity of 1,250,000 bricks per month but this has not been realized in recent years. Clay for the refractory brick is trucked to the plant from one of the former Union Mining Company workings on Little Allegany Mountain just east of Barrelville. Production from this mine is between 30,000 and 36,000 tons annually. Only about 30 percent of the clay mined is flint clay; the remainder is plastic clay of refractory and semirefractory grade. Although generally considered to be the Mount Savage clay, it is probably the Lower Kittanning clay. Clay for the face brick is a red clay brought in by truck from nearby in Pennsylvania.

The Union Fire Brick Company plant south of Grantsville in the Castleman basin is the largest refractory products plant in western Maryland. Its production capacity is 1,750,000 bricks per month; the work is done in two tunnel kilns. First-grade refractory brick is the principal product; some calcined clay is also produced. Production of raw clay has varied in quantity and has not been stable. For maximum capacity about 70,000 tons of clay must be mined annually. Of this 25 percent must be plastic clay, the remainder flint clay. The raw flint clay comes from a twin stripping operation on both sides of Tarkiln Run in the area first referred to by Ries (1902, p. 503). Plastic clay of refractory grade has been found in restricted pockets along with the flint clay and has also been strip mined from several localities on Meadow Mountain along the east side of the Castleman basin. The flint clay at Tarkiln Run, originally considered to belong to the Bolivar clay, is now known to be in the Mount Savage bed, and the soft clay mined on Meadow Mountain has come from the Middle Kittanning beds.

The potential capacity of the refractory products plants in western Maryland is 4,250,000 bricks per month. The clay production necessary to make this quantity of brick is between 2,500 and 3,000 tons of high-grade plastic clay and 7,500 and 9,000 tons of flint clay per month. The total refractory clay needs for brick manufacture would be between 120,000 and 144,000 tons annually if the plants operated at capacity.

OUTLOOK

The future of the refractory products industry in western Maryland depends upon the availability of raw clay of refractory grade. A brief review of the known bodies of refractory clay shows that the need for more clay is critical. One of the two original source areas for clay, that on Big Savage Mountain west of Mount Savage, is known to be mined out and has not been worked for many years. The Little Allegany Mountain area is also essentially worked out; only the Barrelville mine has been worked, intermittently, within the past 20 years. The area north of Frostburg is the only major producing area left in the Georges Creek basin. Its limitations are not definitely known but it has passed its productive peak.

Until the recent activity in the Castleman basin the refractory clay production in western Maryland had shown a steady decline since the peak period during the First World War and early 1920's. Now the figures indicate an increase of production. The new Union Fire Brick Company plant in the Castleman basin is primarily responsible for this. In the light of the need for the discovery of new clay bodies it is significant that this plant is utilizing a raw clay deposit known to exist at least as far back as 1900. The Union Fire Brick Company plant is keyed for production at a scale that can be maintained only by strip mining and the bulk of known strippable clay in their deposit has already been taken.

It is obvious that new bodies of refractory clay must be found and developed in western Maryland if the future of the refractory products industry of this State is to be assured. How much clay lies ahead in the present workings is not known, as systematic prospecting ahead of mining is not normally done. Thus there is no basis for estimating clay reserves and consequently no way of judging how long the present working properties will support the industry.

PART II. GEOLOGY AND REFRACTORY CLAY DEPOSITS OF THE CASTLEMAN BASIN

Introduction

The recent construction by the Union Fire Brick Company of a modern refractory products plant near Jennings in Garrett County, Maryland, has stimulated search for refractory clay deposits in the Castleman coal basin. Previously little interest had been shown in the clays of this basin, which is isolated from the brick plants in the Georges Creek coal basin by lack of adequate transportation facilities. The only industrial area with direct access to the Castleman basin is around Meyersdale in southern Somerset County, Pennsylvania, where there are no refractory products plants.

The study of the clays in the Castleman basin was begun as a surface examination to determine the value and extent of known deposits and to prospect for possible extensions and for new deposits, but interpretation of resulting information on the few mines and prospects was hampered by the lack (1) of stratigraphic information and (2) of an adequate geologic map. Surface prospecting was attempted, but it was soon found that outcrops of bedrock, other than sandstone, were essentially nonexistent.

Trenching of possible outcrops was tried in the flat areas and swales on the backslopes of the ridges. However, the bedrock units were so weathered and covered by slope wash that the depth required for the trenches was prohibitive. Except in a few places, deep test pits or core drilling are the only methods that are satisfactory for prospecting the likely outcrop areas of the clay-bearing strata.

With the advent of U. S. Bureau of Mines Project 823 the surface prospecting was abandoned. Instead a study was made of the stratigraphy of the clay beds in the drill cores, and a geologic map of the basin was prepared. Information gained from this work has revealed the stratigraphic distribution of the principal refractory clay beds and has indicated their relative importance as potential producing beds in the Castleman basin. In addition, the understanding of the stratigraphy gained from the drilling has permitted correlation of the known clay deposits with relative certainty. The geologic map, Plate 8, shows the approximate outcrops of some of the principal coal beds and the limits of the areas underlain by them are the same as the limits of areas underlain by many of the clay-bearing beds. Also shown on the map are the locations of the 40 diamond drill holes put down in the central part of the basin by the U. S. Bureau of Mines on Project 823.

LOCATION AND GEOGRAPHIC FEATURES

The Castleman basin is in the north-central part of Garrett County (see Fig. 1), and extends to the northeast into Somerset County, Pennsylvania. The Maryland portion of the basin is included on topographic maps of the U. S. Geological Survey issued in 1949. Five $7\frac{1}{2}$-minute quadrangle sheets—Avilton, Grantsville, Accident, Bittinger, and McHenry on a scale of 1:24,000, cover the area. The basin is a syncline that begins at Deep Creek Lake in the southwest corner of the McHenry quadrangle and plunges gently northeastward into Pennsylvania. Strata from the Pottsville formation to the upper beds of the Conemaugh formation are included in the Maryland part of the syncline. Resistant sandstone beds in the Pottsville formation form bounding ridges that converge gradually southwestward and coalesce near Deep Creek Lake, making the basin a topographic as well as a geologic unit. At the Pennsylvania state line the distance between the bounding ridges is 7.5 miles. The length of the basin along the axis of the syncline from Deep Creek Lake to the Pennsylvania line is 16 miles.

Meadow Mountain, the bounding ridge on the east side of the Castleman basin, is a southward continuation of Allegheny Mountain, which marks the eastern boundary of the Allegheny plateau in Pennsylvania. The bounding ridge on the west side of the Castleman basin is called Negro Mountain in both Maryland and adjacent parts of Pennsylvania. The crests of both ridges are about equal in height and their average elevation is approximately 2950 feet. Meadow Mountain has three summits with altitudes greater than 3000 feet and Negro Mountain has four, including the highest summit in the basin, 3075 feet, at the Hi-Point Lookout Tower, about 1.5 miles south of the Pennsylvania state line. At intervals the crests of both mountains are broken by shallow wind gaps, and where the mountains coalesce at Deep Creek Lake the ridge is cleft by a narrow water gap through which Cherry Creek flows south into the lake.

Approximately five-sixths of the total area of the Castleman basin is drained to the northeast by the Casselman River; the remaining sixth is a small portion of the south end of the basin drained by Cherry Creek. Two forks of the Casselman River, North Branch and South Branch, are the principal streams in the central part of the basin. The forks join to form the Casselman River about 1.5 miles north of Jennings. The river and its principal tributaries lie in deep, rather narrow valleys but have prominent floodplains through parts of their courses. The Casselman River meanders northward through the central part of the basin and into Pennsylvania.

The area that lies between the bounding ridges and is drained by the Casselman River and its tributaries is an upland of broad hills whose summit elevations decrease gradually toward the north-central part of the basin. The north half of the basin has been deeply incised by the river and its tributaries and

here the relief is 400 feet and more. The south half of the basin has no large streams, the valleys are shallower, and the relief is generally less than 300 feet. The drainage systems in this end of the basin, and in particular that of Cherry Creek, are characterized by broad areas of swamp and marshland. Strike valleys are present in many places at the foot of the backslopes of the ridges sharply separating these slopes from the irregular hilly upland within the basin.

The crests of the bounding ridges and their backslopes, which form the flanks of the basin, are heavily wooded and have very few clearings. In the central hilly portion of the basin most of the hilltops and the broader areas of floodplain are under cultivation, but the steep valley walls are wooded.

Grantsville is the only town in the Castleman basin. Jennings is the only other community consisting of more than a dozen homes. Grantsville is in the center of the basin on the National Pike, U. S. Highway 40, which crosses the north end of the basin. One paved road, Maryland Route 417, extends north from Grantsville into Pennsylvania and a second, U. S. Highway 219, extends north from U. S. Highway 40 about 3 miles east of Grantsville to Salisbury and Meyersdale, Pennsylvania. A single paved road, Maryland Route 495, runs south of Grantsville through the center of the basin to a junction about a mile south of the crossroads settlement of Bittinger. Maryland Route 495 is a gravel road extending from this junction southward across Meadow Mountain toward Swanton, Maryland. A narrow hard-surfaced road continues southwestward from the junction, leaves the basin through Cherry Creek gap, and joins U. S. Highway 219 just north of Deep Creek bridge, about 11 miles north of Oakland, the county seat. All other roads serving the Castleman basin are dirt roads.

The basin is served by a single track railroad—the Castleman River Railroad—which enters from Pennsylvania and runs along the east bank of the Casselman River. It is in operation as far south as a coal mine known as the Number One Mine about 2 miles south of Jennings. The tracks extend only a short distance beyond the mine. The Castleman River Railroad runs north to Meyersdale, Pennsylvania, where it joins the main line of the Baltimore and Ohio Railroad.

Agriculture is the principal occupation of the people in the Castleman basin. In contrast with the Georges Creek basin very little coal is mined. Many coal mines have been opened at one time or another but mostly as local fuel mines; coal beds sufficiently thick to permit commercial operations are relatively scarce. No more than half a dozen mines have produced coal commercially in recent years and some of these have been short-lived stripping operations. Scarcity of commercial coal beds in the Castleman basin is accounted for by the total absence of Monongahela strata, in particular the Pittsburgh coal bed at the base of this formation, and by the general decrease in thickness of

certain coal beds of the Allegheny and Conemaugh formations that are important producing beds in the Georges Creek and Upper Potomac basins. Refractory clay was not mined in the Castleman basin before 1944 and has been mined only by the Union Fire Brick Company.

GENERAL GEOLOGY

STRATIGRAPHY

Strata of the coal measures totaling approximately 1300 feet in thickness are present in the Castleman basin. These strata comprise the Pottsville, Allegheny, and the greater part of the Conemaugh formations. The Pottsville formation is exposed on the crests and steep outer scarp faces of the bounding ridges. Measurements from two drill holes in the central part of the basin and from another about a mile north of the state line in Pennsylvania indicate that the thickness of the Pottsville formation averages about 200 feet and shows relatively little variation. It is evident from the brief study given exposures of the Pottsville along the basin rim that the formation increases slightly in thickness to the southwest and probably averages 250 feet in thickness in the south end of the basin.

The contact of the Pottsville and Allegheny formations is rarely discernible in surface outcrops. The Brookville coal is not generally present and at many places its horizon is completely obliterated by the coalescing of the Clarion and Homewood sandstones. For this reason the Pottsville and Allegheny formations must as a rule be mapped as a single unit. In some parts of the Castleman basin the Mercer coal is represented by a bed of bony coal and shale 1 to 4 feet thick. In many places it crops out just below the crest on the outer face of the ridge. Where the Mercer coal can be identified with certainty the position of the Brookville coal above it can ordinarily be estimated. The position of the Brookville horizon can be estimated approximately also from its relation to known outcrops of the Mount Savage coal. However, both the Mercer and the Mount Savage coals are discontinuous and their outcrops cannot as a rule be found on the heavily forested, talus-covered slopes of the ridges.

The Allegheny formation underlies the back slope of each bounding ridge from just below its crest to approximately the foot of the slope. Exposures on the forested slopes consist chiefly of sandstone ledges. The softer strata between the sandstones form swales that may or may not show water seepages from the underlying coal beds. Exposures of coal beds and other nonresistant strata are exceedingly rare and are limited to road cuts, stream gullies, and mines or prospects. The average thickness of Allegheny strata in 13 drill holes that penetrate the formation is 280 feet; individual thicknesses range from 245 feet to 310 feet.

In the Castleman basin the coal beds and coal groups of the Allegheny formation tend to be somewhat more regular in sequence than in the Georges Creek basin. Exceptions are in local areas where sandstones of the Allegheny formation coalesce to exclude the intervening coal-bearing beds and form thick, elongate bodies. One large sandstone body of this kind is described in detail in the discussion of the Allegheny formation in Part I of this report, page 31. The Mount Savage and Lower Kittanning coal groups vary considerably in thickness and character from place to place but are, nevertheless, more constant in the character of their sequence than they are in the Georges Creek basin. The Middle Kittanning coal group shows a distinct regularity of sequence, characterized by the presence of three coal beds, over large parts of the Castleman basin. The Upper Kittanning coal is persistent and is locally underlain by an underclay in the calcareous phase. Coal of minable grade and thickness is present in some places. The Upper Kittanning-Upper Freeport interval, the average thickness of which, taken from drill-hole records, is about 70 feet, is appreciably thinner than in the Georges Creek basin. In this interval the Lower Freeport coal horizon, which can generally be identified, is marked in most areas by an underclay consisting of an upper calcareous part underlain by a thin bed of claystone that locally contains flint clay. The Lower Freeport coal is present along the east flank of the basin between the latitude of Bittinger and U. S. Highway 40. The Upper Freeport coal is ordinarily present, and commonly of minable thickness and grade, everywhere except in areas in and marginal to the sandstone body. This coal characteristically has associated with it a thin rider coal that lies 5 to 15 feet above the main bed.

The lower member of the Conemaugh formation has an average thickness of 490 feet in the 13 drill holes that penetrated it. As noted in Part I, page 40, the individual units within the member are considerably more persistent and regular in thickness in the Castleman basin than in the Georges Creek basin. Several other features of the lower member of the Conemaugh in the Castleman basin warrant reiteration. In the Upper Freeport-Brush Creek interval the Mahoning units are almost entirely in the redbed phase. A few sandy sections were cut by the drills but no trace of the Mahoning coal was found anywhere in the basin. A thin bed of Cambridge shale, a marine zone, associated with a calcareous underclay, and locally with an inch or two of coal, is present north of the latitude of Jennings. This marine zone is a lateral phase of the lower part of the Meyersdale redbed, which is present throughout the basin south of the latitude of Jennings. The coal beds of the lower member of the Conemaugh are generally thinner than in the Georges Creek basin. The only minable coal is the Lower Bakerstown bed, which averages about 25 inches in thickness. The Barton coal, which is mined extensively in the Georges Creek basin, rarely exceeds 12 inches in thickness in the Castleman basin.

Little information is available on the character of the upper member of the

Conemaugh in the Castleman basin. The Barton coal is the highest coal bed mapped and no study of the beds above it has been made except in the few drill holes that include some of the basal part of the upper member. The presence of the Pittsburgh coal within a quarter of a mile north of the Pennsylvania state line indicates that most of the upper member of the Conemaugh formation is present in the north end of the basin.

AREAS OF OUTCROP

The areal distribution of some of the major stratigraphic units in the Castleman basin is shown on the geologic map, Plate 8. The Pottsville and Allegheny formations are mapped together for the reasons stated on page 32. The upper and lower members of the Conemaugh are mapped separately. The inferred Mauch Chunk and Pottsville contact and the approximate traces of coal outcrops are the principal features mapped. The coal beds shown are, in ascending order, the Middle Kittanning, Upper Freeport, Brush Creek, Lower Bakerstown, Harlem, and Barton. The traces of these beds as shown on the map are fairly reliable in the drilling area between U. S. Highway 40 and the latitude of Bittinger. Most of the mines in the Castleman basin are in this area and these, together with the drill-hole records, have furnished good control for mapping. In the north and south ends of the basin the traces are less reliable. Throughout the basin the approximate position of the horizon of each coal bed has been mapped whether coal happens to be present or not; thus the representation on the map of the trace of the Upper Freeport or some other coal bed in an area does not necessarily mean that coal is actually present in that area.

Prospecting for refractory clays can be limited to those parts of the basin that lie in a belt between the crests of the bounding ridges and the approximate trace of the Upper Freeport coal. Farther within the basin only the Thornton and Thomas clays offer even remote possibilities for discovery of bodies of refractory clays. The Thomas clay crops out below the Lower Bakerstown coal and the Thornton lies in the lower half of the interval between the Upper Freeport and Brush Creek coals.

STRUCTURE

The Castleman basin is a shallower syncline than the Georges Creek-Upper Potomac structure. Dips on the flanks of the syncline rarely exceed 15 degrees. The east flank is slightly steeper than the west and the axis lies somewhat east of center throughout most of the structure. The rate of decrease in dip from the flanks to the axis is not uniform. The dip flattens abruptly to about 9 or 10 degrees at most points along the foot of the backslopes of the bounding ridges. From here to the axis the flattening is gradual. The dip of the flanks continues relatively steep southward almost to the end of the syncline before

it flattens appreciably. The dip decreases noticeably southward along the west or Negro Mountain flank of the structure somewhat north of the latitude of McHenry. On the east, or Meadow Mountain flank, the dip begins to decrease somewhat farther to the southwest. This difference imposes a slight asymmetry on the emergent end of the syncline and the axis of the structure curves gently toward the west limb.

Minor structures within the Castleman syncline are not prominent. Several instances of local steepening and flattening of dip were noted but the only noteworthy one is a narrow structural terrace along the backslope of Negro Mountain. This terrace roughly follows the strike and extends northward almost to U. S. Highway 40 and southward to a point a little beyond the Accident road at Foxtown. In the Foxtown area it is in part responsible for the outcrop pattern of the Upper Freeport coal horizon. An excellent section across the terrace is shown in the strip mine of the Union Fire Brick Company on the northeast side of Tarkiln Run. Here the fortuitous combination of this structure with an unusual stream-erosion pattern on the mountain flank makes possible strip mining of the local Mount Savage clay body. The Union Company's stripping starts on the north side of Tarkiln Run west of Amish road (see Figure 18) approximately at the northwest side of the terrace. Upslope from this point the dip steepens abruptly. To the southeast the terrace, with dips of 5 degrees and less, extends a short distance beyond Amish road. Between the road and the river the dip steepens slightly, averaging about 7 degrees. Approximately at the river the dip increases abruptly to 14 degrees, becoming comparable in steepness with dips on the backslopes of the bounding ridges elsewhere in the basin. The width of the terrace in the Tarkiln Run area is about 2000 feet.

At several places in the Castleman basin local exposures of shale show excessively steep dips, some of which are obviously localized in the shale inasmuch as the overlying sandstone beds dip normally. In one exposure an overlying sandstone bed is offset about 2.5 feet by a small strike fault and the steep dips in the shale are the result of drag. Only a few minor faults of this kind have been found; all are strike faults.

No surface evidence of major faults has been found. Because of the poor outcrops it would be difficult to detect a strike fault unless its throw were sufficient to cause notable disruption of the crop traces of the major coal beds. A local variation in thickness of 30 feet or more is common for the interval between coal beds of the Allegheny formation, and a 20-foot variation in thickness is allowable in the coal-bed intervals of the Conemaugh formation. Thus a strike fault with as much as 20 or 30 feet of throw might go entirely unnoticed where outcrops are not continuous. Because the bounding ridges of the basin show no evidence of offset there is no reason to suspect normal faulting that does not parallel the strike. No discrepancies in the drill-core

records were found that could not be explained simply by variation in thickness and character of the strata.

REFRACTORY CLAY BEDS IN THE CASTLEMAN BASIN

The combined evidence from the drill cores, the clay and coal mines, and the surface mapping and prospecting indicates that certain underclay zones in the Castleman basin are more apt to contain clay of refractory grade than others. None of the three lines of evidence, however, is applicable to the entire basin and most of the evidence is from the central third of the basin, an area corresponding roughly to that drilled on U. S. Bureau of Mines Project 823. The underclays in this area are inferred to be representative of the underclays of the basin as a whole and the meager data on clays in the north and south ends of the basin support this inference.

The principal clay beds are in the Allegheny formation. The two clays in the Conemaugh formation, the Thornton and the Thomas beds, can be eliminated as potential refractory clay producing horizons; they were studied along with clay beds of the Allegheny formation and information on their grade and character is presented in this report. Neither bed contains sufficient high-grade clay to warrant detailed prospecting. The clays in the Pottsville formation run true to form and all that were examined were accordingly found to be worthless.

Within the Allegheny formation, clay of refractory grade with a fusion point of Cone 30 or better was found in the Mount Savage, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport, and Upper Freeport underclays. Only the Lower Freeport underclay was everywhere too thin and too spotty in its distribution to be a potential commercial bed.

The five remaining clay beds warrant detailed prospecting throughout the area. The Mount Savage clay is the most important bed and the only big producer of flint clay in the basin. The Bolivar clay must be rated second as a flint clay bed, although its value in this role remains to be substantiated by production. The Middle Kittanning and Lower Kittanning clays are the most promising sources for soft clay. They also contain minor amounts of flint clay. Of these two clays only the Middle Kittanning bed has been mined.

MOUNT SAVAGE CLAY

The Mount Savage coal group was penetrated in 15 of the 40 drill holes in the Castleman basin and was partly cut in at least 3 additional holes. The sections show the usual variable development of coal beds. In sections relatively free of sandstone the Brookville, Mount Savage and Scrubgrass coal horizons are distinguishable, and coal is commonly present at the Mount Savage horizon and less commonly at the Brookville and Scrubgrass horizons. The Mount Savage clay is present in only 4 of the holes and only 2 have clay

of minable grade and thickness. In the drill-hole and surface sections that include the Mount Savage clay, the clay bed is not more than 7 or 8 feet below the Mount Savage coal and is most commonly directly beneath it. This feature is in contrast to the section containing the Mount Savage clay in its type area in the Georges Creek basin. Here the clay is at a considerable distance below the coal, with a thin channel sandstone commonly intervening.

In some of the drill holes the Mount Savage coal group is greatly restricted or even wholly replaced by sandstone. It is noteworthy that in all sections where the Mount Savage clay is present few sandy beds are developed within the coal group.

The Tarkiln Run Clay Body

The only extensive deposit of Mount Savage clay in the Castleman basin is exposed in the valley walls of Tarkiln Run where the latter crosses Amish road on Negro Mountain, approximately 3 miles airline southwest of Grantsville. Although the existence of this clay body was known for many years (see page 107) it was not mined before 1944. After a preliminary examination, which included some diamond drilling, strip mining was begun on the northeast wall of the valley by what is now the Union Fire Brick Company. The Company built a large refractory products plant near Jennings. By the summer of 1948 the stripping had advanced northeastward to a point where the increasing depth of overburden was approaching the limit beyond which mining would be uneconomical and a second stripping operation was begun on the southwest wall of Tarkiln Run.

Geology of the Area.—Details of the geology of the Tarkiln Run area are shown in Figure 18. Tarkiln Run and a smaller tributary stream lying north of it flow down a broad V-shaped dip slope of the Homewood sandstone. To the north and south these intermittent streams have stripped back the soft beds of the Mount Savage and Lower Kittanning coal groups to such an extent that the Homewood sandstone is exposed all the way down the slope to the North Branch of the Casselman River. This is the only locality on either flank of the basin where Pottsville strata are exposed all the way to the base of a bounding ridge. The unusual outcrop pattern reflects the presence of the structural terrace described on page 115.

The section of strata exposed by the stripping operations is shown in Figure 19. The Mount Savage coal group is well developed, with all the coal horizons represented by coal or highly carbonaceous shale (see Plate 7). Little sandstone is present within the group. The Kittanning sandstone, which separates it from the Lower Kittanning coal group, is poorly developed and is represented in most parts of the strippings by a zone of interbedded siltstone and sandstone. The Lower Kittanning coal group is completely exposed only in the northeast stripping in the vicinity of Amish road and to the north of it. It is

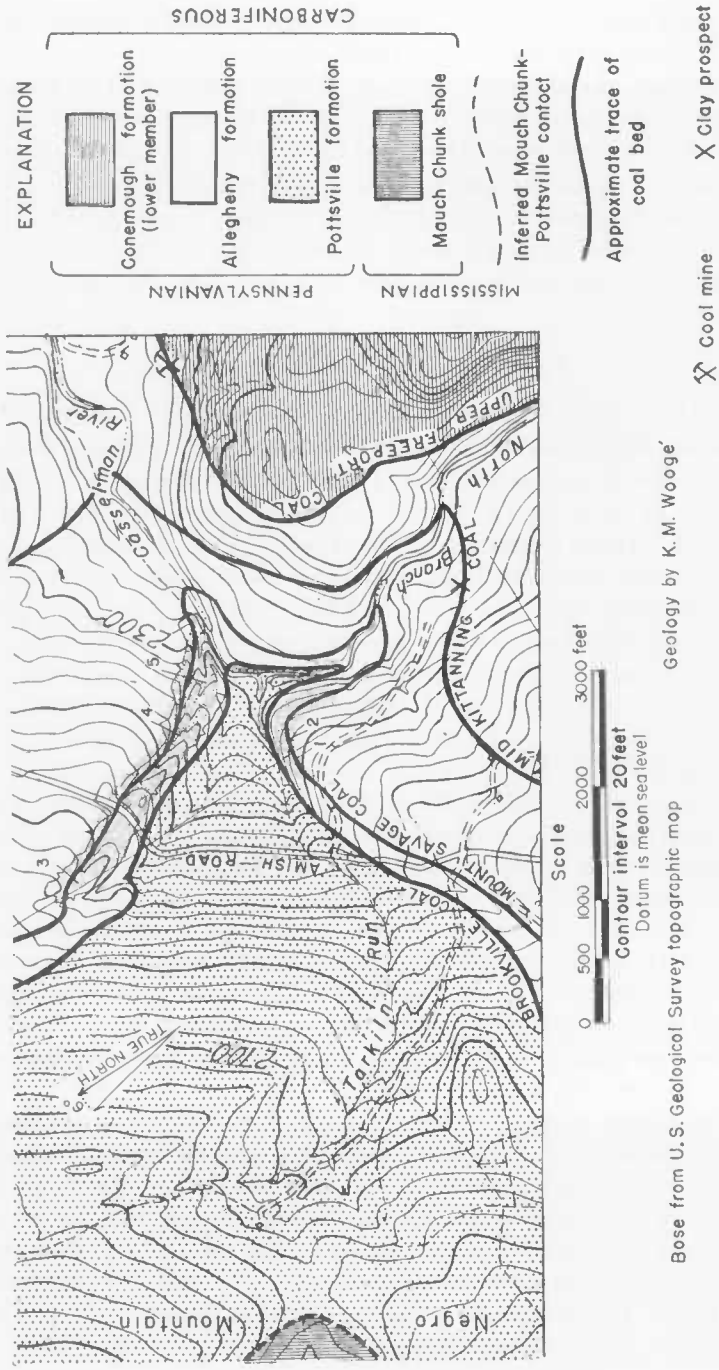


FIGURE 18. Geologic Map of the Tarkiln Run area

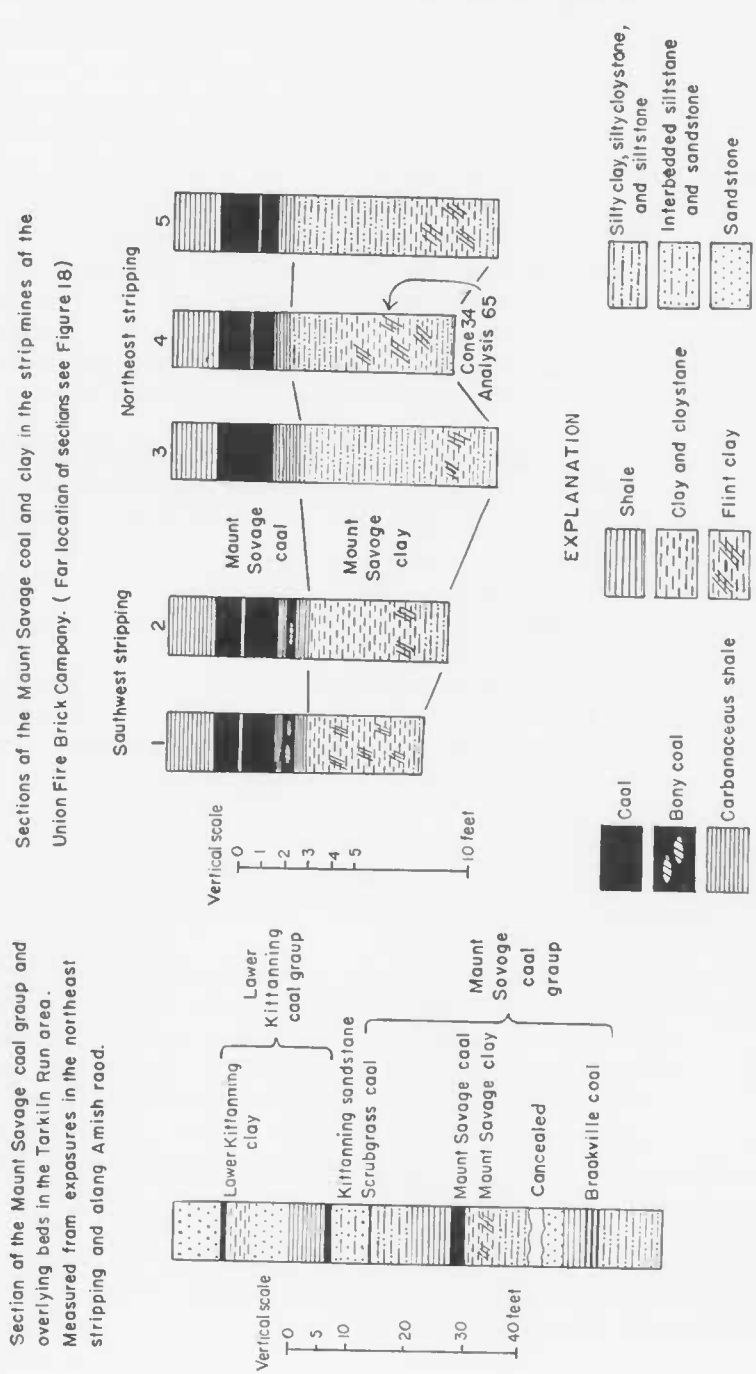


FIGURE 19. Sections of the Mount Savage coal group, Mount Savage clay, and adjacent beds in the Tarkiln Run area.

nowhere exposed in its entirety in a single locality but can be pieced together from connected exposures. Two coals are present. The upper one is underlain by plastic clay that contains small pockets of clay sufficiently pure to be mined with the Mount Savage flint clay and used as refractory bond clay. This clay is probably the equivalent of the "Baker and Clink" soft clay mined on Big Savage Mountain in the Georges Creek basin.

Above the Lower Kittanning coal group is a massive conglomeratic unit, the Worthington sandstone, which underlies the dip slope that extends northeastward from the stripping. The local thickness of this unit is not known but is more than 12 feet and, along with the depth of overburden, has determined the northeast limit of the stripping. This limit was reached in 1948; the last cut removed about 40 feet of overburden to recover an average of not more than 3 feet of flint clay.

The stripping operations have not penetrated beneath the floor of the Mount Savage clay so the lower part of the coal group is not exposed in the excavations. A nearly continuous section from the clay to the beds immediately below the Brookville coal is exposed in the north gutter of Amish road at the west side of the northeast stripping. The Brookville coal and adjacent beds are also exposed in a ledge on the west bank of the river below the southwest stripping operation.

The valley of Tarkiln Run, between the stripping operations, is strewn with great quantities of float. In addition to sand and sandstone boulders, fragments of flint clay are abundant and in some parts of the valley are more numerous than other types of material in the float. As it is not likely that outliers of the clay bed are locally present in this area, the flint clay, along with other resistant lithologic types, was evidently left behind by the streams that stripped off the clay-bearing beds. Because of the heterogeneity of these residual deposits the amount of clay in them cannot be estimated. It is not recoverable by practical mining methods.

Character of the Clay Body.—The Mount Savage clay body consists principally of a dark brown to brown-gray, locally fragmental flint clay of a type sometimes referred to as "mahogany" flint clay. The bed is generally separated from the overlying Mount Savage coal by impure gray soft clay that ranges from a few inches to as much as 8 feet in thickness. (see Plate 7.) Rarely the soft clay is absent and the flint clay is in contact with the coal. Except for a few small lenses the soft clay has not been sufficiently high grade to mine as a refractory bond clay.

Both the thickness and the purity of the flint clay vary throughout the exposed portions of the clay body. The principal impurity that affects the grade of the clay is silt. At the north end of both strippings the silt content of the flint clay is sufficient to reduce it to very stony flint clay or silty clay-

stone. Throughout the strippings thin beds of silty claystone are encountered locally in the clay bed. The bottom part of the bed is everywhere silty and grades rapidly into the floor rock, which is generally a compact siltstone that contains a variable amount of interstitial clay. The thickness of the basal silty zone of the clay bed is variable; it averages somewhat less than a foot. Locally a bed of silty, semihard clay lies between the floor rock and the flint clay.

Ironstone concretions are a common impurity in the flint clay bed but they are large and break free of the surrounding clay on mining, and are easily separated by hand on loading. Concretions are as much as 2.5 feet in diameter but the average size is between 1 foot and 1.5 feet. Many are septarian and contain calcite, siderite, and barite fillings.

The approximate average thickness of the flint clay was between 2.5 and 3 feet in the area that has been mined. Local thicknesses of as much as 5 feet are recorded. Some of the clay with more than average thickness is localized in narrow, elongate, riblike bodies with steep sides. A channel sample of 3 feet of flint clay was taken from the bed shown as number 5 in Figure 19. The fusion point of this sample was Cone 34; the chemical analysis is Analysis 65 in the Appendix.

Extent of the Flint Clay Body.—The extent of the clay body northward from the northeast stripping is not known. Most of the diamond drill holes put down by the Union Fire Brick Company on the northeast side of Tarkiln Run have been obliterated by the advancing face of the stripping. The few remaining holes just northeast of the stripping face suggest that the clay body narrows greatly within a short distance to the northeast and is reduced to about $\frac{1}{3}$ of its breadth in the northeast stripping. On the southwest side of Tarkiln Run, in the west end of the stripping, the flint clay passes into a sandy claystone phase similar to that at the north end of the northeast stripping. No flint clay float has been found along the crop upslope from the sandy claystone either northeast or southwest of Tarkiln Run, so it is possible that the transition to material of this type marks the limit of the clay body. The extent of the clay body south of the southwest stripping is not known.

Seven of the U. S. Bureau of Mines drill holes that penetrate the Mount Savage coal group in the Castleman basin show clay at the Mount Savage horizon but only in three holes is it of minable grade. One of the holes, 16-CB, is sufficiently near the Tarkiln area to be considered to have penetrated the Tarkiln clay body. The other holes with Mount Savage clay, holes 25-CB, 5-CB, 7-CB, 21-CB, 20-CB, and 23-CB, lie to the south and southeast of hole 16-CB and the Tarkiln area (see Plate 8). The holes with clay of minable grade are 16-CB, 25-CB, and 7-CB; these lie roughly in a line extending a little east of south from the Tarkiln area. Of the other two holes in this line, hole 5-CB penetrates brown clay similar to the impure soft clay associated with the

flint clay and hole 18-CB is too shallow to reach the Mount Savage horizon. Thus it appears that the clay body exposed in the Tarkiln area extends southward diagonally across the Castleman basin.

The westward extent of the Mount Savage clay body in the central part of the basin is not known. Holes 1-CB and 3-CB do not reach the Mount Savage horizon. Hole 11-CB, however, penetrates clastic Mount Savage strata composed predominantly of siltstone with interbeds of sandstone. Farther to the west clastic materials including sandstone and conglomerate are in the interval of the Mount Savage coal group in holes 28-CB and 30-CB. There is, therefore, no evidence that the clay body extends west of the line of holes 10-CB, 25-CB, 5-CB, and 7-CB. To the east of this line lie the only other holes that show clay at the Mount Savage horizon, holes 21-CB, 20-CB, and 23-CB. Some of the clay they contain is too thin and some is too impure to be of value. In hole 23-CB the Mount Savage beds are silty throughout and probably are at or near the edge of the clay body.

Summarizing the evidence from the U. S. Bureau of Mines drill holes, the Mount Savage clay body of the Tarkiln Run area can be traced to the south and southeast and appears to increase in breadth in this direction. Its lateral limits are not clearly defined nor are the drill holes that penetrate it closely enough spaced to preclude the possibility that the clay body is absent over large parts of the area within these limits. Clay of minable grade and thickness is indicated only adjacent to the Tarkiln area (holes 16-CB and 25-CB) and at the extreme south end of the clay body in hole 7-CB.

The variation in details of the Mount Savage coal group throughout the area of the clay body is shown in the drill-hole sections on Figure 20. The section for hole 16-CB is similar to that in the Tarkiln Run strippings (see Figure 19) but differs in showing a thick unit of interbedded siltstone and sandstone directly overlying the Mount Savage coal and between it and the Scrubgrass horizon. This sandy unit is also in hole 21-CB. The presence of this sandstone, the thickness locally attained by the impure Scrubgrass coal in holes 5-CB and 20-CB, and the total absence of coal at the Mount Savage horizon in hole 20-CB are variations that suggest a different interpretation of the Mount Savage coal group section in the Big Savage Refractories Company stripping on Big Savage Mountain (see page 66) in the Georges Creek basin. The coal in this stripping may very well be a local development of the Scrubgrass, and the sandstone locally over the clay may be equivalent to that noted above in holes 16-CB and 21-CB.

Another feature in both the Tarkiln Run stripping and hole 16-CB, but not shown elsewhere in sections of the Mount Savage coal group, is the relatively great thickness (20 to 25 feet) of beds between the Mount Savage and Brookville coals. In other parts of the clay body this interval averages about 10 feet; the minimum, 5 feet, was cut in hole 21-CB.

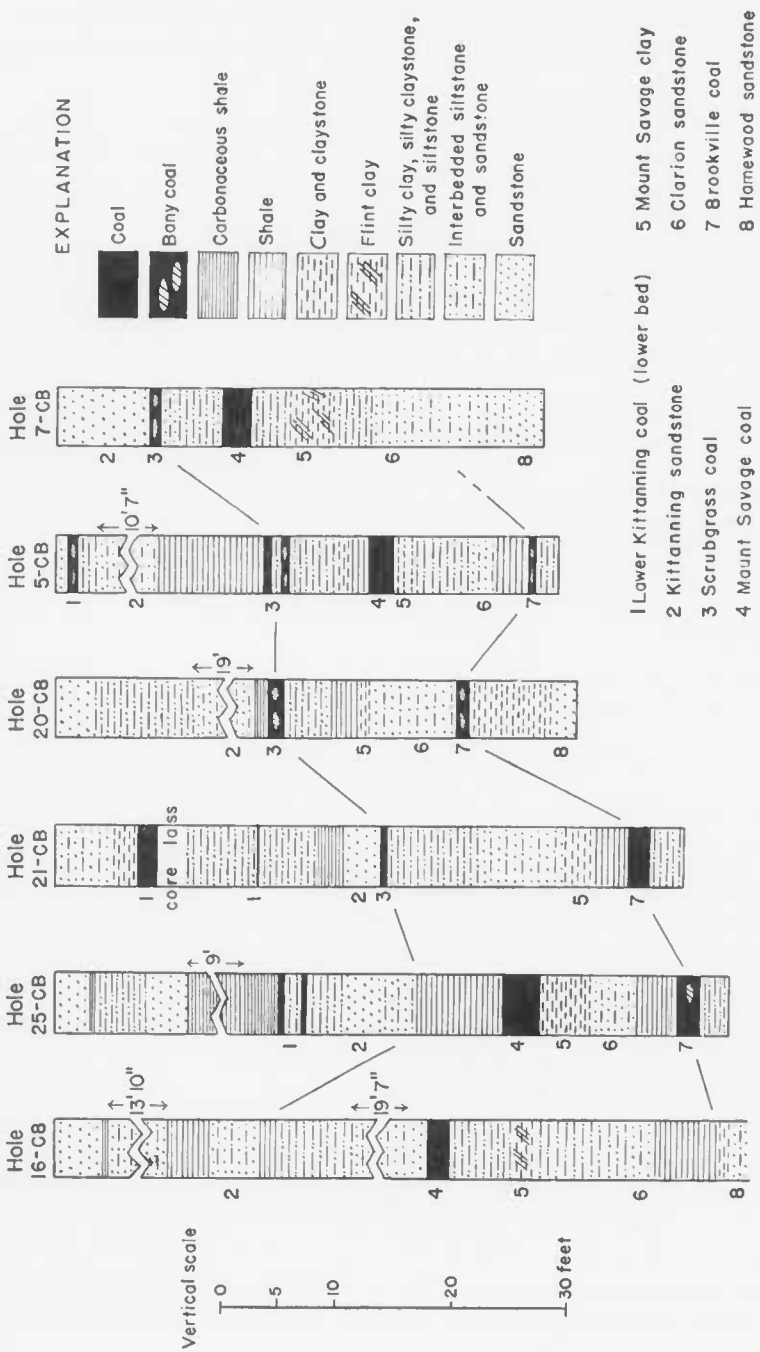


FIGURE 20. Sections of the Mount Savage coal group from U. S. Bureau of Mines drill holes between the Tarkiln Run area and Meadow Mountain.

Details of the Mount Savage clay bed vary considerably from hole to hole. Sections of the clay from the three holes that contained refractory-grade clay are given below.

Section of the Mount Savage clay in Drill Hole 16-CB

	Feet	Inches
Coal (Mount Savage). Core lost.		
Gray silty clay and claystone	5	10
Dark brown ("mahogany") flint clay, locally fragmental. Slightly siliceous in upper part (Cone 33.5, Analysis 54)	1	9
Gray silty claystone grading to siltstone with interbedded fine-grained sandstone	2	2
Black shale with plant fossils	5	6
Brookville coal horizon.		

Section of the Mount Savage clay in Drill Hole 25-CB

	Feet	Inches
Coal and bone (Mount Savage)	3	0
Clay (Cone 30, Analysis 60)		
Brown siliceous flint clay	0	3
Tan semiplastic clay with minor claystone. Locally silty	3	2
Gray claystone and semiplastic clay	1	3
Dark gray to black siltstone interlaminated with fine-grained white sandstone	3	9
Dark gray shale, silty in upper part	3	6
Coal and bone (Brookville)	1	10

Section of the Mount Savage clay in Drill Hole 7-CB

	Feet	Inches
Coal with shale partings (Mount Savage)	2	4
Dark gray to brown-gray silty semiplastic clay	3	1
Brown semiplastic clay (Cone 30, Analysis 45)	0	8
Light brown flint clay (Cone 33.5, Analysis 46)	1	5
Light and dark brown fragmental flint clay (Cone 34, Analysis 47)	1	5
Gray silty claystone	0	6

In the three sections only that in hole 7-CB can qualify as a minable bed in both grade and thickness. In both these respects it compares favorably with the better sections in the Tarkiln Run strippings.

Evaluation of the Tarkiln Run Area.—Practically all of the strippable clay in the Tarkiln Run area has been taken and the future of the deposit depends on underground mining. Mining could proceed by adits from the present stripping faces. However, because of the variability in thickness and character of the clay, exploratory holes should be drilled over an area extending at least 1000 feet in from the stripping faces on both sides of Tarkiln Run to determine the best areas for mining. Drilling on 300-foot centers should furnish sufficient detail to determine whether the body warrants underground mining

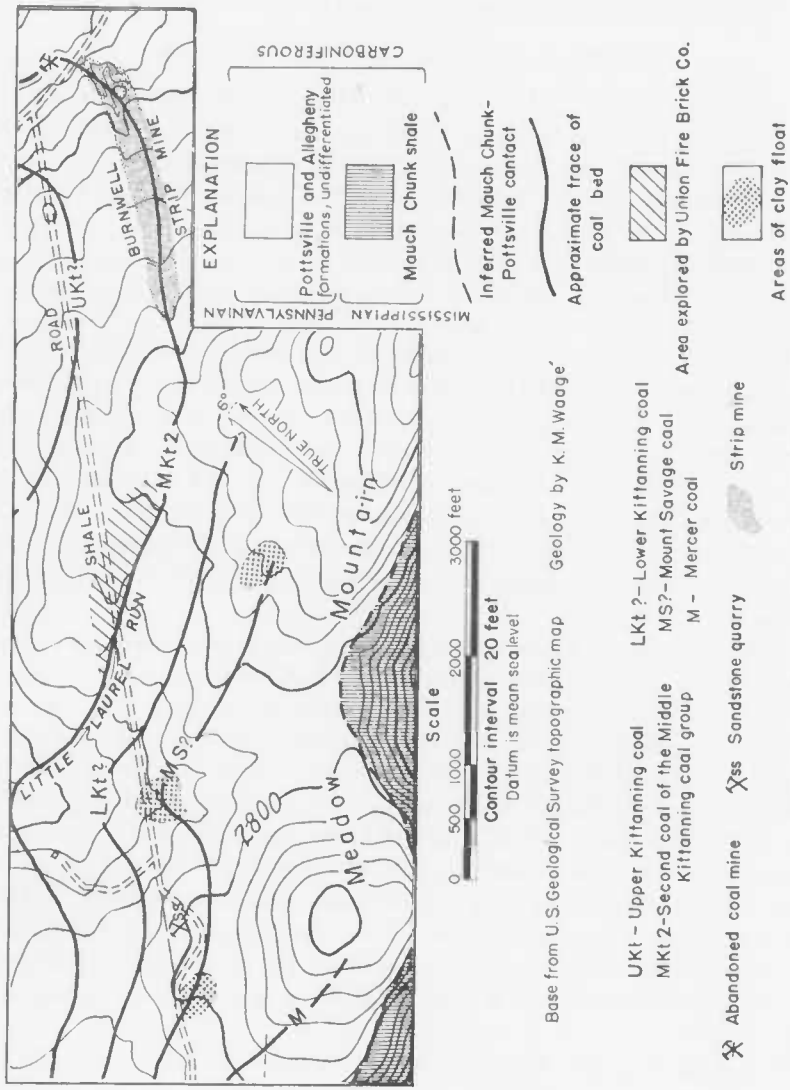


FIGURE 21. Geologic map of the Little Laurel Run area

and, if it does, to block out reserves. Exploratory drilling should also be extended both northeast and southwest from the immediate vicinity of the Tarkiln Run strippings to determine the limits of the clay body.

The Mount Savage Clay on Meadow Mountain

The proximity of hole 7-CB to the outcrop area of the Mount Savage coal group on Meadow Mountain and the section of good Mount Savage flint clay in this hole suggest that the clay bed may be exposed nearby. Prior to the drilling of holes 5-CB, 7-CB, 20-CB, and 23-CB along Meadow Mountain, several areas showing flint-clay float were found upslope from the outcrop of the Middle Kittanning clay. The location of some of these areas is shown on Figure 21. The float consists of accumulations of white plastic clay and particles of flint clay covering local flat, benchlike areas on the backslope of the ridge. All these benches terminate on the northwest or downslope side in a fairly steep area in which massive sandstone crops out in irregular ledges or occurs as large float blocks. This outcrop pattern shows that the clay-bearing strata lie stratigraphically below a massive sandstone. Because of the obscurity of outcrops on the mountain slopes and the lack of exploratory drill holes or test pits in the float areas, neither the relative position below the known Middle Kittanning crop line nor the details of the sequence including the clay bed can be determined. These little-known crop areas of clay remain unprospected.

The U. S. Bureau of Mines drill holes have not furnished conclusive evidence as to whether the float areas mark the Lower Kittanning or Mount Savage outcrop. The three areas of flint-clay float shown on the slope of Meadow Mountain above the crop of the Middle Kittanning in Figure 21 are probably all part of the same clay body. This body lies upslope to the northeast of hole 20-CB, in which the Mount Savage coal group is well developed although the clay bed itself consists only of 1 foot of brown claystone. At the Lower Kittanning horizon no coal is present in hole 20-CB and silty claystone is the only underclay material. A thick body of Worthington sandstone is above the Lower Kittanning coal group and 19 feet of interbedded sandstone and siltstone represents the Kittanning sandstone unit above the Mount Savage coal group. To the northeast in hole 23-CB more than 20 feet of massive Kittanning sandstone is present.

The record from hole 20-CB furnishes no diagnostic data that would help to identify the clay in question. The outcrop pattern of the clay-float areas at the southwest end of Shale road offers a little more in the way of evidence. The Pottsville and Mauch Chunk contact lies near the crest of the saddle through which the Jennings-New Germany road crosses Meadow Mountain. Between this contact and the area of clay float there is not space for an appreciable thickness of beds unless the dip is considerably steeper than the

meager outcrop evidence suggests. A heavy seepage of water in the woods just northeast of the intersection of Shale road and the Jennings road together with several prospect pits in this vicinity indicate the presence of coal. This is most likely the Mercer bed, which is known to be relatively thick and persistent in the area lying just to the southwest of the Jennings road. Between the clay float area and the seepage that is assumed to indicate the Mercer coal there are no outcrops, but sandstone float is heavy locally and this may represent the Homewood sandstone. If these suppositions are correct the clay in question must be the Mount Savage because of its proximity to the Homewood sandstone. Immediately downslope from the clay-float area a massive sandstone crops out. Its presence causes the jog in Shale road and it was quarried here at one time. No massive Kittanning sandstone was present in hole 20-CB and its absence could be argued as a point favoring the interpretation of the clay as the Lower Kittanning and the sandstone as the Worthington. However, the proximity of the clay to the Mauch Chunk contact is more reliable evidence than the presence or absence of the Kittanning sandstone, especially considering (1) the variability of the Allegheny units, (2) the distance of hole 20-CB from the crop, and (3) the fact that a massive Kittanning sandstone is present in hole 23-CB and other drill holes to the north and in hole 7-CB to the southwest.

A second, smaller area of clay float was found upslope from the Middle Kittanning crop a short distance above the road between Maynardier Ridge and Meadow Mountain just northeast of where the road turns sharply to the west down the slope toward Bittinger. This float area lies due south of drill hole 7-CB within the area where a projection of the south-southeast-trending Mount Savage clay body would be likely to crop out on Meadow Mountain if it crosses the basin from the Tarkiln Run area. Flint-clay fragments are scattered in a light clayey soil over a narrow flat that is bordered on the downslope side by an area of sandstone float blocks. The topographic position of this clay crop with respect to the crest of Meadow Mountain is slightly different from the position of the similar float areas along Shale road; the backslope of the ridge is somewhat steeper and the float area slightly farther from the crest than are the Shale road float areas.

The Shale road and Maynardier Ridge road float areas are not necessarily derived from clay bodies in the same underclay zone. The evidence indicates that the float in both areas is either from the Lower Kittanning or the Mount Savage clay bed; beyond that the evidence is not conclusive although it favors the Mount Savage clay for the Shale road float areas. The presence of a good bed of Mount Savage flint clay and the absence of clay in the Lower Kittanning coal group in drill hole 7-CB, which is near the Maynardier Ridge road float area, suggests that this float is also derived from the Mount Savage bed.

A single prospect pit has been dug in one of the Shale road float areas by the

Union Fire Brick Company, in the belief that the clay float is a continuation of the Middle Kittanning clay, which the company has prospected in some detail in this area. Unfortunately the pit was located off the crop in an area of wash and did not reach bedrock. No other prospecting has been done in either Shale road or the Maynardier Ridge road float areas. Both areas deserve detailed exploration. Test pits or drill holes should be located just southeast of the outcrop of the sandstone that lies downslope from the area of clay float. This will insure sufficient overburden over the clay to show it in relatively unweathered condition. Pits dug in the highly weathered zone at the crop are likely to show completely disrupted beds. It would be better still, if diamond drilling is to be undertaken, to begin exploration back from the edge of the sandstone crop and include the basal several feet of sandstone in the hole. The flats should be explored first and if results are encouraging the outcrop can be followed where it swings downslope in the gullies that drain the mountain side.

Evaluation of the Meadow Mountain clay.—The clay body on Meadow Mountain, unlike that on Negro Mountain, cannot be expected to offer a good opportunity for strip mining even though the clay should turn out to be of equally good quality. In the first place, no structural terrace is present on the flank of Meadow Mountain; the dip is fairly uniform and averages about 14 degrees. Secondly, a massive, locally quartzitic sandstone about 20 feet thick occurs a short distance above the clay wherever the clay has been found. This sandstone, whether Kittanning or Worthington, would limit stripping operations to a relatively narrow belt of the crop between the sandstone outcrop and the outcrop of the clay. A rough estimate of the width of this belt on the flats is about 100 feet, or at the very most two 60-foot cuts from the actual crop of the clay bed. Where the crop swings downslope along stream gullies, the breadth of clay available for stripping would be less.

It is not known how far downslope the clay outcrop extends along the gullies adjacent to the float areas. In the crop pattern shown in Figure 21 the crop lines of the coal bed in these gullies are drawn on the basis of topography. The actual position of the coal and clay beds would have to be determined by exploratory drilling or pitting.

Because the Shale road and Maynardier Ridge road areas are the only known extensive areas of flint clay float on Meadow Mountain at what could be the Mount Savage horizon, they are the best areas for detailed prospecting in the basin. Nowhere else, either on Meadow Mountain or Negro Mountain have similar float areas at or near the probable Mount Savage outcrop been reported.

Other Probable Localities of Mount Savage Clay

Meadow Mountain near U. S. Highway 40.—Drill-hole records and an outcrop furnish sufficient evidence to support the possibility that either the Mount

Savage or Lower Kittanning clay occurs north of U. S. Highway 40 on Meadow Mountain. An old coal stripping known as the Stone House stripping is located along the south side of U. S. Highway 40 on Meadow Mountain. This strip mine is entirely in the Middle Kittanning coal group and exposes three coal beds and a clay bed. The outcrop pattern of these beds is shown in Figure 22.

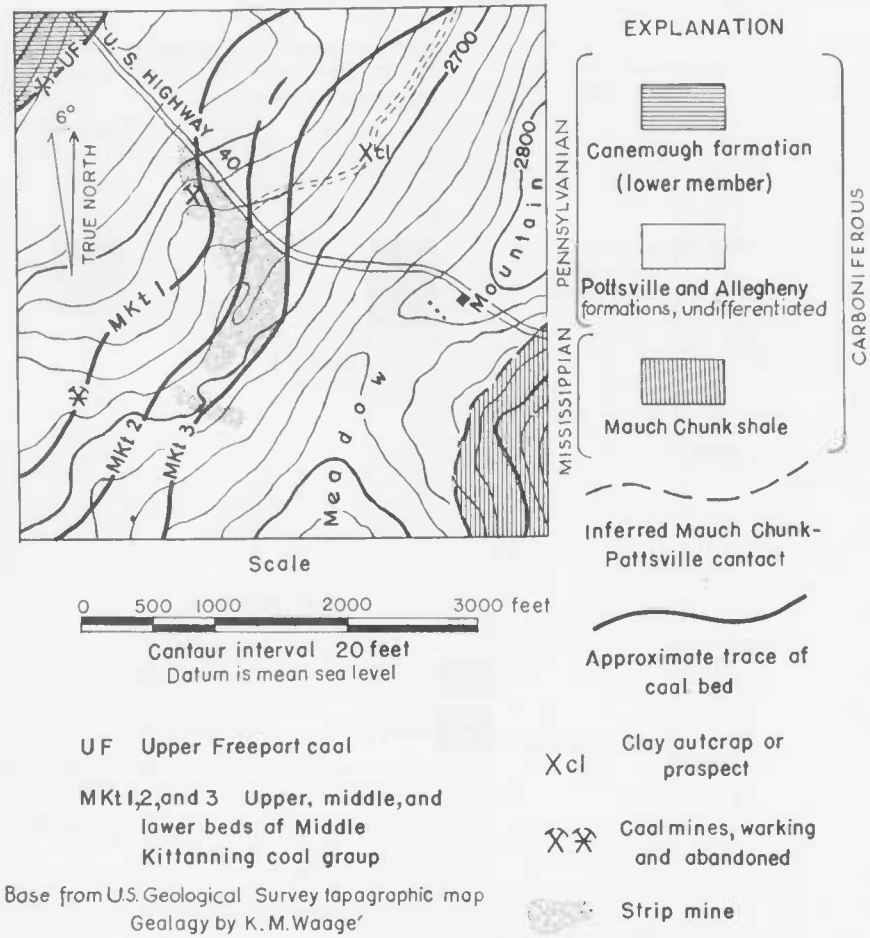


FIGURE 22. Geologic map of the Stone House area

The Union Fire Brick Company tested the clay possibilities in this vicinity with five diamond drill holes so spaced as to provide a composite section 175 feet thick including the Middle Kittanning, Lower Kittanning, and part of the Mount Savage coal groups. This composite section is shown graphically in Figure 23. Neither the Lower Kittanning nor Mount Savage clays in the drill holes are of value but the records serve to show a typical section of the

two coal groups. The Mount Savage coal is underlain by 4 feet of what the drill records refer to as "run-of-mine" clay, a term usually applied to silty plastic or semiplastic clay. A short distance above the Lower Kittanning coal is a bed described as white soft clay that is 1.8 feet thick. This probably corresponds to the "Baker and Clink" clay. The white color is doubtless due to weathering as this clay is near the top of one of the holes.

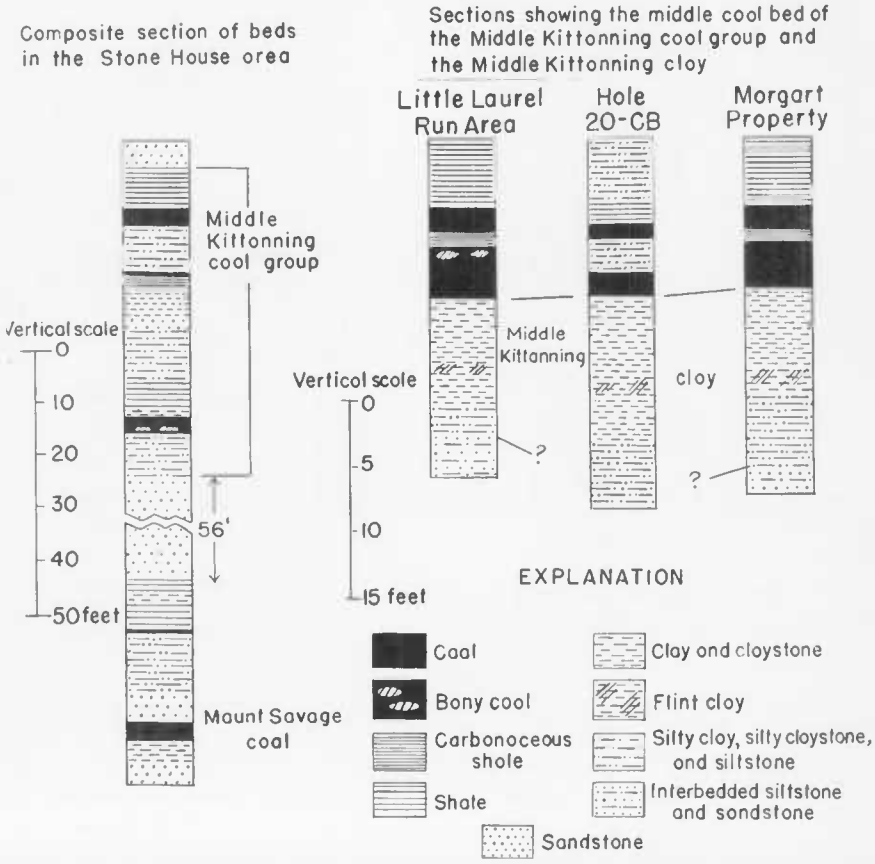


FIGURE 23. Sections of the Middle Kittanning coal group, Middle Kittanning clay, and associated beds along Meadow Mountain.

Northeast across U. S. Highway 40 from the Stone House stripping an old logging road enters the woods. Between 1000 and 1200 feet from the highway the logging road, shown in Figure 22, crosses a swampy seepage area. On the east side of the logging road a ditch, presumably dug for drainage, exposes a light gray to white plastic clay. This is probably the clay associated with the coal bed responsible for the seepage. No flint clay was found in the float along the road but a piece of "mahogany" flint clay a little more than 2 inches long

and an inch in diameter was found in the roots of a tree that had recently overturned alongside the drainage ditch. As the outcrop pattern shown on Figure 22 indicates, this exposure of clay occurs at a position where it could be interpreted either as the Lower Kittanning or the Mount Savage clay, or as an area combining float from both beds. Neither of these clay beds has been prospected on Meadow Mountain north of U. S. Highway 40. The clay outcrop furnishes a good starting point for exploration in this area. One or two drill holes in the area of the ditch could determine whether the lead is worth following to the northeast along the mountain.

Negro Mountain near U. S. Highway 40.—At Ashby's tavern on U. S. Highway 40, 0.7 mile up Negro Mountain from the intersection of U. S. Route 40 and Amish road, an artesian well is reported to have penetrated about 5 feet of flint clay at a depth of 30 feet. No driller's log or cuttings exist to support this report. The well section, as remembered by Mr. Ashby, resembles that of the Mount Savage and lower part of the Lower Kittanning coal groups farther south in the basin near the Tarkiln Run area. The projected trace of the Mount Savage beds, based primarily on the topography and the expectable distance downslope from the Pottsville and Mauch Chunk contact, would cross U. S. Highway 40 at a point between 600 and 700 feet up the hill from Ashby's tavern. An old dirt road enters the highway from the southwest at about this point and several old, long-abandoned coal openings lie to the west of the dirt road within a distance of 800 feet from the highway. The coal bed once mined here may be the same as a 27-inch coal bed reported in the Ashby well at the horizon of the Brookville coal several feet below the flint clay bed. Above the clay a 9-foot sandstone bed was reported and this may be correlative with the the sandstone ledge cropping out in the highway cut between Ashby's tavern and the dirt road. With this much confirmation of what was reported in the artesian well record it is worth a shallow drill hole or two to prove or disprove the presence of a thick bed of flint clay in this area.

LOWER KITTANNING CLAY

With the exception of the local lenses of soft clay in the upper part of the stripping northeast of Tarkiln Run, no exposures of undoubted Lower Kittanning clay are known in the Castleman basin. The localities where some doubt exists as to whether the Mount Savage or Lower Kittanning clay is present were described in the discussion of the Mount Savage clay. Subsurface information on the Lower Kittanning clay was furnished by 21 U. S. Bureau of Mines drill holes that penetrated the coal group. Although beds of clay of minable grade were found in several holes, none of them were more than 2 feet in thickness.

Character and Distribution

Clays associated with the Lower Kittanning coal beds are chiefly silty semiplastic clays that are gray, tan, or black in the raw state. Claystone is

also common but its purer forms, flint and semiflint clay, are relatively rare. Tan semiflint clay is the predominant type where the purer clays are present. Locally the semiplastic clay is silt-free and, with weathering, is altered to a light gray or white plastic clay, sufficiently pure to be used as a refractory bond clay.

The Lower Kittanning clays occur in association with both of the coal beds commonly present in the coal group. At many places where the coal group is well-developed, the uppermost clay occurs as a binder separating two splits of the upper coal bed. Another clay is also present in some places as the underclay of the lower split of coal. The lower clay bed of the coal group underlies the lower coal bed. This sequence is shown in the following drill-hole section.

Section of the Lower Kittanning coal group in Drill Hole 6-CB

	Feet	Inches
Sandstone (Worthington).		
Coal	1	2
Dark gray argillaceous sandstone	1	9
Fragmental silty claystone and semiflint clay	0	6
Coal	0	9
Interbedded siltstone and sandstone	7	0
Shale	5	0
Coal and bone (lower bed of Lower Kittanning)	2	7
Black to gray claystone and silty claystone	2	0
Fragmental siliceous flint clay and black claystone	1	6
Gray and black claystone	1	8
Sandstone (Kittanning).		

Throughout the Castleman basin the sequence within the Lower Kittanning coal group varies considerably in detail. In the above section and in the one that follows, the strata between the upper and lower coal beds are in a sandy phase. This sandy phase characterizes the coal group in the area of Salt Block Mountain and the portion of Meadow Mountain to the east and northeast of it. Clay is present locally in this area but has nowhere been found to be very thick where the sandstone is present. The one test made of the Lower Kittanning clay in this area is cited in the following section.

Section of the Lower Kittanning coal group in Drill Hole 4-CB

	Feet	Inches
Sandstone (Worthington).		
Siltstone grading to black shale	1	6
Coal	1	0
Semiflint clay, silty and pyritic	0	9
Siltstone, argillaceous at top	3	9
Sandstone	6	6
Siltstone with zones of granular siderite	6	4
Gray to black shale and coaly shale, locally silty	4	9
Coal	0	5
Tan semiplastic clay (Cone 31, Analysis 44)	1	1
Silty semiplastic clay grading to siltstone	9	0
Interbedded siltstone and sandstone (Kittanning).		

The thickest section of Lower Kittanning clay encountered in the drilling was in hole 3-CB. In this hole the upper part of the Lower Kittanning coal group is absent and its interval is occupied by the Worthington sandstone, which is locally conglomeratic.

Section of the Lower Kittanning coal group in Drill Hole 3-CB

	Feet	Inches
Conglomeratic sandstone (Worthington).		
Carbonaceous shale with laminae of coarse sand	1	10
Fragmental claystone	0	8
Coal, bone, and shale	5	3
Gray to black fragmental, pyritic, semiplastic clay and claystone	4	1
Brown and gray fragmental flint and semiflint clay (Cone 32, Analysis 41)	1	10
Carbonaceous shale	1	10
Quartzitic sandstone (Kittanning).		

The Lower Kittanning clay shows up, therefore, in three areas. The first of these, already mentioned, takes in Salt Block Mountain and the part of Meadow Mountain east of it. A second area includes drill hole 3-CB, whose section is given above, and hole 7-CB, which penetrated 3 feet of slightly silty semiplastic clay under the upper coal of the Lower Kittanning coal group. A third area is indicated in hole 13-CB, which shows a section of the coal group similar to that in hole 6-CB and has a 1-foot bed of fragmental semiflint clay associated with the lower of the two coal horizons.

Evaluation of the Clays

The Lower Kittanning coal group shows little promise of containing clay bodies of commercial value. The clays are thin and not commonly of good grade. However, there is always the possibility that the soft clays along the crop have been improved by weathering and can be used as bond clays. If deposits of bond clay occur in areas where they can be worked along with the Mount Savage flint-clay bed, as in the Tarkiln Run area, they may be valuable even though the bodies are small.

MIDDLE KITTANNING CLAY

The clay that ranks second in value to the Mount Savage clay in the Castleman basin is the Middle Kittanning clay. It has been the chief source of soft clay for the Union Fire Brick Company plant at Jennings and has been worked in three different stripping operations on Meadow Mountain.

The Middle Kittanning coal group in the Castleman basin contains three fairly persistent coal beds. Clay occurs commonly as the underclay of the middle coal. In some places the coal group is somewhat more complex and there are more than three coals, but a study of the details of the section has shown that the clay is everywhere associated with the same coal bed.

Soft clay is predominant and the most common clay type is a tan semi-

plastic clay that weathers to a light gray or white plastic clay. It ranges from less than a foot to as much as 10 feet in thickness. In some places a brown or gray flint clay, commonly siliceous, lies beneath the soft clay and this is commonly 1.5 feet thick. Very thin layers of a bluish, almost vitreous flint clay are present at some localities but this clay type is not known to occur in beds more than 2 or 3 inches thick. Both the soft clay and the flint clay pass laterally into silty or even sandy phases within short distances. The soft clay is known to be of refractory grade only where it has been weathered. Silt and iron, mostly in the form of siderite, are common impurities.

Meadow Mountain Deposits

The Middle Kittanning clay has been found intermittently along its outcrop on Meadow Mountain from U. S. Highway 40 southwest to Maryland Route 459 in the Pleasant Valley area southeast of Bittinger. Within this area of outcrop it has been strip mined, along with its overlying coal, at three places, yielding a small quantity of refractory soft clay at each place. Information on the Middle Kittanning clay has come from these strip mines, from prospecting along the crop by the Union Fire Brick Company, and from exposures along some of the roads that cross Meadow Mountain.

Stone House Strip Mine.—During the early 1940's a strip mine in the coals of the Middle Kittanning coal group was opened on the south side of U. S. Highway 40 on Meadow Mountain. The mine has received its name, Stone House, from being on the same property as a large stone farmhouse that was originally a stagecoach stop on the old National Road, now U. S. Highway 40. Relatively little coal was removed in the stripping operation; and the mine was abandoned until 1946, when the Union Fire Brick Company worked the clay for a short time.

The geology of the Stone House area is shown in Figure 22. A composite section of strata, compiled from the core records of exploratory holes drilled by the Union Fire Brick Company in and around the stripping, is given in Figure 23. The stripping operations exposed the entire section of the Middle Kittanning coal group. The thickest coal bed in the group is the upper of the three coal beds common to the sequence. The second or middle coal, the one underlain by the clay, is less than 8 inches thick in the Stone House area. The basal coal bed was mined in the southeast end of the stripping. The clay bed has a typical section and consists of 4 or 5 feet of soft clay with a few inches to a foot of dominantly silty flint clay at the base. Ironstone concretions and limonite-stained claystone and soft clay are present locally in and beneath the zone of silty flint clay.

When the soft clay was first stripped from the crop, fusion tests made at the clay plant ran Cone 29 and occasionally Cone 30. After the first stripping cut, which was about 60 feet in breadth, samples from the face of the cut ran

Cone 26. Because of this abrupt decrease in grade away from the outcrop the mine was abandoned.

A bed of plastic clay between 1 and 2 feet thick is present immediately above the lower coal of the Middle Kittanning coal group in the Stone House area. This clay has been rumored to have an exceptionally high alumina content, but tests run on a weathered sample collected in the stripping indicate that this is not true. The fusion point was Cone 29 and the alumina content (see Analysis 61) was 29.59 per cent, which is normal for semirefractory-grade clays.

The Stone House clay bed has never been worked or even prospected on the north side of U. S. Highway 40 and nothing is known about the coal and clay beds of the Allegheny formation in the heavily wooded land between the highway and the Pennsylvania state line.

Burnwell Coal Company Stripping.—Nothing is known about the Middle Kittanning clay for a distance of about 3.5 miles southwest along Meadow Mountain from the Stone House stripping. Within this distance there have been two strip mines opened in coal but no clay is present in either one. Both strippings are interpreted as being in the upper coal bed of the Middle Kittanning coal group. As this was the only coal bed worked in these operations the Middle Kittanning clay was not reached by the excavations. Both strip mines are located northeast of the New Germany road. The oldest one, abandoned since the early 1940's, is locally called the Power Line stripping because of its location on the north side of the clearing for the power line that traverses the basin. The second stripping, opened in the spring of 1948 by the Bowman brothers, is about 1500 feet northeast of the Power Line stripping.

At the Jenkins mine, a little over 0.5 mile south of the New Germany road on Shale road, a coal in the Middle Kittanning group has been mined underground and has also been strip mined by the Burnwell Coal Company from the underground mine entry southwest along the crop for a distance of about 2500 feet. This coal is the second coal bed of the Middle Kittanning coal group and is underlain by the Middle Kittanning clay. The Union Fire Brick Company worked the clay in the Burnwell stripping near the crop but was not able to utilize the clay down dip because of a change in grade similar to that in the Stone House stripping.

The clay in the Burnwell stripping has a section similar to that in the Stone House stripping. From 4 to 9 feet of soft clay underlies a coal about 4 feet thick, including a persistent binder more than a foot thick. Below the soft clay is a bed of silty flint clay and claystone from a few inches to about 1.5 feet thick. This underlying bed in some places is silt-free and contains minor amounts of brown and gray fragmental flint clay. In most places beneath the flint clay a silty clay grades downward to argillaceous siltstone. Ironstone

concretions and limonite-stained clay appear to be restricted to the silty flint clay and the beds below it.

About 3700 feet northwest of the Burnwell stripping, and approximately down the dip from its south end, drill hole 23-CB penetrated the following section:

Section of part of the Middle Kittanning coal group in Drill Hole 23-CB

	Feet	Inches
Coal	1	6
Carbonaceous siltstone and silty claystone	4	2
Coal	2	0
Silty, tan semiplastic clay	1	6
Fragmental claystone, minor flint clay and semiflint clay with ironstone concretions in lower foot	2	3
Tan semiplastic clay (Cone 30, Analysis 58)	3	6
Tan, silty semiplastic clay with grains of siderite throughout	1	0
Argillaceous siltstone.		

This clay section differs in details from that of the Burnwell stripping but it is probable that the zone of fragmental claystone and flint clay correlates with the silty flint clay bed in the stripping. If this is so the quality of the clay beneath the flint bed improves down dip, whereas that above the flint bed becomes silty and thins down dip. Although the distance between the two sections is too great to warrant reliance upon this relationship, the possibility that the clay under the flint bed may be of refractory grade should not be overlooked in prospecting the Middle Kittanning clay. Both surface and subsurface sections indicate that the Middle Kittanning clay is, at least locally, a compound underclay.

Little Laurel Run Area.—Southwest along Meadow Mountain from the end of the Burnwell stripping the outcrop of the Middle Kittanning clay crosses a low divide, then swings back downslope to the head of Little Laurel Run, which it follows across Shale road. The geology of this locality is shown on Figure 21. Some test pitting and diamond drilling were done by the Union Fire Brick Company along the clay outcrop and downslope from it. The test hole farthest to the northeast was within 2000 feet of the south end of the Burnwell stripping and other holes and test pits prospected the area between this point and the place where the Middle Kittanning outcrop crosses Shale road.

The Little Laurel Run exploration showed a section of clay similar to that in the Burnwell stripping. A coal from 4 to 6 feet thick with a persistent binder about 2 feet thick overlies the clay. The bed of soft clay beneath the coal ranges in thickness from 4 to 10 feet and is underlain by a bed of impure flint clay about 1.5 feet thick. Not all the holes penetrated the flint clay bed or its silty claystone equivalent, but those that did revealed a bed of impure soft clay as much as 2.5 feet thick beneath it. Fusion tests run on the upper bed of soft clay gave results between Cone 26+ and Cone 27+; one test run on the impure

flint clay gave a fusion point of Cone 24. The top of the shallowest clay tested was 11 feet beneath the surface; the sample from this bed had a fusion point of Cone 27. If refractory-grade clay is present at all it is probably a thin layer at the outcrop of the clay bed.

Morgart Property.—The Middle Kittanning clay bed is not exposed and has not been prospected for approximately one mile to the southwest from the intersection of Little Laurel Run and Shale road. South of the Jennings road it is exposed in a stripping and in exploratory pits on the property of Mr. Louis Morgart of Jennings. In addition to the surface cuts a number of diamond drill holes have been put down on different parts of the Morgart property. Most of this exploratory work was done along the crop of the second coal in the Middle Kittanning coal group although other coals farther up the mountain have also been prospected. A geologic map of the Morgart property and surrounding land is given in Figure 24.

The part of the Morgart property lying south of the Jennings road and the Maynardier Ridge road within a radius of 3000 feet from their intersection is the most heavily prospected area on the backslopes of either Meadow Mountain or Negro Mountain. In this area the character of the Middle Kittanning clay is well known from test pits and drill holes and from a stripping worked for a short time by the Union Fire Brick Company. A representative section of the Middle Kittanning clay from the Morgart property is shown in Figure 23. The section differs from the sections in the strippings already described only in its details. The overall thickness of the coal bed over the clay is similar to that found in the Little Laurel Run area and averages between 4 and 5 feet. The binder in the coal, however, is reduced to 6 inches or less of shale that occurs about 2 feet from the top of the bed. The thickness of the soft clay under the coal averages about 5 feet. The recorded range in the area is from 1 to 7.5 feet. Tests of samples from the crop of this clay have given fusion points as high as Cone 30, but the clay under 10 or more feet of cover shows the usual drop in grade to Cone 26 and under.

The silty flint clay bed beneath the soft clay locally contains lenses of good flint clay and semiflint clay as much as 4 feet thick. Although these lenses are small they appear to be more numerous and attain a greater thickness than do the lenses of flint clay in the strippings to the northeast. Tests made on hand-picked flint clay from the Morgart property show fusion points of Cone 31 and Cone 33. The flint clay bodies are too small and too scattered to be considered of commercial value. They are also subject to abrupt change in the content of silt and sand and grade laterally into argillaceous sandstone. In some places the silty flint clay, or pure flint clay, also grades downward through argillaceous sandstone to a lenticular sandstone that reaches a maximum recorded thickness of 5 feet.

Beneath the silty flint clay bed and the sandstone bed locally associated

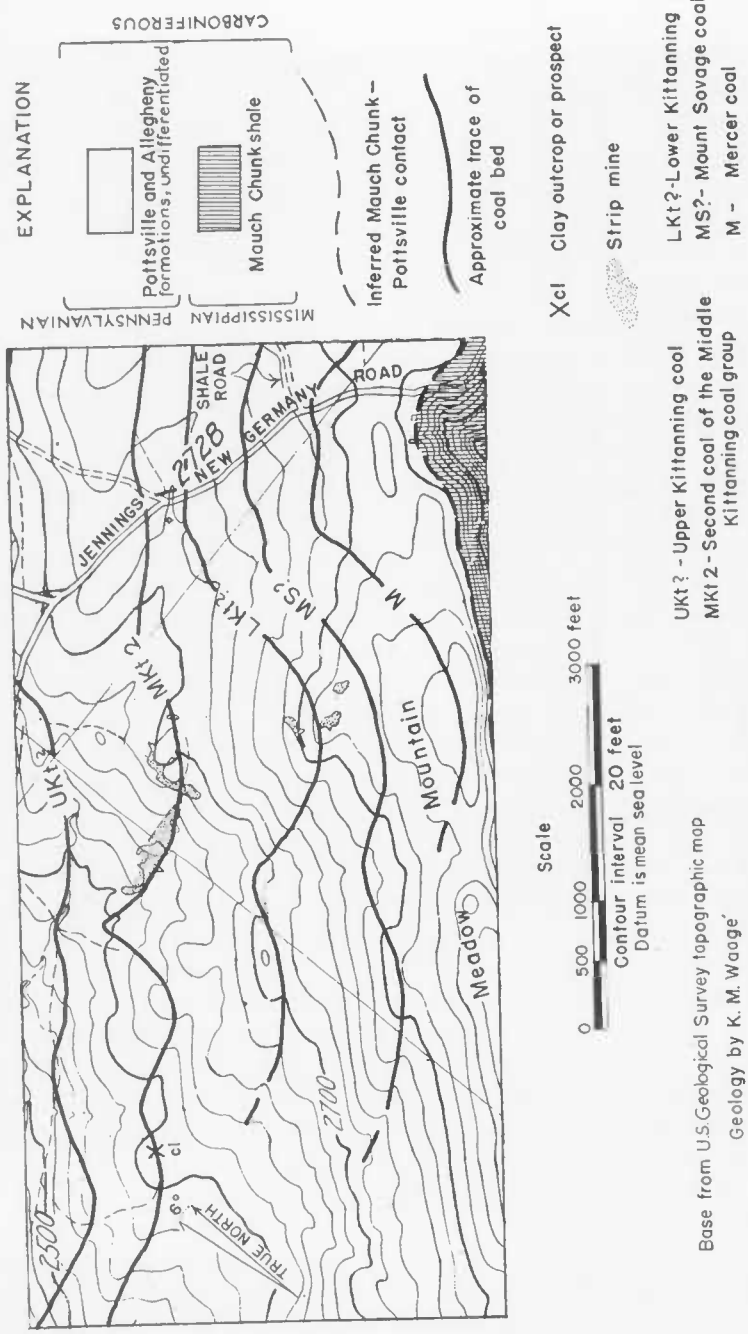


FIGURE 24. Geologic map of the Morgart Property and adjoining land

with it is a soft clay that is 14 to 16 feet thick in the two Union Fire Brick Company drill holes that penetrate it. So far as is known this clay has not been tested. It is doubtless the equivalent of the clay in U.S.B.M. drill hole 23-CB (see page 136) that has a fusion point of Cone 30 in the raw state. This does not necessarily mean that the correlative clay on the Morgart property will also be of high grade, but considering its thickness, the Morgart deposit is worth testing.

The Middle Kittanning coal and clay have been traced for approximately 2000 feet southwest from the Union Fire Brick Company stripping in the intensively prospected area of the Morgart property. Hand-dug pits and trenches made by bulldozers expose the coal at intervals along the crop but rarely show the underlying clay. In the last trench showing coal, the clay prospect shown on Figure 24, a partly exposed section of the Middle Kittanning clay has less than 4 feet of plastic clay underlain by a bed of good flint clay about 2 feet thick. The flint clay is silty in the basal few inches and grades rapidly downward into an argillaceous siltstone that forms the floor of the trench. The Middle Kittanning clay is not exposed on or adjacent to the Morgart property southwest of this trench.

Pleasant Valley Area.—Between the Morgart property and the Swanton road, Maryland Route 495, the Middle Kittanning coal and clay are exposed at only one place, in a shallow gutter on the north side of the old road that leads southeast from Bittinger across Meadow Mountain (see Plate 8). The outcrop is about 600 feet east beyond the last fork before the road crosses Meadow Mountain. Here a black shale is underlain by coal smut beneath which is soft clay and, at the base, gray flint clay and silty flint clay. The condition of the exposure does not permit accurate measurement of the section. The flint clay appears to be about a foot thick, the soft clay 3 or 4 feet thick. Flint clay float can be traced northeast across the spur from the outcrop along the west edge of a clearing but is lost in the gully on the northeast side of the spur.

On the Swanton road in the Pleasant Valley area the Middle Kittanning clay is exposed in a cut on the east side of the road about 2000 feet southeast of the turnoff to the Pleasant Valley Recreation Center. The outcrop section exposed is:

Section of part of the Middle Kittanning coal group, Swanton Road

	Feet	Inches
Weathered light gray, fine silty plastic clay (Cones 17 and 18)	3	+
Dark to light gray semiflint clay with thin seams of "blue" flint clay	0	6
Limonite-stained claystone	0	4
Weathered gray plastic clay	0	6
Interbedded siltstone and silty shale	3	0

Just beyond this section to the south and separated from it by only a few feet, a weathered black shale is exposed. This is probably the shale overlying the basal coal of the Middle Kittanning group. Heavy seepage of water in a gully just north of the clay outcrop is interpreted as coming from the second Middle Kittanning coal bed, which overlies the clay. It is obvious from the outcrop that part of the clay bed beneath the coal is not exposed and some doubt exists as to whether the clay in the road cut lies above or below the silty flint clay zone seen in the other Middle Kittanning sections. If the flint clay present in the cut is the same bed that divides the soft clay elsewhere then the soft clay below it has been greatly reduced in thickness in this area. The presence of irregular limonite nodules in the soil above the soft clay in the cut and the low fusion point of the clay indicate that it is high in iron and of considerably lower grade than in other crop areas along Meadow Mountain.

Character of the Meadow Mountain Clay

The deposits of Middle Kittanning clay described from exposures along Meadow Mountain show a striking uniformity in sequence of clay types within the 11 miles of intermittent outcrop between U. S. Highway 40 and the Swanton road. Much of this uniformity results from the weathering of the clay, a process that reduces all the nonflinty clay types to plastic clay at or near the crop. Though this obscures some of the details of the clay bed section it serves to accentuate the distribution of the gross clay types. On the basis of these types, as they appear in the weathered zone, the Middle Kittanning clay along Meadow Mountain can be represented by the following section:

Composite Section of the Middle Kittanning clay

	Range in feet
Coal with binder (Second coal of Middle Kittanning coal group)	½ to 6
Gray to white plastic clay, may be silty locally	2 to 8
Silty flint clay associated with siltstone and sandstone. May contain small, thin bodies of good flint clay. Compact ironstone concretions and limonite hardpan common	½ to 5
Gray plastic and semiplastic clay, minor claystone. Commonly silty. May be limonite-stained or carry ironstone concretions	0 to 15

Several drill holes along the foot of the backslope of Meadow Mountain penetrate sections of Middle Kittanning clay differing only in details from this generalized section. The section of hole 23-CB on page 136 is one of these. Another hole, drilled along Jennings road adjacent to both the Little Laurel Run area and the Morgart property has the following section, which is similar to the sections on the crop.

Section of part of Middle Kittanning coal group in Drill Hole 20-CB

	Feet	Inches
Coal	1	7
Black claystone binder	2	9
Coal	1	8
Tan claystone and semiplastic clay	6	9
Brown and gray fragmental semiplastic and semiflint clay, small ironstone concretions in basal 6 inches (Cone 27, Analysis 57)	1	4
Tan silty claystone and silty semiplastic clay, fragmental silty claystone in basal 5 inches	4	5
Interbedded siltstone and silty, tan semiplastic clay and claystone	14	0
Sandstone.		

Although the Middle Kittanning clay is not complex in section it is obviously the compound type of underclay and represents more than a single cycle of underclay deposition. The local presence of a sandstone associated with the silty flint clay zone is evidence that the cycle that began with the deposition of the basal part of the bed was interrupted.

The grade of clay in the three parts of the Middle Kittanning bed differs considerably from place to place. The basal clay underlying the silty flint zone has been tested only in drill hole 23-CB, where a sample in the raw state had the surprisingly high fusion point of Cone 30. This clay looked better on inspection than clay from the same bed in any other drill holes or exposures and probably represents the best in this part of the Middle Kittanning bed.

The clay in the silty flint zone is only locally of good grade as it is commonly silty and ferruginous. Small bodies of high-grade flint clay are known on the Morgart property. The most promising area for flint clay in the Middle Kittanning bed probably lies between the Jennings-New Germany road and the road over Meadow Mountain southeast of Bittinger.

The value of the Middle Kittanning clay on Meadow Mountain is dependent on the value of the soft clay bed that constitutes its upper 5 to 8 feet. The fusion point of this clay in the raw state rarely exceeds Cone 26, but when weathered the clay shows an increase in refractoriness to as much as Cone 30. Thus under the most favorable conditions it can qualify as a refractory bond clay. Because of the quantity of this clay indicated along Meadow Mountain a sample was submitted to Professor T. N. McVay, ceramic engineer at the University of Alabama, for more detailed testing. The sample was obtained from a 6-foot bed of soft clay immediately underlying the coal in a Geological Survey test pit on the Morgart property. The depth of overburden, principally bedrock, was 20 feet and the clay was only slightly weathered. McVay

reported the clay to be soft and fairly plastic and submitted the following information on the sample:

Residue on 100-mesh sieve	2.0 per cent
Water of plasticity	24.1
Linear drying shrinkage	4.0
Linear firing shrinkage	8.6
Total shrinkage	12.6
Drying behavior	Good
Color of fired pieces	Gray
Condition of bars after firing	Hard, low porosity
P. C. E.	Cone 23–26

The clay has low refractoriness but might be used for the manufacture of buff or gray structural clay products and ladle brick. However, it might need some grog as the firing shrinkage is fairly high.

A second sample was taken from the 3 feet of plastic clay exposed on the Swanton road in the Pleasant Valley area. This clay is high in iron with a fusion point of Cones 17 to 18 and is thus inferior to the clay from the Morgart property. McVay reports that the Swanton road clay can be used for making common brick but the fired color is brownish red and thus not very satisfactory even for this purpose.

Drilling Area of U. S. Bureau of Mines Project 823

Away from the flank of Meadow Mountain and within the central part of the Castleman basin the Middle Kittanning clay is much less regularly developed and the sequence of clay types found in the clay along Meadow Mountain is not generally recognizable. In the 40 holes drilled by the U. S. Bureau of Mines in the central part of the basin 25 penetrate the Middle Kittanning coal group. Clay or silty clay is present in 16 of these holes but is only thick enough and seemingly pure enough in 2 holes to warrant testing. Both of these holes, 20-CB and 23-CB, are close to the flank of Meadow Mountain and their sections have already been described. In the remainder of the drill holes the Middle Kittanning clay includes tan semiplastic, semiflint, and flint clays most of which are silty and interbedded with siltstones.

The drill-hole records show that the Middle Kittanning clay is widespread and fairly persistent. The distribution of the 16 holes containing clay suggests that there are three broad areas in which the clay bed is present, separated by two narrow north- and northwest-trending areas in which the clay zone consists of clastic beds. The clay body that crops out on Meadow Mountain from the Burnwell strip mine to the last clay prospect to the south on the Morgart property, narrows rapidly northwestward as the content of siltstone increases on both the northeast and southwest sides. Clay occurs only as far northwest as hole 8-CB, which is at the apex of the roughly triangular area known to

contain clay. The areas of siltstone on either side are relatively narrow and apparently converge on the Negro Mountain side of the basin. Although the evidence is insufficient to prove this pattern of distribution suggested by the drill holes, no Middle Kittanning clay has been found on Meadow Mountain either between the Stone House strip mine and the Burnwell strip mine or between the south prospect on the Morgart property and the Bittinger-Meadow Mountain road. Both of these areas lie approximately where the siltstones that enclose the clay body would cross the mountain if projected from the pattern indicated by the drill holes.

Negro Mountain

In contrast to the number of exposures on Meadow Mountain only two occurrences of clay are known on Negro Mountain that can be assigned to the Middle Kittanning bed. One of these is an outcrop along an old logging road in the Tarkiln Run area that was prospected by the Union Fire Brick Company. The location of this prospect, a trench on the west side of the logging road, is shown by the prospect symbol on the Middle Kittanning coal outcrop in Figure 18. The prospect trench exposed 1.5 feet of good brown flint clay overlain by at least 3 feet of soft clay. On the hill directly above the trench is an old abandoned coal mine. Two test pits were put down by the Union Fire Brick Company sufficiently near the mine to penetrate the coal bed, which was believed to rest directly on the clay. No clay was found below the coal. The only probable explanation of this is that the coal in the mine is the upper coal bed of the Middle Kittanning coal group. The clay underlies the middle coal bed, which may be very thin or entirely absent here. The estimated stratigraphic distance separating the clay in the trench and the coal in the mine is between 10 and 15 feet. This is about the thickness of the corresponding interval in the section of the Stone House area on Meadow Mountain, where the upper coal bed is also considerably thicker than the middle coal bed.

Evidence for the second occurrence of the Middle Kittanning clay is merely a scattering of small flint clay particles in a roadside bank on the south side of U. S. Highway 40 about 1000 feet west of its intersection with Amish road. A coal that is probably the upper bed of the Middle Kittanning crosses under the highway about 300 feet downhill from the float area.

Evaluation of the Middle Kittanning Clay

To date the Middle Kittanning clay has been the principal source of soft clay for the refractories plant at Jennings and it appears to be the only clay bed in the Castleman basin that has any potentiality for furnishing appreciable quantities of soft clay in the future. From what is now known of the clay bed it offers two possibilities for high-grade clay bodies. The most common of these is the weathered crop clay that has been demonstrated to be very

shallow and to necessitate strip mining of long narrow crop areas. The second possibility is a type of clay body in which the clay in the unweathered state is of refractory grade. Only one drill hole, 23-CB, indicates the local presence of this type of clay in the Middle Kittanning bed. The chances are that such clay bodies are small and very few in number. However, this single occurrence of high-grade unweathered clay was below the silty flint clay zone, a part of the Middle Kittanning bed that has not been thoroughly prospected. The flint clay in the Middle Kittanning clay bed has so far shown no promise of occurring in sufficiently persistent bodies to be mined for itself.

The Middle Kittanning clay deserves more prospecting on both Meadow Mountain and Negro Mountain. The areas in the middle latitudes of the Castleman basin that are within relatively short trucking range from the refractory products plant have not yet been thoroughly prospected. Perhaps the best area for further prospecting is the Tarkiln Run area, where there is an indication that the Middle Kittanning clay is as well developed as it is on Meadow Mountain. The area around U. S. Highway 40 and a short distance south of it where the Middle Kittanning crop crosses and recrosses Amish road also warrants exploratory drilling. However, the only hope for finding bodies of surface clay larger than those in the Meadow Mountain area is in the swampy south end of the basin, where the dips flatten out and the outcrop belts are broader than on the flanks of the basin. Nothing is known of the clay in this area.

UPPER KITTANNING CLAY

Character and Distribution

In the Castleman basin the underclay of the Upper Kittanning coal contains little clay of refractory grade. Throughout the central part of the basin, where it is known in considerable detail from sections in the U. S. Bureau of Mines drill holes, the underclay appears to be as variable in character and thickness as in the Georges Creek basin. Three principal phases of the underclay occur in the 38 drill holes that penetrate the underclay zone. The most common phase is a clastic one in which the underclay is generally a thin, dark gray, silty, semiplastic clay or silty claystone that grades downward into interbedded siltstone and fine sandstone. This type of underclay occurs in 18 of the 38 holes. In 11 of the holes the underclay is in a calcareous phase that consists most frequently of silty calcareous claystone (see Figure 16, hole 17-CB) or of semiplastic to semiflint clay with limestone pellets. Bedded argillaceous limestone is less commonly present.

The third phase includes limestone-free underclays containing semiplastic, semiflint, and flint clays whose color is tan or light gray or a mixture of the two. These clays are locally fragmental, silty, and ferruginous. Only 3 of the 38 holes show clay of this type and none show a clay bed of both refractory

grade and minable thickness. In the remaining 6 of the 38 drill holes the Upper Kittanning coal and its underclay are absent, having been removed by channeling prior to the deposition of the overlying Freeport sandstone.

The thickest recorded section of Upper Kittanning clay from the drill holes clearly shows that the bed is, at least locally, a compound underclay. Other sections from all phases of the underclay also suggest this. The details of the thickest clay bed are as follows:

Section of the Upper Kittanning clay in Drill Hole 8-CB

	Feet	Inches
Bone (Upper Kittanning coal).		
Gray silty claystone	0	4
Flint clay fragments in silty, sideritic claystone matrix	1	10
Light gray-brown semiplastic clay (Cone 28, Analysis 49)	1	10
Gray silty claystone with siderite concretions	4	4
Interbedded siltstone and fine sandstone	1	1
Fragmental claystone with some fragments of flint and semiflint clay	3	4
Gray silty claystone grading to siltstone	3	8

The three drill holes, 21-CB, 8-CB, and 33-CB, containing limestone-free Upper Kittanning clay, lie in a narrow, northwest-trending belt. All but one of the drill holes showing the underclay in a calcareous phase lie to the northeast of this belt. Some of these holes nearest the clay belt have thin beds of good clay associated with the calcareous beds.

Prospects or surface exposures of the Upper Kittanning clay are not known along the flanks of the central part of the basin. Distribution of the clay in the drill holes indicates that the most promising area for outcrops of the clay in this part of the basin is along Negro Mountain between the Tarkiln Run area and U. S. Highway 40. Here the outcrop of the Upper Kittanning coal lies southeast of Amish road and should not be far upslope from the Upper Freeport outcrop as the interval between these two beds is locally less than 65 feet. Projected to the southeast the belt of Upper Kittanning clay would emerge about in the Little Laurel Run area on Meadow Mountain but there is no evidence for extending the clay in this direction beyond drill hole 21-CB.

Pleasant Valley Flint Clay

Were it not for a single exposure of good flint clay in the Pleasant Valley area the Upper Kittanning clay bed could be omitted from serious consideration as a possible source of refractory clay in the Castleman basin. The exception serves to emphasize the fact that a thorough prospecting program cannot afford to overlook the underclay of any major coal horizon in the Allegheny formation.

The Pleasant Valley exposure is in a road cut and gutter on the south side of the Swanton road (Maryland Route 495) approximately 1100 feet southeast

of the turnoff to the Pleasant Valley Recreation Center. Coal smut, overlain by black shale, marks the Upper Kittanning coal. The identification of this bed is based on the calculation of intervals from undoubted exposures of the Brush Creek and Lower Bakerstown coal beds in nearby mines and prospect pits. Beneath the coal smut is a bed at least 2 feet thick of weathered soft clay whose exact thickness is obscured by slumping. Below this is about 4 feet of mottled gray and dark gray flint clay, silty flint clay, and claystone. The upper 1.5 to 2 feet of the flint clay is appreciably less siliceous than the lower part of the bed. At the base of the bed the clay grades downward to an argillaceous siltstone within a few inches. A channel sample of the entire 4-foot bed of clay was tested; it has a fusion point of Cone 32.5. The upper 2 feet of flint clay, which was tested separately, has a fusion point of Cone 33. Chemical analysis of the latter sample (Analysis 64) shows that the clay is low in fluxible impurities but is higher in silica and lower in alumina than the best Mount Savage flint clay.

This clay has never been prospected and its extent along the crop from the exposure is not known. The bed warrants prospecting in this area and its presence here marks the Upper Kittanning clay as a potential producing bed in the south end of the Castleman basin.

North Amish Road

A bed of clay that is doubtfully assigned to the Upper Kittanning bed has been prospected in a single pit along Amish road north of U. S. Highway 40. Approximately 0.7 mile north of the highway a coal and an underclay containing both flint and plastic clay are exposed in a road cut on the north side of Little Shade Run. At this locality a Union Fire Brick Company test pit exposed a coal bed underlain by a foot of flint clay with a fusion point of Cone 33. Beneath the flint clay is 5 feet of somewhat weathered gray soft clay with a fusion point of Cone 26. This clay bed is in the approximate area where the Upper Kittanning should crop out and it shows a coal similar in thickness to that in Upper Kittanning mines less than a mile distant. However, the spatial relationships of the outcrops of the coals of the Allegheny formation in this area are obscure and it is remotely possible that the clay may be the Middle Kittanning bed. The Amish road outcrop is the only exposure of clay reported along the flank of Negro Mountain north of U. S. Highway 40.

LOWER FREEPORT CLAY

The underclay of the Lower Freeport coal is of no value in the Castleman basin. It was found in 14 of the 39 drill holes that penetrated the horizon and in 4 of these only a thin, silty plastic clay was present. The remaining 10 holes had a better developed underclay bed consisting in some holes of argillaceous

limestone and calcareous claystone and in other holes of argillaceous limestone underlain by a thin bed of semiplastic to semiflint clay and claystone.

Because of its discontinuous nature, its lime content, and the rare occurrence of its thin claystone phase, the Lower Freeport underclay holds little or no promise of containing commercial bodies of refractory clay in the Castleman basin. Locally the claystone phase is of refractory grade, as in the following section.

Section of the Lower Freeport underclay, Drill Hole 13-CB

	Feet	Inches
Interbedded siltstone and sandstone (Butler sandstone).		
Gray silty shale (Lower Freeport coal horizon at base)	8	1
Calcareous claystone with lenses of argillaceous limestone	3	10
Light gray and tan fragmental semiplastic clay and semiflint clay (Cone 30, Analysis 50)	1	8
Fragmental silty claystone	0	8
Interbedded siltstone and sandstone (Freeport sandstone).		

This section is believed to represent the best development of the Lower Freeport clay that is likely to be found in the basin. The bed is not worth prospecting and the only value of locating it on the crop is to avoid confusing it with the Bolivar clay, which lies from 12 to 25 feet above it in the section. The sections of the two clay beds are somewhat similar but can readily be distinguished by the greater thickness and complexity of the Bolivar clay. The presence of the relatively persistent Upper Freeport coal a short distance above the Bolivar clay is also diagnostic.

BOLIVAR CLAY

The Bolivar clay has never been prospected in the Castleman basin in spite of the fact that the Upper Freeport coal, which lies a short distance above it, is the second largest coal-producing bed in the basin. As a result nothing is known of the character of the Bolivar clay on the outcrop except for the little information that can be gained from float fragments and ditch crops. Subsurface information is plentiful, however, in the central part of the Castleman basin, where all 40 of the U. S. Bureau of Mines drill holes penetrated the Bolivar clay horizon.

General Character

The Upper Freeport underclay zone is the thickest and most heterogeneous underclay in the Allegheny formation. Its two principal parts are (1) an upper limy claystone or argillaceous limestone unit, the Freeport limestone, and (2) a lower complex claystone unit, the Bolivar clay. The relations of these two units within the underclay zone are described in detail in Part I of this report (page 88). The Bolivar clay is the most persistent clay bed in the Allegheny

formation, and as a rule is present wherever the Upper Freeport coal is present. It is absent, along with the Upper Freeport coal, in the south end of the drilling area in the Castleman basin, where a thick body of sandstone occupies the entire upper part of the Allegheny formation (see p. 31). Throughout its broad extent the Bolivar clay varies greatly in grade. In most places it consists of a mixture of pure and impure clay types and is therefore not of economic value. In some parts of the Castleman basin, however, the Bolivar clay contains lenticular bodies of flint clay that are sufficiently thick and pure to indicate that the clay may be of local importance as a source of refractory flint clay. The distribution of drill holes penetrating high-grade clay shows no recognizable areal pattern and therefore suggests that the good clay occurs in scattered areas of irregular shape.

Details of the Bolivar Clay Bed

Where the Bolivar clay is well-developed it appears as a double bed of claystones separated by a clastic bed that varies in thickness. Commonly the clastic bed consists of siltstone but interbeds of sandstone occur locally. In some places the clastic bed is represented only by silty claystones that differ little from the surrounding claystone and the double-bedding is obscure. A detailed section of the entire Upper Freeport underclay from drill hole 26-CB is given in Figure 25. Here the compound nature of the clay is shown both by the presence of two beds of claystone separated by the clastic bed and by the repetition of claystones within the upper of the two beds.

The two beds of the Bolivar clay are similar in character; claystone is the predominant rock type and it is generally fragmental. The colors range from dark gray and brown to light gray and tan with the lighter shades the more common. A combination found in many places, particularly in the upper bed, is a bluish-gray siliceous claystone matrix with light gray or light tan fragments. In the lower bed the claystones are commonly browner. This is not everywhere so, however, and cannot be used as a guide for identifying the beds. Soft clays are less common than claystones. Both plastic and semiplastic clay is locally present, in each of the two beds; they occur along with the claystone or as the only clay types.

Analyses and fusion tests were made of Bolivar clay samples from seven drill holes. Clay of refractory grade was indicated in both the upper and lower beds. Although the evidence is far too meager to warrant generalization regarding the relative grade of clay in the two beds, several minor differences were noted in the analyses. The lower bed was slightly but consistently more calcareous than the upper and also tended to be higher in iron. Where tests on sections of good clay were fairly complete both beds showed an increase in insoluble matter (expressed as SiO_2 in the analyses) upward within the bed.

Sections of the Bolivar clay that contain flint clay of refractory grade are

given in Figure 26. The clay of the lower bed in hole 4-CB is the best clay encountered. It is not typical of the Bolivar in its general appearance, being nearly black because of its unusually high content of carbonaceous matter. The upper clay bed in this same hole is also black and is probably of refractory grade. The clay with the fusion point of Cone 34 (Analysis 43) is a hard dark brown to black flint clay with a conchoidal fracture; it is similar to the best

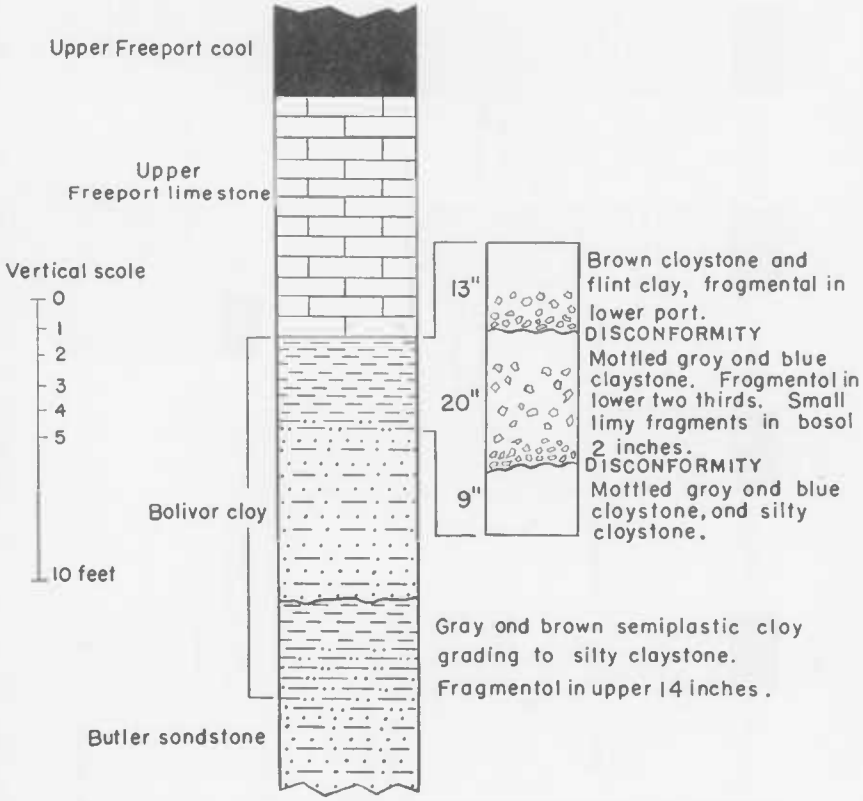


FIGURE 25. Details of the Upper Freeport underclay zone in hole 26-CB. The underclay zone includes the rocks between the Upper Freeport coal and the Butler sandstone.

grade of Mount Savage flint clay in all but its darker color. Most flint clays of the Bolivar beds are not as pure as this. The fragmental flint clay bed in hole 24-CB is more typical. It is locally a light brown fragmental flint clay of excellent quality but some of the fragments are siliceous flint clay and some are silty claystone. Accordingly the silica content is appreciably higher although the fusion point is much the same (Cone 33) as for the clay in hole 4-CB. Most of the Bolivar flint clays tested run Cone 32 or Cone 33 and contain a

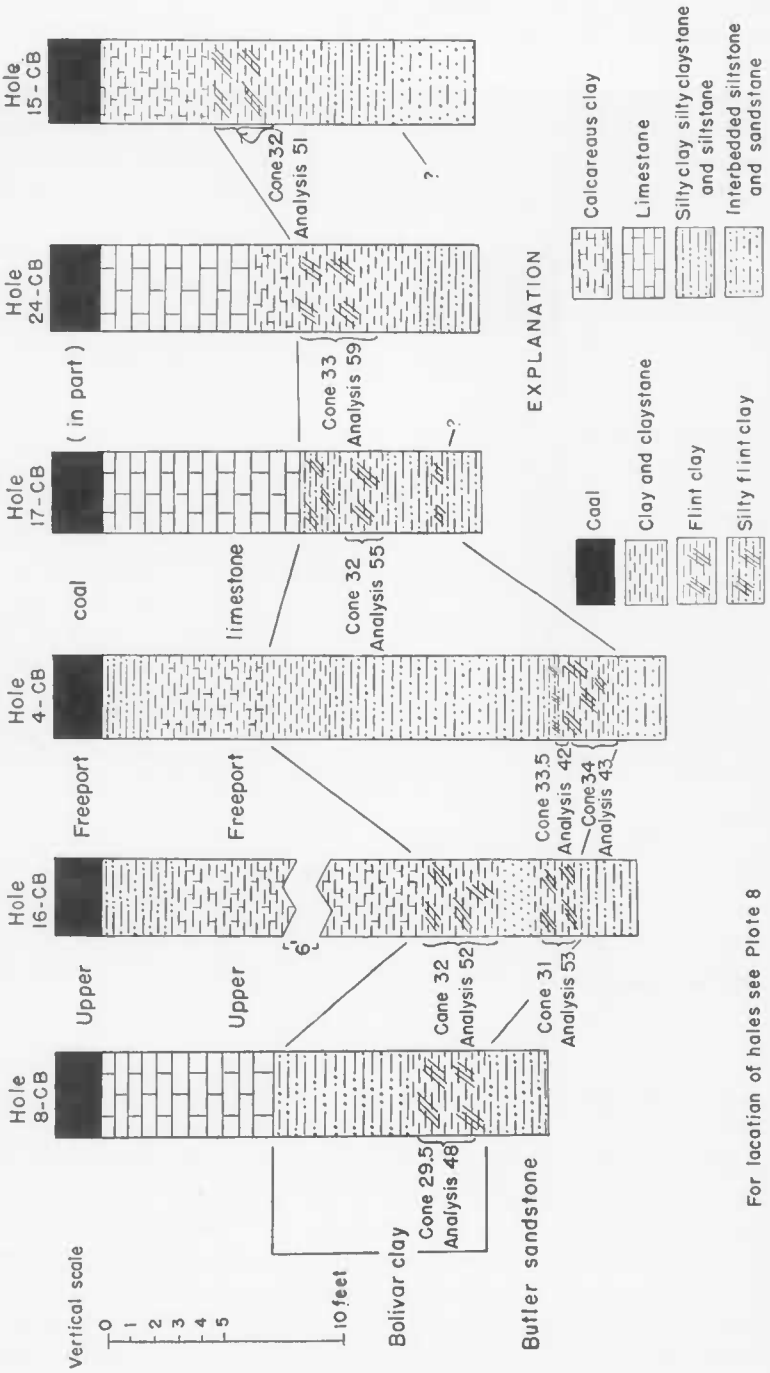


FIGURE 26. Sections of the Upper Freeport underclay zone from U. S. Bureau of Mines drill holes in the Castleman basin.

considerable amount of siliceous clay, claystone, and silty claystone. However, all of the clays with fusion points of Cone 32 and above have appreciable amounts of the more pure, smooth, glassy flint or semiflint clay either as fragments or as interstitial material.

The principal impurity other than silica is iron and it occurs commonly as massive siderite in the interstitial material of fragmental clays. Ironstone concretions are also present. Calcareous matter is an important impurity in some samples. It is most commonly present in the upper part of the upper bed, which is gradational into the overlying Upper Freeport limestone. The slight lime content of the lower clay bed shows up only in chemical analyses and cannot be detected by field test with dilute hydrochloric acid.

Outcrops of the Bolivar Clay

Float from the Bolivar clay was observed a short distance below the outcrop area of the Upper Freeport coal just west of a mine opening in the coal about 600 feet south of the North Branch of the Casselman River at a point approximately ½ mile downstream from where Tarkiln Run joins the river (see Figure 18). Gray and blue-gray flint clay fragments are plentiful along the slope in the vicinity of the mine. The locality is about 0.75 mile north-northwest of hole 16-CB, where more than 3 feet of clay with a fusion point of Cone 32 is present in the upper bed of the Bolivar clay.

A weathered section of the Bolivar clay is exposed in the east gutter of the road along the east side of Salt Block Mountain near the crest of a low rise about 0.7 mile north of the intersection with the New Germany road. Here the Freeport coal is either absent or obscured. The rise is capped by a sandstone under which a gray to white plastic clay is exposed in the road gutter. Beneath the plastic clay is a weathered bed of claystone consisting of fragmental, silty claystone and siliceous flint clay. The plastic clay, probably a lateral phase of the Upper Freeport limestone, has had the limestone pellets leached from it. The nearest drill holes (holes 6-CB and 12-CB) show limestone pellets in the clay under the Upper Freeport coal but they are not sufficiently concentrated to form beds of limestone. The white plastic clay on the outcrop was not tested. It would be worthwhile to put down a test hole back from the crop in this area to sample the soft clay. If it is of refractory grade the relation of outcrop to topography is such (see Plate 8) that a small strip mine would be feasible.

The Bolivar clay crops out again about 0.3 mile northeast of the New Germany road, where the Upper Freeport outcrop, here represented by coal blossom in the road gutter, swings back across the road toward Meadow Mountain. At this place gray claystone, flinty claystone, and minor amounts of flint clay have been observed.

Many more areas in which the Bolivar clay is exposed could probably be

located by careful searching below the outcrop of the Upper Freeport coal. In the central part of the Castleman basin the best places for such prospecting are the outcrop area along the Salt Block Mountain road and below the Upper Freeport coal outcrop on the northwest side of the basin from the Ridgley Hill area to U. S. Highway 40. In the south end of the central part of the basin, the upper part of the Allegheny formation is sandy and the Bolivar clay is absent.

Evaluation

The Bolivar clay contains some bodies of high-grade refractory clay, mostly hard clay. It is a better potential source of refractory flint clay than the Middle Kittanning clay because the beds appear to be thicker and it is the only clay in the basin that could conceivably take the place of the Mount Savage bed should the latter give out. Whether the Bolivar contains accessible clay bodies that are of sufficient grade to mine is not known. The possibility that there are such bodies is strong and the Bolivar bed should be explored in all areas where it can be reached by mines from the outcrop.

CLAYS IN THE CONEMAUGH FORMATION

The clays in the lower member of the Conemaugh formation offer little promise of being sources of refractory clay in the Castleman basin. With the exception of the clays in the interval between the Upper Freeport and Brush Creek coal beds and, in some places, the underclay of the Lower Bakerstown coal, all the underclays in the section are in the calcareous phase. The Thornton clay is locally present from 30 to 40 feet above the Upper Freeport coal and clay is found in some places associated with the upper part of the Mahoning redbed. The clays of the latter bed lie between 30 and 50 feet below the Brush Creek coal. The Lower Bakerstown underclay, where not dominantly calcareous, is an impure, silty, semiplastic clay in the unweathered state. However, in at least one area, it is known to weather to a plastic clay sufficiently pure to be used as a semirefractory bond clay.

Clays between the Upper Freeport and Brush Creek Coals

The strata in the section between the Upper Freeport and Brush Creek coal beds (see page 35) are not as variable in thickness and lithologic character in the Castleman basin as they are in the eastern coal basins. Throughout most of the basin one or both parts of the double Mahoning redbed are present. The Thornton clay, associated with the lower redbed and marking the horizon of the Mahoning coal, is a heterogeneous bed of fragmental claystones, semiplastic clays, and silty varieties of these types. It resembles the Bolivar clay in some respects, principally in its compound nature and variety of claystones. The Thornton clay is fairly persistent but is not very thick and has not been

found to contain clay bodies of refractory grade. Many of the fragmental claystones contain a large proportion of flint clay but the matrix is generally excessively silty or ferruginous. Green claystones, semiflint clays, and flint clays are common and in most places are high in iron.

The only section of Thornton clay encountered in the drill holes that is sufficiently free of obvious impurities to warrant testing is given below.

Section of the Thornton clay in Drill Hole 18-CB

	Feet	Inches
Interbedded green silty claystone and fine-grained sandstone (Upper Mahoning sandstone)	4	5
Green claystone with red mottling	9	4
Green and gray fragmental semiflint clay and claystone, some interstitial siderite (Cone 29, Analysis 56)	4	2
Green and gray silty claystone, sideritic throughout	17	1
Green fragmental claystone and semiflint clay	1	6
Interbedded siltstone and sandstone (Lower Mahoning sandstone)	14	5

The clay of this section is promising except for its iron content, which is somewhat over 10 percent. Similar bodies of clay are probably present in local areas throughout the basin and some may be exposed on the outcrop. It would be worthwhile to test weathered clays at the Thornton outcrop to determine whether the leaching has been sufficient to remove most of the iron in the exposed clay and if so to determine to what depth the clay has been thus improved. Although small bodies of good unweathered clay could occur at the Thornton horizon it is unlikely that they would be large enough or consistent enough in grade to be of value. Weathered clay on the outcrop might conceivably include small but economically valuable bodies of soft clay that would qualify as semirefractory bond clay.

The clay associated with the Upper Mahoning redbed is similar to the Thornton clay. It contains the same kinds of clay and has an even larger proportion of green-colored clays. It appears to be a compound clay and is characterized by great variation. Beds of relatively pure claystone are rare and it is doubtful that any minable bodies of unweathered clay of refractory grade occur. Like the Thornton clay it could conceivably weather to yield a surface clay of semirefractory grade. Although both the clays between the Upper Freeport and the Brush Creek coal might include surface bodies of soft clay, they do not warrant prospecting before the better clay beds in the Allegheny formation.

Thomas Clay

The underclay of the Lower Bakerstown coal, where not in the calcareous phase, is called the Thomas clay. In the Castleman basin the Lower Bakerstown coal is the principal producing coal bed and the character of the tough, semiplastic, locally limy clay below it is well known. Where it occurs in the

unweathered state in mines, in drill core samples, and in fresh cuts, the clay is worthless. On the outcrop it weathers to a gray or white plastic clay and locally is leached of much of its impurities.

Three samples of the Thomas clay, differing from one another in the degree of weathering and taken from different places in the Castleman basin, were submitted to Professor T. N. McVay at the University of Alabama for preliminary ceramic tests. Sample 1 came from a 3-foot section of fresh, silty, semiplastic clay just beneath the coal more than 450 feet from the entry in the Number One mine of the Allegheny Coal Corporation on the Casselman River south of Jennings. Sample 2 was a crop sample of partly weathered clay from the bank of a gully behind the barn on the farm of Dan Brennaman about 1.75 miles north of Grantsville. Sample 3 was a crop sample of weathered clay exposed in the Pleasant Valley Recreation Center.

The following report on the samples was submitted by McVay.

Sample 1: The clay is fairly hard and slakes as angular fragments in water. It is not plastic enough, when crushed to pass nine mesh, to be used. It might be satisfactory for brick if ground fine enough.

The clay has a P. C. E. of below Cone 8 and is not refractory. It is unlikely that this clay is of any value.

Sample 2: This is a soft fairly plastic clay which can be easily worked.

Residue on 100 mesh sieve	7.4 per cent
Water of plasticity	22.9
Linear drying shrinkage	4.6
Linear firing shrinkage (2000 deg. F.)	5.9
Total shrinkage (all shrinkages based on length of plastic bar)	10.5
Drying behavior	Good
Conditions of bars after firing	Hard
Color of fired bars	Brown, poor
P. C. E.	Cone 17–18

The clay is not refractory enough for a fire clay. It could be used for making common brick but the color is poor as there is little demand for a brick with brown color.

Sample 3: The clay is fine-grained easily worked and has the general characteristics of a ball or refractory bond clay.

Residue on 100 mesh sieve	1.5 per cent
Water of plasticity	30.2
Linear drying shrinkage	7.9
Linear firing shrinkage (2200 deg. F.)	8.5
Total shrinkage	16.4
Drying behavior	Fair, some warpage
Color of fired pieces	Gray
P. C. E.	Cone 27–28
Condition of bars after firing	Hard, low porosity

The clay may be classed as a refractory bond clay but it is not high grade as the P. C. E. is Cone 27-28. It has excessive warpage in firing and cannot be used alone. It could be used in mixtures where high refractoriness is not necessary.

How much of the change in grade from Sample 1 to Sample 3 can be attributed to weathering and how much depends upon the composition of the unweathered clays is not known. Chemical analyses of Samples 1 and 3 (analyses 62 and 63, respectively) show a reduction in fluxible impurities that can be attributed to weathering, but the appreciably higher content of alumina in Sample 3 may in part be a reflection of the composition of the unweathered clay. A better-than-average-looking semiplastic clay from the Thomas bed in hole 3-CB has been tested and has a fusion point of Cone 19, which is considerably higher than that of the raw clay from the Number One mine. The alumina content in the clay from hole 3-CB is 25 percent, the same as in Sample 3 but over 5 percent more than in Sample 1. It seems probable therefore, that leaching of the Thomas clay can produce semirefractory bond clay only where the unleached clay is fairly good.

The weathered body of Thomas clay on the Pleasant Valley Recreation Center lies close to the surface on the backslope of the hill between Maryland Route 495 and Cunningham Lake (see Plate 8). It is almost all on the northwest side of the road along the hill and a good exposure of it can be seen in the gully in the middle of the slope. Whether the grade of the clay persists to the foot of the slope under the shallow cover is not known but the clay body is in an excellent position for strip mining. This particular clay body is on state-owned land and probably could not be acquired for strip mining; however, similar topographic situations where the outcrop of the Lower Bakerstown coal extends part way up the backslopes of other hills exist farther to the southwest in the basin. If the Thomas clay is of good grade on these backslopes it could be strip mined. Except under such favorable conditions the Lower Bakerstown clay is probably not worth prospecting.

OUTLOOK FOR REFRACTORY CLAY PRODUCTION IN THE CASTLEMAN BASIN

The clay deposits known and worked in the Castleman basin up to January 1950 contain insufficient quantities of both flint and plastic refractory clay to support a plant with the capacity of that of the Union Fire Brick Company at Jennings. Although new clay bodies that can be worked by underground mining methods can possibly be found through intensive and methodical prospecting, the possibility of discovering deposits that can be worked by strip mine methods is remote. From the outset the Union Fire Brick Company's plant has been geared to the high rate of clay production afforded by strip mining. It appears inevitable that clay products production will have to be

adjusted to underground mining of clay rather than strip mining if the local industry is to be successful.

Even with the adjustment of output of clay products to underground mining, additional clay bodies will have to be found if the industry is to survive. This will require considerable exploration. The present study has served to show that the several underclays of the Allegheny formation are relatively unknown throughout their areas of outcrop and in adjacent areas within reach of mining. For the most part these beds have never been prospected and only the more obvious clay bodies, all of which were discovered through the development of their overlying coal beds, have received any attention. As a result it is not possible to state whether refractory clay production in the Castleman basin has, or has not, a future. An active exploratory program of shallow diamond drilling in the most promising areas for clay prospecting could, within a comparatively short time, answer this important question.

FUTURE PROSPECTING

The foregoing discussion of the relative merits of the different clay beds in the Castleman basin shows that none of the underclays in the Allegheny formation, with the exception of the Lower Freeport clay, can be completely ignored in the search for new clay bodies. Certain beds, however, hold promise of the greatest return for time and money invested and these deserve the most intensive exploration. The Mount Savage clay bed is of course the foremost of these and the best prospective source of refractory flint clay. Other beds that may also contain bodies of high-grade flint clay are, in order of their probable importance, the Bolivar clay, Middle Kittanning clay and Upper Kittanning clay. Refractory-grade soft clay is apt to occur locally with the Mount Savage flint clay but is not as plentiful as in the Lower and Middle Kittanning clays. Most of the soft clays of refractory grade have thus far been found in the weathered zone on the outcrop and this is no doubt the best place to explore for such soft clay. The clays in the Conemaugh formation are of secondary importance and can be omitted from consideration unless there is a critical shortage of soft clay. In this event certain outcrop areas of the Thomas clay might warrant exploration.

As an aid in prospecting, the approximate outcrop of the Middle Kittanning coal is shown on the geologic map (Plate 8). The trace is not everywhere the same coal bed in the Middle Kittanning group but it serves to show the outcrop area of the group. By estimating the distances from the positions shown for the Middle Kittanning coal and the Upper Freeport coal, the outcrop areas of most of the major clay beds can be approximated and the prospecting concentrated in the parts of these areas where nonresistant strata are obviously present. Undoubtedly the map will prove to be in error in some places. Because of the lack of data on the beds underlying the flanks of the basin, the

map is far from being a finished product and exploration for new refractory clay bodies should add much information.

In addition to the specific data on areas for prospecting in the discussions of the individual clay beds, a few considerations of a more general nature are needed to complete the background of information necessary for effective exploration of the clays of the Castleman basin. Most of the promising areas for prospecting noted for the clay beds of the Allegheny formation lie in the central part of the basin between the latitude of Bittinger and U. S. Highway 40. In this area the data from the drill records in the middle part of the basin and from the outcrops on the basin flanks have permitted fairly detailed statements on the best areas for exploration of each clay bed. North of U. S. Highway 40 and south of the latitude of Bittinger, nothing is known about the clays. In the north end of the basin certain leads were noted along U. S. Highway 40 and it may be possible to follow these northeastward for some distance. For the most part, however, the clays on the flanks of both Negro Mountain and Meadow Mountain are unexplored and deserve a few exploratory drill holes to test the Mount Savage and Middle Kittanning beds and possibly some of the higher clay horizons.

Far more important than the northeast end of the basin, from the standpoint of potential clay deposits, is the southwest end lying south of the latitude of Bittinger. Except for the several localities mentioned in the Pleasant Valley area the clays in this end of the basin are entirely unexplored. Very little interest has been shown in the area chiefly because of its distance from the Union Fire Brick Company plant, which is about equidistant from Bittinger and the Pennsylvania state line. Another deterrent to prospecting has been the swampy terrain and lack of outcrops. With the increasing need for more clay the haulage distance becomes a less important factor and exploratory drilling can overcome the disadvantages of lack of outcrops.

The evidence of a flint clay body in the Upper Kittanning underclay marks the Pleasant Valley area as the best starting point for exploration in the south end of the basin. South from this area the structure of the Castleman basin closes and the beds swing around from the flank of Meadow Mountain to the flank of Negro Mountain in a broad arc. In contrast to the flanks of the basin this is an area of low dips and consequently it is the only part of the basin that holds promise of clay bodies which could be worked by strip mining. The Negro Mountain side of this area is the more accessible and could be explored with little difficulty. Several rows of shallow drill holes across the strike should indicate whether more detailed prospecting is warranted. The entire section of the Allegheny strata from the Upper Freeport coal to the Mount Savage coal group should be tested. This could be done with shallow overlapping holes or with one or two deep reference holes with which the shallow holes could be correlated. The larger part of the south end of the basin is without easy access.

Surface exploration could be done on the backslope of the south end of Meadow Mountain, especially along the tributaries to Cherry Creek because these small streams probably cut across the outcrop of the Mount Savage coal group. The area south and southwest of Cunningham Lake, including the peculiar nearly conical knob sometimes called Little Meadow Mountain, also warrants surface prospecting for areas of flint clay float. Results of surface prospecting could be used to guide further exploration with drills or test pits.

In summary, a methodical program is required for exploration of the clay beds in the Castleman basin as a whole. Such a program should concentrate first on the detailed prospecting of the principal clay-bearing beds of the Allegheny formation in the more accessible and better-known central part of the basin. This prospecting should be directed to those parts of the Negro Mountain and Meadow Mountain flanks described in this report as showing indications of clay-bearing beds. After these more obvious possibilities have been thoroughly investigated, general reconnaissance could be carried on throughout the basin in all areas where the character of the clays is unknown. In this latter phase the south end of the basin should be the principal target because it constitutes the largest single unknown area of outcrop of the Allegheny formation in the entire basin.

APPENDIX

Analyses and Fusion Tests of Maryland Coal Measure Clays

In the following tables are listed the results of tests of the clays in the Georges Creek, Upper Potomac, and Castleman basins. Details of the location of each sample tested are given in the locality list following. Analyses 1 to 38 are of samples from U. S. Bureau of Mines drill holes on Project 818 in the Georges Creek and Upper Potomac basins. Complete logs of the drill holes from this project are given in the Appendix of the U. S. Bureau of Mines report on this project (Toenges, et al., 1949, pp. 29–100). Analyses 39 to 60 are from U. S. Bureau of Mines drill holes on Project 823 in the Castleman basin. Complete logs of drill holes from this project will be available in a forthcoming U. S. Bureau of Mines publication. Analyses 61 to 65 are of surface samples in the Castleman basin.

The fusion points and analyses of samples 1 to 61 were made by the Metallurgical Division of the U. S. Bureau of Mines, Tuscaloosa Branch, H. G. Iverson in charge. Analyses 62 to 65 were made by Emerson P. Poste, chemical engineer, of Chattanooga, Tennessee, and the fusion tests on these samples were made by Prof. T. N. McVay of the University of Alabama.

Ultimate Analyses and Fusion Points of Maryland Clays

Analysis No	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Alkalies	Ignition Loss	Total	Fusion Point Cone
Georges Creek and Upper Potomac Basins										
1	56.1	27.0	2.5	1.2				7.7	94.5	29
2	58.3	25.3	2.4	1.6				7.8	95.4	29
3	50.5	29.3	4.0	1.6				11.7	97.1	29
4	48.7	34.3	1.8	1.6				13.0	99.4	34
5	48.4	30.5	4.4	2.3				11.5	97.1	29
6	49.4	27.5	6.6	2.5				10.6	96.6	23
7	57.9	25.9	2.0	2.0				7.4	95.2	28
8	58.9	26.7	2.4	1.4				6.9	96.3	29
9	48.7	20.6	12.5	1.0				11.3	94.1	14
10	48.1	24.8	9.1	1.1				13.4	96.5	19
11	34.3	19.9	21.8	1.1				18.6	95.7	12
12	55.4	28.0	2.2	2.1				9.5	97.2	31
13	54.0	25.3	5.2	1.4	0.5			9.1	95.5	18
14	50.9	28.1	5.3	1.4	0.3			10.6	96.6	16
15	55.5	27.0	2.7	1.5				8.7	95.4	26
16	53.5	26.4	4.7	1.2			3.6	7.9	97.3	28
17	57.1	28.2	1.7	1.2				10.2	98.4	32
18	49.0	28.8	4.6	2.3				12.5	97.2	30

Ultimate Analyses and Fusion Points of Maryland Clays—continued

Analysis No.	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Alkalies	Ignition Loss	Total	Fusion Point Cone
Georges Creek and Upper Potomac Basins—continued										
19	52.1	22.8	3.3	1.3	5.1			10.6	95.2	14
20	56.8	24.4	4.3	1.2	0.6			8.3	95.6	26
21	48.2	30.8	5.0	1.4				13.8	99.2	30
22	48.0	29.8	4.3	2.1				12.5	96.7	30
23	59.7	24.8	2.9	1.4				8.0	96.8	28
24	56.3	25.9	3.1	1.5				9.7	96.5	28
25	56.9	26.2	2.5	1.3				8.1	95.0	28
26	57.8	21.9	7.4	1.3				7.6	96.0	16 to 18
27	56.5	26.5	4.1	1.3				10.2	98.6	30
28	54.9	27.1	2.8	1.6				11.1	97.5	30
29	51.4	28.7	3.1	1.3				10.1	94.6	30
30	44.5	29.4	6.5	1.6				14.2	96.2	26
31	59.7	21.7	4.8	1.1				7.9	95.2	20
32	57.1	25.8	2.4	1.5				9.2	96.0	28
33	51.8	27.7	4.7	1.2				10.7	96.1	28
34	57.6	27.0	1.6	1.9				9.1	97.2	28
35	55.1	27.7	2.9	1.5				9.6	96.8	28
36	47.8	33.3	3.1	1.7				14.0	99.9	32
37	57.0	27.3	1.9	1.6				8.6	96.4	30
38	61.4	23.5	2.8	1.1				7.4	96.2	20
Castleman Basin										
39	54.54	29.63	2.80	1.02	0.63	0.91	1.0	9.36	99.89	28
40	58.47	25.09	3.60	1.11	0.65	1.00	0.88	8.35	99.15	19
41	51.30	33.88	1.75	1.47				9.85	98.25	32
42	51.22	32.65	1.25	1.30				12.39	98.81	33½
43	44.08	37.44	1.60	1.59	0.45	0.36	0.76	13.77	100.05	34
44	52.06	31.88	1.65	2.85				9.52	97.96	31
45	50.22	34.44	2.35	1.61	0.65	0.81	1.06	8.86	100.00	30
46	47.10	34.84	1.20	2.21	0.25	0.36	0.81	12.53	99.30	33½
47	46.51	37.15	0.95	1.55	0.20	0.09	0.81	12.56	99.82	34
48	44.72	31.21	6.20	1.34	1.28	0.53	0.89	13.54	99.71	29½
49	55.52	29.14	3.10	1.64	1.08	0.36	0.90	8.28	100.02	28
50	54.1	30.84	2.65	1.51	0.68	0.98	0.68	9.14	100.58	30
51	51.07	32.97	2.50	1.53				9.89	97.93	32
52	50.10	32.31	2.50	1.14	0.88	0.09	0.82	11.38	99.22	32
53	44.22	31.97	4.10	1.36	2.58	0.09	0.68	14.58	99.58	31
54	48.72	35.70	0.40	1.79				12.04	98.65	33½
55	50.92	30.99	2.70	1.36				11.57	97.54	32
56	39.38	32.27	10.70	1.53	0.85	0.34	0.85	13.32	99.24	29
57	50.66	28.30	5.30	1.20				8.88	94.34	27
58	56.66	28.39	2.40	1.34	0.25	0.57	0.73	8.73	99.07	30
59	55.06	30.53	2.00	1.67	0.13	0.56	0.59	8.75	99.29	33
60	49.18	33.53	2.40	1.42				11.47	98.00	30
61	54.22	29.59	2.20	1.26				9.86	97.13	29
62	57.53	19.87	5.79	1.01	1.02	1.52	2.04	9.43	98.21	7
63	58.28	25.02	2.51	1.11		0.59	2.22	9.82	99.55	27 to 28
64	51.86	31.37	1.92	1.38		0.27	0.07	13.14	100.01	33
65	43.83	36.37	2.48	2.58			0.10	14.88	100.24	34+

LIST OF MARYLAND CLAY SAMPLES

Georges Creek and Upper Potomac Basins

Analysis No.

1. Plastic clay, Bolivar bed. Hole 1-GC, from 387′3″ to 392′3″.
2. Semiplastic clay, Thornton bed. Hole 2-GC, from 455′8″ to 461′.
3. Silty flint clay, Upper Kittanning bed. Hole 2-GC, from 635′2″ to 637′10″.
4. Flint clay, Upper Kittanning bed. Hole 2-GC, from 637′10″ to 641′4″.
5. Silty flint clay, Mount Savage bed. Hole 2-GC, from 767′ to 772′3″.
6. Sideritic flint clay, Mount Savage bed. Hole 2-GC, from 777′5″ to 778′11″.
7. Semiplastic clay, Mount Savage bed. Hole 2-GC, from 778′11″ to 782′11″.
8. Semiplastic clay, Mount Savage bed. Hole 2-GC, from 785′1″ to 788′1″.
9. Sideritic claystone, Lower Freeport bed. Hole 4-GC, from 369′10″ to 371′6″.
10. Sideritic flint clay, Lower Freeport bed. Hole 4-GC, from 371′6″ to 377′6″.
11. Highly sideritic flint clay, Lower Freeport bed. Hole 4-GC, from 377′6″ to 379′.
12. Flinty claystone, Lower Kittanning bed. Hole 5-GC, from 788′6″ to 791′6″.
13. Ferruginous semiplastic clay, Thomas bed. Hole 6-GC, from 453′4″ to 455′4″.
14. Impure semiflint clay, Middle Kittanning bed. Hole 6-GC, from 814′7″ to 817′.
15. Semiplastic clay, Lower Kittanning bed. Hole 9-GC, from 893′ to 899′.
16. Plastic clay, Brush Creek bed. Hole 10-GC, from 698′ to 702′5″.
17. Siliceous flint clay, Upper Kittanning bed. Hole 10-GC, from 912′ to 913′6″.
18. Semiplastic clay, Middle Kittanning bed. Hole 11-GC, from 861′10″ to 864′1″.
19. Plastic clay, Brush Creek bed. Hole 13-GC, from 346′ to 349′.
20. Semiplastic clay, Upper Kittanning bed. Hole 13-GC, from 510′3″ to 515′5″.
21. Sideritic flint clay, Lower Kittanning bed. Hole 14-GC, from 722′5″ to 724′.
22. Semiflint clay, Middle Kittanning bed. Hole 15-GC, from 745′ to 746′2″.
23. Semiplastic clay, Thomas bed. Hole 15-GC, from 354′6″ to 356′.
24. Semiplastic clay, Middle Kittanning bed. Hole 16-GC, from 788′6″ to 792′9″.
25. Plastic clay, Bolivar bed. Hole 17-GC, from 391′ to 395′.
26. Red and green plastic clay, Meyersdale bed. Hole 19-GC, from 367′6″ to 371′6″.
27. Flinty claystone, Thornton bed. Hole 19-GC, from 470′ to 472′.
28. Siliceous flint clay, Bolivar bed. Hole 18-GC, from 596′10″ to 598′5″.
29. Semiplastic clay, Bolivar bed. Hole 18-GC, from 598′5″ to 599′9″.
30. Ferruginous flint clay, Thornton bed. Hole 20-GC, from 574′9″ to 577′9″.
31. Gray silty plastic clay, Meyersdale bed. Hole 20-GC, from 413′ to 416′6″.
32. Semiplastic clay, Middle Kittanning bed. Hole 20-GC, from 787′3″ to 790′.
33. Ferruginous semiplastic clay, Middle Kittanning bed. Hole 21-GC, from 797′6″ to 799′6″.
34. Slightly silty semiplastic clay, Lower Kittanning bed. Hole 21-GC, from 835′7″ to 838′9″.
35. Mixed claystone and semiflint clay, Middle Kittanning bed. Hole 22-GC, from 418′6″ to 425′.
36. Mixed semiflint and flint clay, Middle Kittanning bed. Hole 23-GC, from 616′ to 618′.
37. Semiplastic clay, Lower Freeport bed. Hole 25-GC, from 648′6″ to 650′10″.
38. Silty semiplastic clay, Middle Kittanning bed. Hole 25-GC, from 753′ to 755′6″.

Castleman Basin

39. Mixed semiplastic and semiflint clay, Bolivar bed. Hole 1-CB, from 592′ to 593′.
40. Plastic clay, Thomas bed. Hole 3-CB, from 348′ to 351′6″.
41. Semiflint clay, Lower Kittanning bed. Hole 3-CB, from 802′4″ to 804′2″.

42. Flint clay, Bolivar bed. Hole 4-CB, from 699′9″ to 700′5″.
43. Flint clay, Bolivar bed. Hole 4-CB, from 700′5″ to 702′4″.
44. Semiplastic clay, Lower Kittanning bed. Hole 4-CB, from 891′1″ to 892′7″.
45. Semiplastic clay, Mount Savage bed. Hole 7-CB, from 446′4″ to 447′.
46. Flint clay, Mount Savage bed. Hole 7-CB, from 447′ to 448′5″.
47. Flint clay, Mount Savage bed. Hole 7-CB, from 448′5″ to 449′10″.
48. Sideritic flinty claystone, Bolivar bed. Hole 8-CB, from 588′10″ to 591′2″.
49. Semiplastic clay, Upper Kittanning bed. Hole 8-CB, from 625′4″ to 627′2″.
50. Mixed semiplastic clay and claystone, Lower Freeport bed. Hole 13-CB, from 234′8″ to 237′.
51. Semiflint clay, Bolivar bed. Hole 15-CB, from 336′1″ to 338′11″.
52. Flint clay, Bolivar bed. Hole 16-CB, from 508′2″ to 511′3″.
53. Mixed flint and semiflint clay, Bolivar bed. Hole 16-CB, from 513′3″ to 514′8″.
54. Flint clay, Mount Savage bed. Hole 16-CB, from 728′3″ to 730′.
55. Flinty claystone, Bolivar bed. Hole 17-CB, from 642′6″ to 644′3″.
56. Ferruginous claystone, Upper Mahoning bed. Hole 18-CB, from 397′8″ to 402′.
57. Semiplastic clay, Middle Kittanning bed. Hole 20-CB, from 190′ to 191′9″.
58. Semiplastic clay, Middle Kittanning bed. Hole 23-CB, from 218′2″ to 221′8″.
59. Mixed flint clay and flinty claystone, Bolivar bed. Hole 24-CB, from 387′1″ to 390′7″.
60. Mixed semiplastic clay and flint clay, Mount Savage bed. Hole 25-CB, from 557′5″ to 560′10″.
61. Plastic clay, overlying basal coal bed of Middle Kittanning coal group. Stone House strip mine, Meadow Mountain. Channel sample of 2 feet.
62. Tough semiplastic clay, Thomas bed. Working face over 450 feet from entry, Number One mine of Allegheny Coal Corporation. Channel sample of 3 feet.
63. Plastic clay, Thomas bed. Stream gulley northwest of road in Pleasant Valley Recreation Center, 0.4 mile from junction with Maryland Route 495. Channel sample of 6 feet.
64. Flint clay, Upper Kittanning bed. Road cut southwest side of Maryland Route 495 about 1100 feet southeast of turnoff to Pleasant Valley Recreation Center. Channel sample of upper 2 feet of 4-foot bed.
65. Flint clay, Mount Savage bed. Union Fire Brick Company strip mine, Tarkiln Run area, Negro Mountain. Channel sample of 3-foot bed.

BIBLIOGRAPHY

Allen, V. T. (1935) Mineral composition and origin of Missouri flint and diaspore clays, Missouri Geol. Survey and Water Resources, Bienn. Rept., Appendix IV.

Ashley, G. H. (1928) Bituminous Coal Fields of Pennsylvania, Introductory Volume, Pennsylvania Geol. Survey, 4th ser., Bull. M6, Part 1.

——— (1945) The Pittsburgh-Pottsville Boundary, Jour. Geology, vol. 53, no. 6, pp. 374–390.

Clark, W. B., Martin, G. C., and others (1905) Report on the Coals of Maryland, Maryland Geol. Survey, vol. 5, pt. 4.

Condit, D. D. (1912) Conemaugh formation in Ohio, Ohio Geol. Survey, 4th ser., Bull. 17.

Foose, R. M. (1944) High-alumina clays of Pennsylvania, Econ. Geology, vol. 39, no. 8, pp. 557–577.

Grim, R. E., and Allen, V. T. (1938) Petrology of the Pennsylvanian underclays of Illinois, Geol. Soc. America Bull., vol. 49, pp. 1485–1514.

Hennen, R. V., Reger, D. B. (1914) Preston County, West Virginia Geol. Survey County Repts.

Lamborn, R. E. (1930) Geology of Jefferson County, Ohio Geol. Survey, 4th ser., Bull. 35.

Leighton, Henry (1941) Clay and shale resources in Pennsylvania, Pennsylvania Geol. Survey, 4th ser., Bull. M-23.

Lesley, J. P. (1876) On the record of the Boyd's Hill well at Pittsburgh, Pennsylvania 2d Geol. Survey, Rept. L, Appendix E, pp. 221–227.

Martin, G. C. (1902) The Geology of Garrett County, and The Mineral resources of Garrett County in Martin, G. C., and others, Garrett County, Maryland Geol. Survey.

——— (1908) U. S. Geol. Survey Geol. Atlas, Accident-Grantsville folio (no. 160).

Moore, R. C., and others (1944) Correlation of Pennsylvanian formations of North America, Geol. Soc. America Bull., vol. 55, pp. 657–706.

O'Hara, C. C. (1900) The Geology of Allegany County in O'Hara, C. C., and others, Allegany County, Maryland Geol. Survey.

Orton, Edward (1878) Supplementary Report on the Hanging Rock District, Ohio Geol. Survey, vol. 3, chap. 89.

Platt, Franklin (1875) Clearfield and Jefferson Coal District, Pennsylvania 2d Geol. Survey, Rept. H.

———, and Platt, W. G. (1877) Cambria and Somerset District, Pennsylvania 2d Geol. Survey, Rept. H3.

Platt, W. G. (1880) Report of Progress in Armstrong County, Pennsylvania 2d Geol. Survey, Rept. H5.

Reger, D. B. (1923) Tucker County, West Virginia Geol. Survey County Repts.

Renick, B. C. (1924) The Correlation of the Lower Allegheny-Pottsville section in western Pennsylvania, Jour. Geology, vol. 32, no. 1, pp. 64–80.

Ries, Heinrich (1902) Report on the clays of Maryland, Maryland Geol. Survey, vol. 4, pt. 3.

——— (1903) The clays of the United States east of the Mississippi River, U. S. Geol. Survey, Prof. Paper 11.

——— (1927) Clays, their occurrence, properties and uses, 3d edition, John Wiley and Sons, New York, pp. 446–455.

Rogers, H. D. (1836) Pennsylvania Geol. Survey, 1st Ann. Rept.

——— (1838) Pennsylvania Geol. Survey, 2d Ann. Rept.

——— (1839) Pennsylvania Geol. Survey, 3d Ann. Rept.

——— (1840) Pennsylvania Geol. Survey, 4th Ann. Rept.

Rogers, H .D. (1858) The Geology of Pennsylvania, vol. 1, William Blackwood and Sons, Edinburgh.

——— (1859) The Geology of Pennsylvania, vol. 2, pt. 1, J. B. Lippincott and Co., Philadelphia.

Singewald, J. T., Jr. (1911) Report on the Iron Ores of Maryland, with an account of the iron industry, Maryland Geol. Survey, vol. 9, pt. 3.

Stevenson, J. J. (1873) Notes on the Geology of West Virginia, Am. Philos. Soc. Trans., n.s., vol. 15, pp. 15–32.

——— (1878) The Ligonier Valley, Pennsylvania 2d Geol. Survey, Rept. K^3.

Stout, Wilbur Stull, R. T., McCaughey, W. J., and Demorest, D. J., (1923) Coal Formation Clays of Ohio, Ohio Geol. Survey, 4th ser., Bull. 26.

——— (1947) Generalized section of rocks of Ohio, Ohio Geol. Survey, 4th ser., Information Circular No. 4.

Swartz, C. K., Price, W. A., and Bassler, H. (1919) Coal Measures of Maryland, Geol. Soc. America Bull., vol. 30, pp. 567–596.

Swartz, C. K., and Baker, Wm. A., Jr. (1922) Second Report on the Coals of Maryland, Maryland Geol. Survey, vol. 11, pt. 1.

Toenges, A. L., Turnbull, L. A., and others (1949) Investigation of lower coal beds in Georges Creek and north part of Upper Potomac Basins, Allegany and Garrett Counties, Md., U. S. Bur. Mines, Tech. Paper 725.

Wanless, H. R. (1939) Pennsylvanian Correlations in the Eastern Interior and Appalachian Fields, Geol. Soc. America, Special Paper 17.

———, and Weller, J. M. (1932) Correlation and extent of Pennsylvanian cyclothems, Geol. Soc. America Bull., vol. 43, pp. 1003–1016.

Wanless, H. R., and Shepard, F. P. (1936) Sea level and climatic changes related to late Paleozoic cycles, Geol. Soc. America Bull., vol. 47, pp. 1177–1206.

Watts, A. S., Schurecht, H. G., Swartz, C. K., and Hall, G. M. (1922) The Fire Clays of Maryland, Maryland Geol. Survey, vol. 11, pt. 2.

Weller, J. M. (1930) Cyclical sedimentation in the Pennsylvanian and its significance, Jour. Geology, vol. 38, no. 2, pp. 97–135.

White, I. C. (1891) Stratigraphy of the Bituminous Coal Field of Pennsylvania, Ohio, and West Virginia, U. S. Geol. Survey, Bull. 65.

———, (1903) The Appalachian Coal Field, West Virginia Geol. Survey, vol. 2, pt. 2.

Wilmarth, M. Grace (1938) Lexicon of Geologic Names of the United States, U. S. Geol. Survey, Bull. 896.

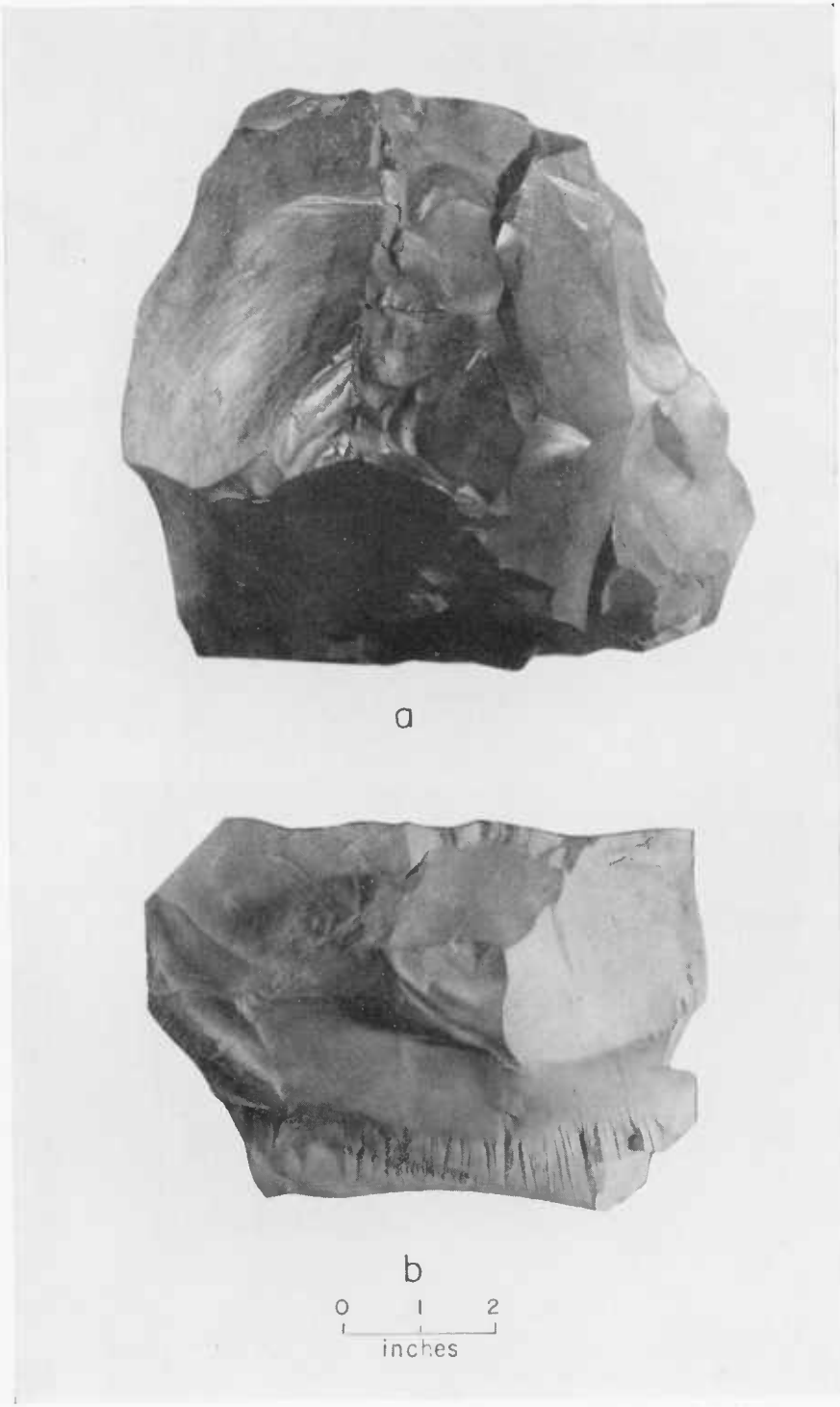


PLATE 1. Flint clay (×0.5). (a) Mount Savage flint clay from the Union Fire Brick Company strip mine on Tarkiln Run, Castleman Basin. (b) Mount Savage flint clay from the Big Savage Refractories Company stripping on Big Savage Mountain.

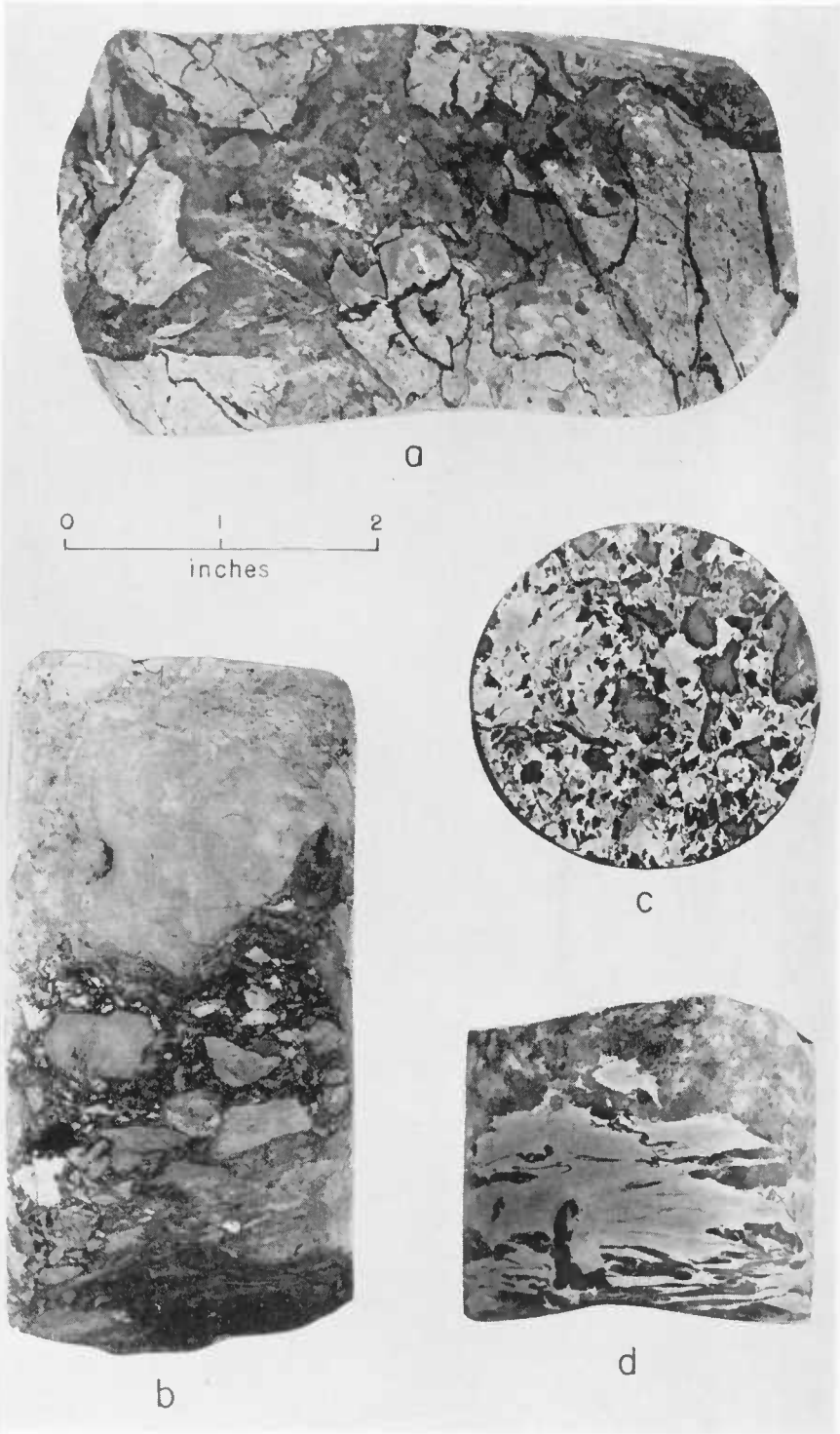


PLATE 2. Fragmental claystones (×1). (a) Mount Savage flint clay from the Tarkiln Run stripping. (b) Bolivar flint clay from drill hole 19-CB. (c) Claystone from the Thornton clay, drill hole 7-CB. (d) Flinty claystone from the Thornton clay, drill hole 19-GC.

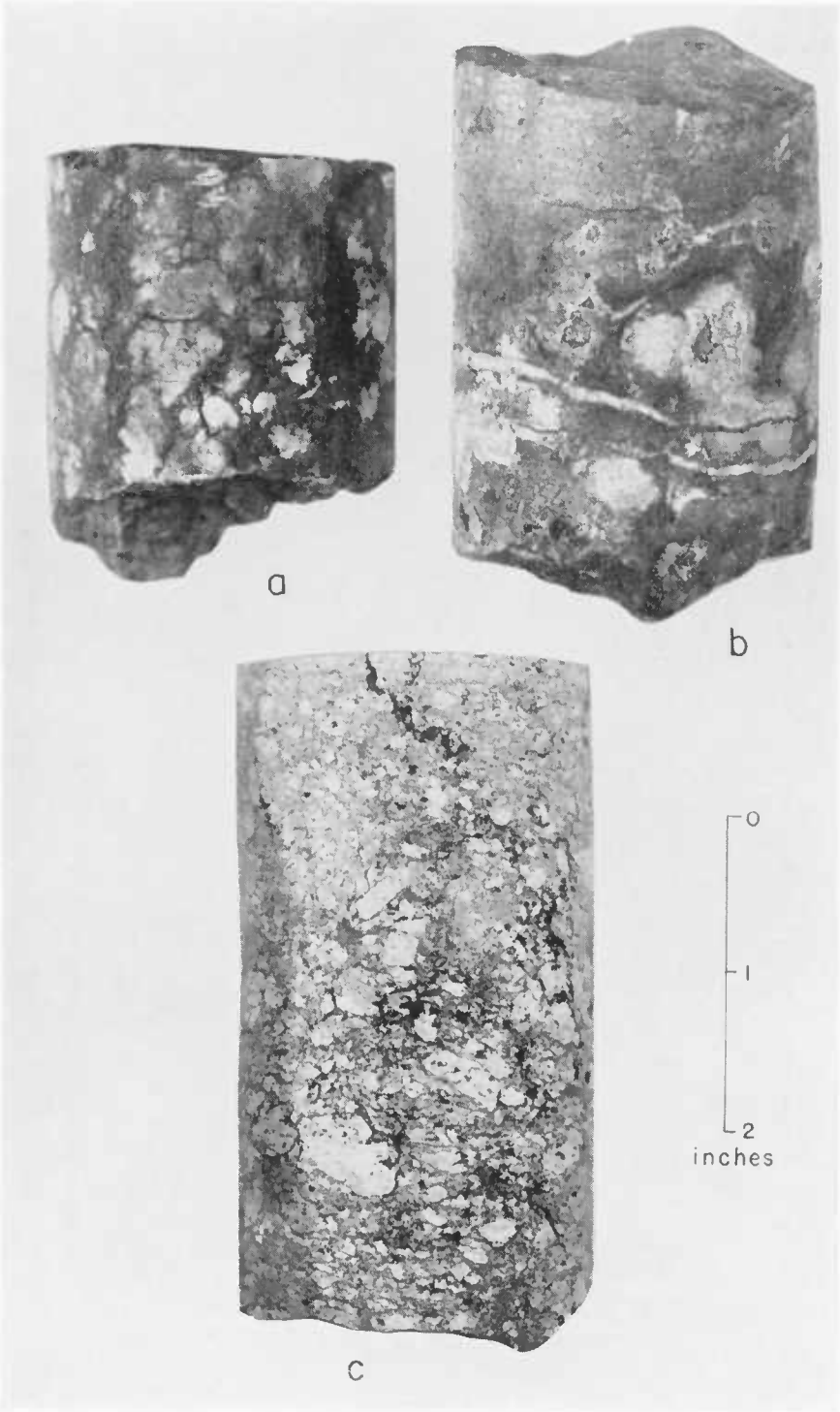
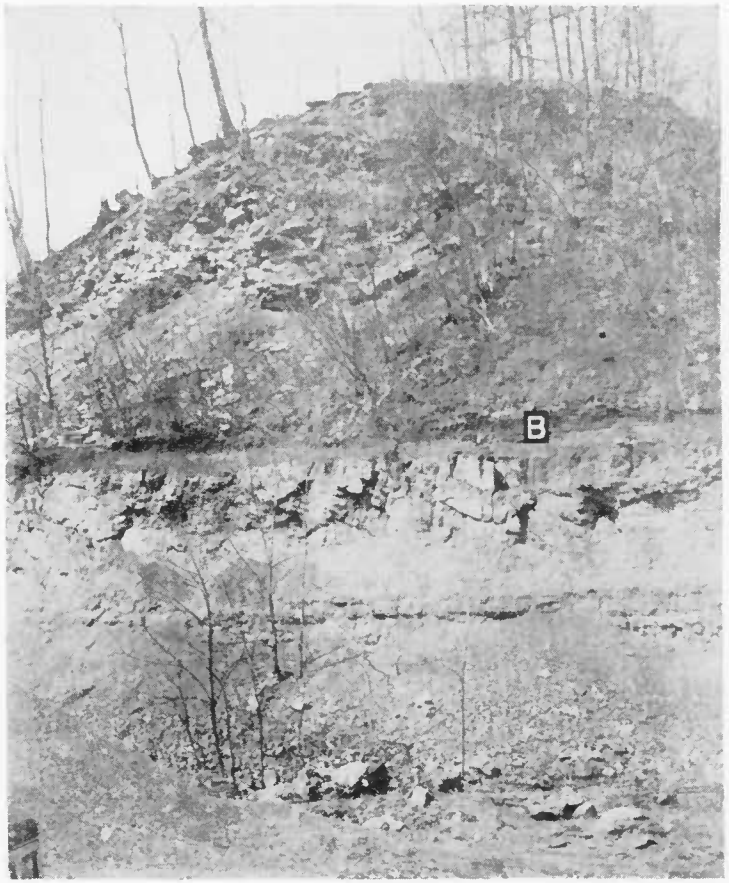


PLATE 3. Calcareous underclays (×1). (a) Limestone pellets in the Harlem underclay, drill hole 4-CB. (b) Limestone pellets and partings of gypsum in the Upper Freeport underclay, drill hole 22-GC. (c) Argillaceous limestone showing pellet structure, Barton limestone, drill hole 39-CB.



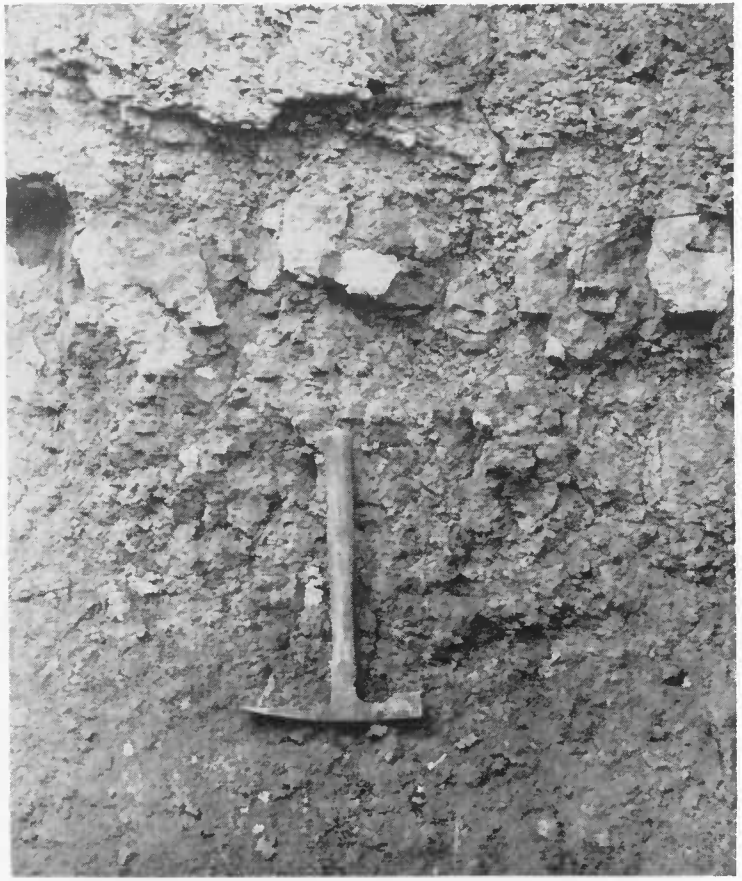


PLATE 4. Argillaceous limestone beneath the Barton coal (B). Left: Road cut along U. S. Highway 40 just west of the Casselman River. Right: Close-up of the limestone bed.

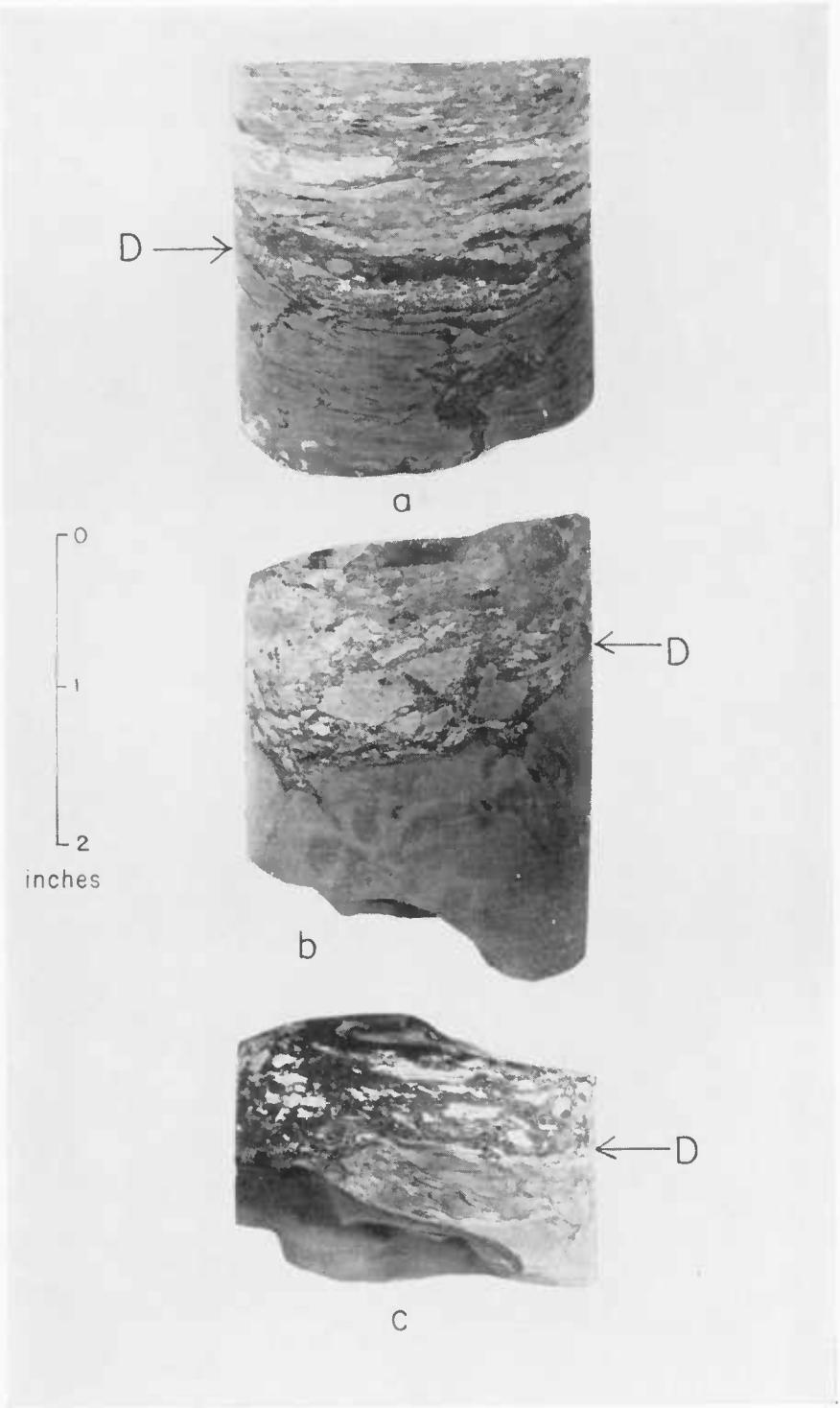


PLATE 5. Disconformities (D) within compound underclays (×1). (a) Layer of sand grains lies above disconformity in Middle Kittanning clay from drill hole 8-GC. (b) Contact of flinty claystone (below) and fragmental claystone, Bolivar clay, drill hole 19-CB. (c) Gray flint clay (below) in contact with varicolored fragmental clay, Bolivar clay, drill hole 22-GC.

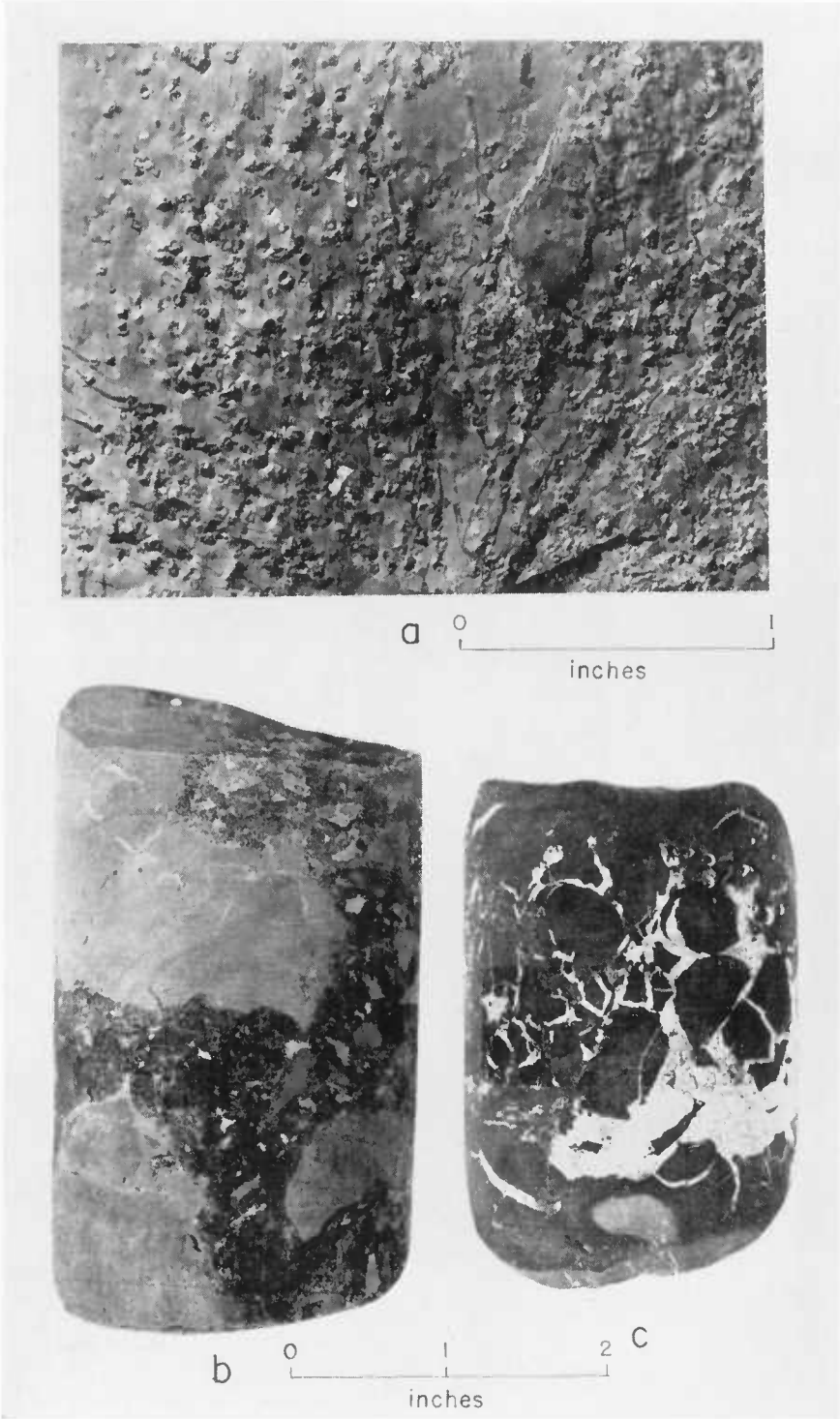
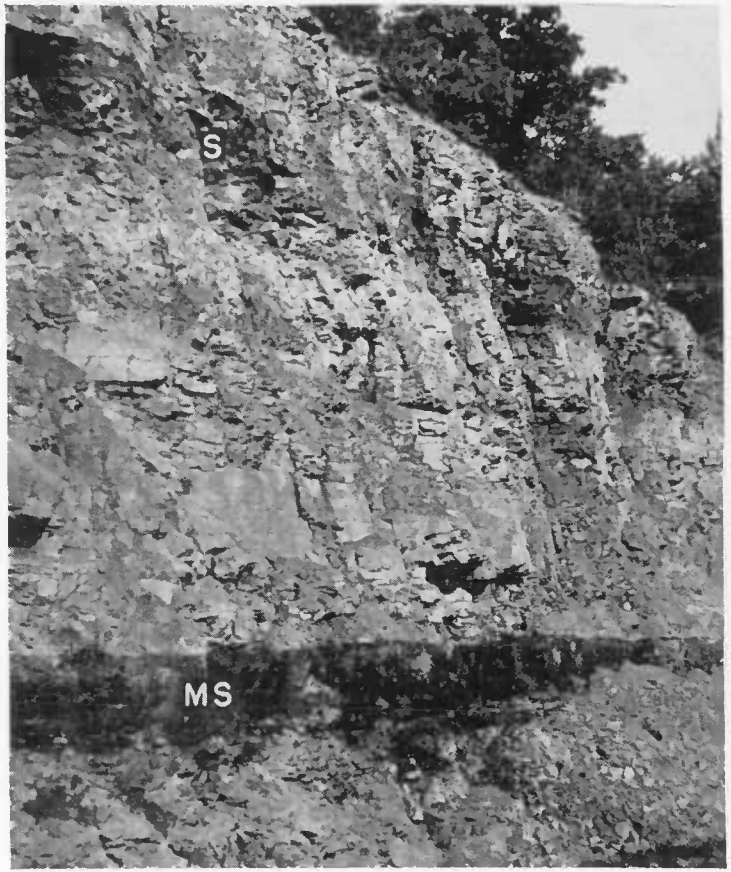


PLATE 6. Siderite in underclays. (a) Grains of siderite in Lower Kittanning flint clay, drill hole 14-GC (×2). (b) Fragmental claystone with interstitial sideritic clay (dark), Bolivar clay, drill hole 14-GC (×1). (c) Septarian ironstone concretion with calcite filling, Bolivar clay, drill hole 5-GC (×1).



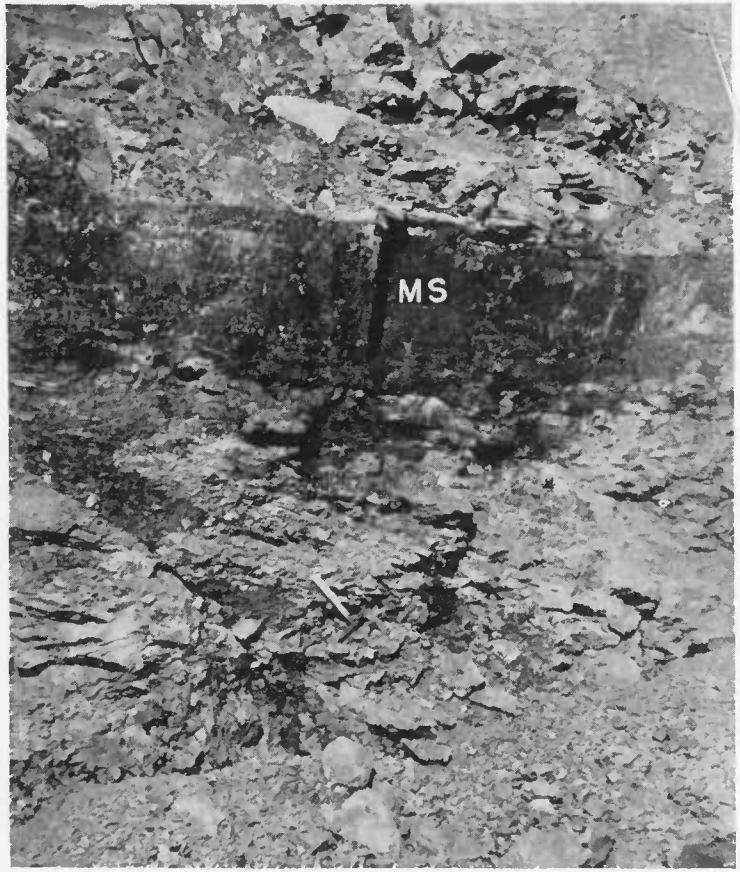
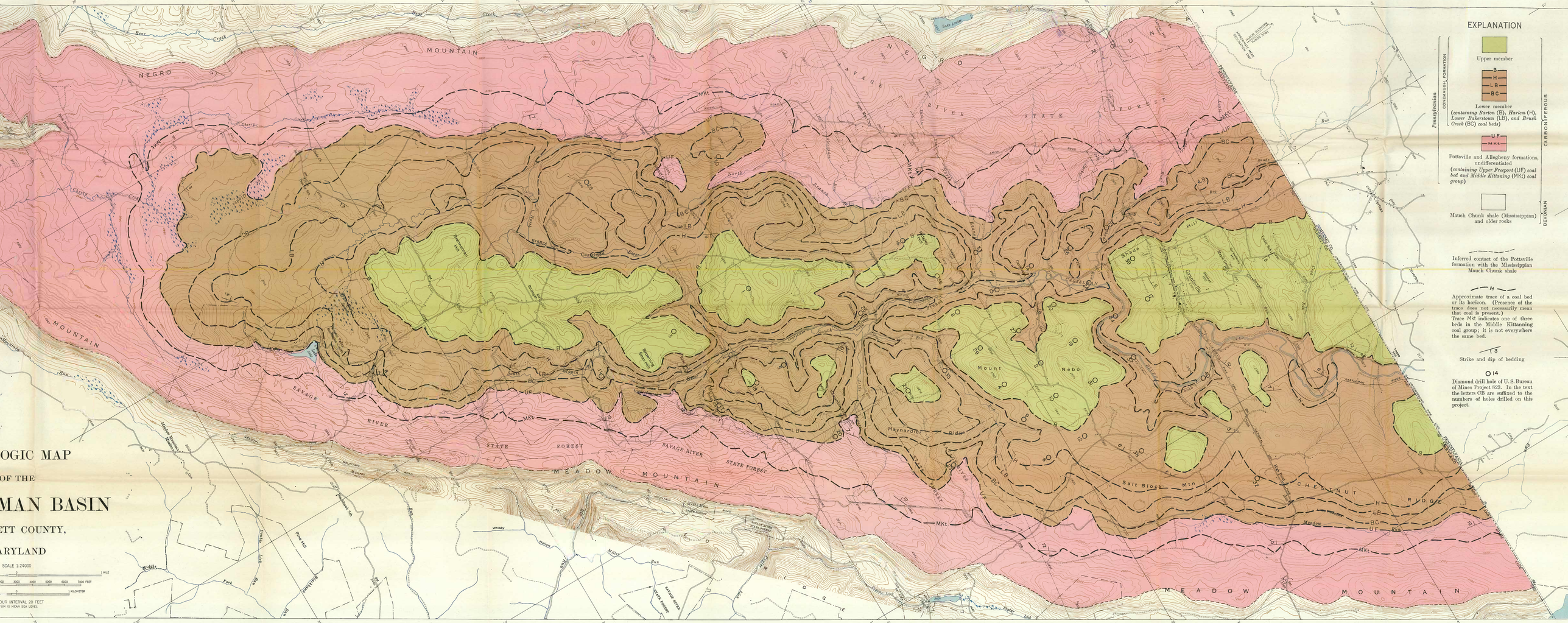


PLATE 7. Exposures in the Tarkiln Run strip mines of the Union Fire Brick Company. Left: Mount Savage coal (MS) and clay overlain by shale. Upper dark shale (S) marks Scrub-grass coal horizon. Right: Clay beneath the Mount Savage coal. The lower 4 feet is flint clay.

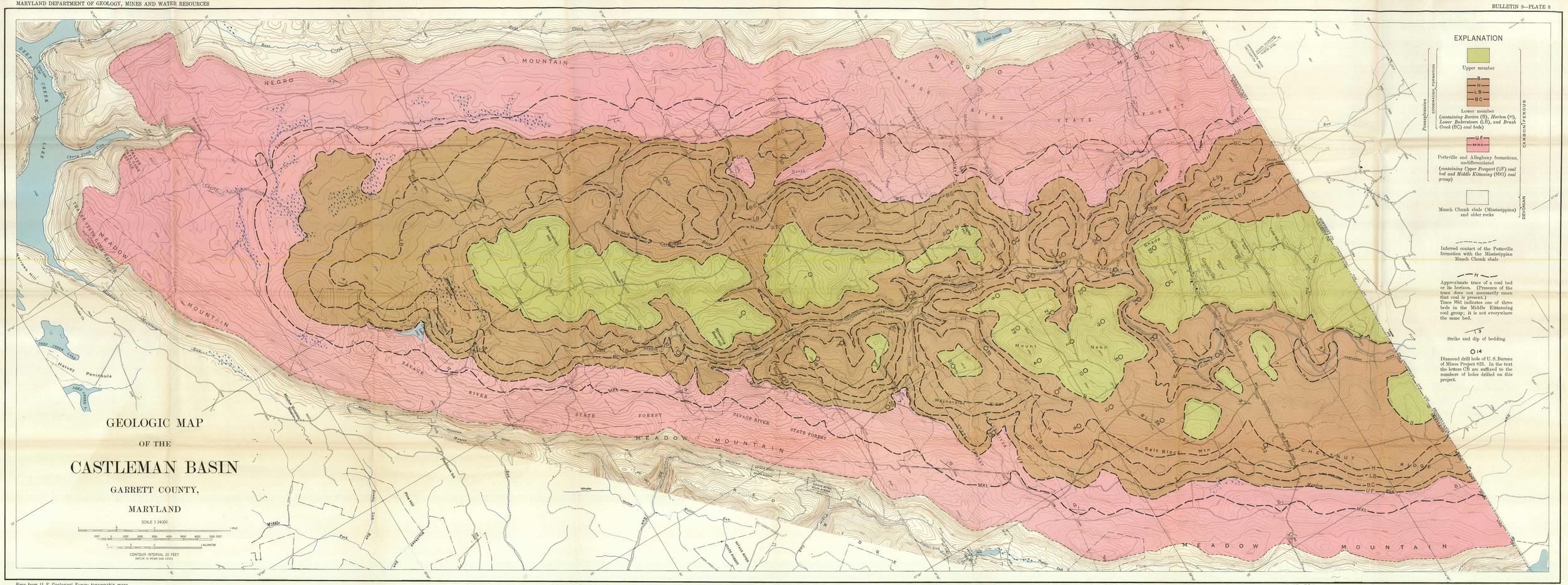
INDEX

(Page numbers in *italics* indicate detailed descriptions)



A. Hoen & Co., Inc.

Geology by K. M. Waage assisted by H. P. Bange



GEOLOGIC MAP
OF THE
CASTLEMAN BASIN
GARRETT COUNTY,
MARYLAND

SCALE 1:24000
1 MILE
7000 FEET
1 KILOMETER
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

EXPLANATION

CARBONIFEROUS

Pennsylvanian

CONEMAUGH FORMATION

🟩 Upper member

▨ B, H, LB, BC — Lower member (*containing Barton* (B), *Harlem* (H), *Lower Bakerstown* (LB), *and Brush Creek* (BC) *coal beds*)

🟥 UF, MKt — Pottsville and Allegheny formations, undifferentiated (*containing Upper Freeport* (UF) *coal bed and Middle Kittaning* (MKt) *coal group*)

DEVONIAN

☐ Mauch Chunk shale (Mississippian) and older rocks

Inferred contact of the Pottsville formation with the Mississippian Mauch Chunk shale

— H — Approximate trace of a coal bed or its horizon. (Presence of the trace does not necessarily mean that coal is present.) Trace Mkt indicates one of three beds in the Middle Kittanning coal group; it is not everywhere the same bed.

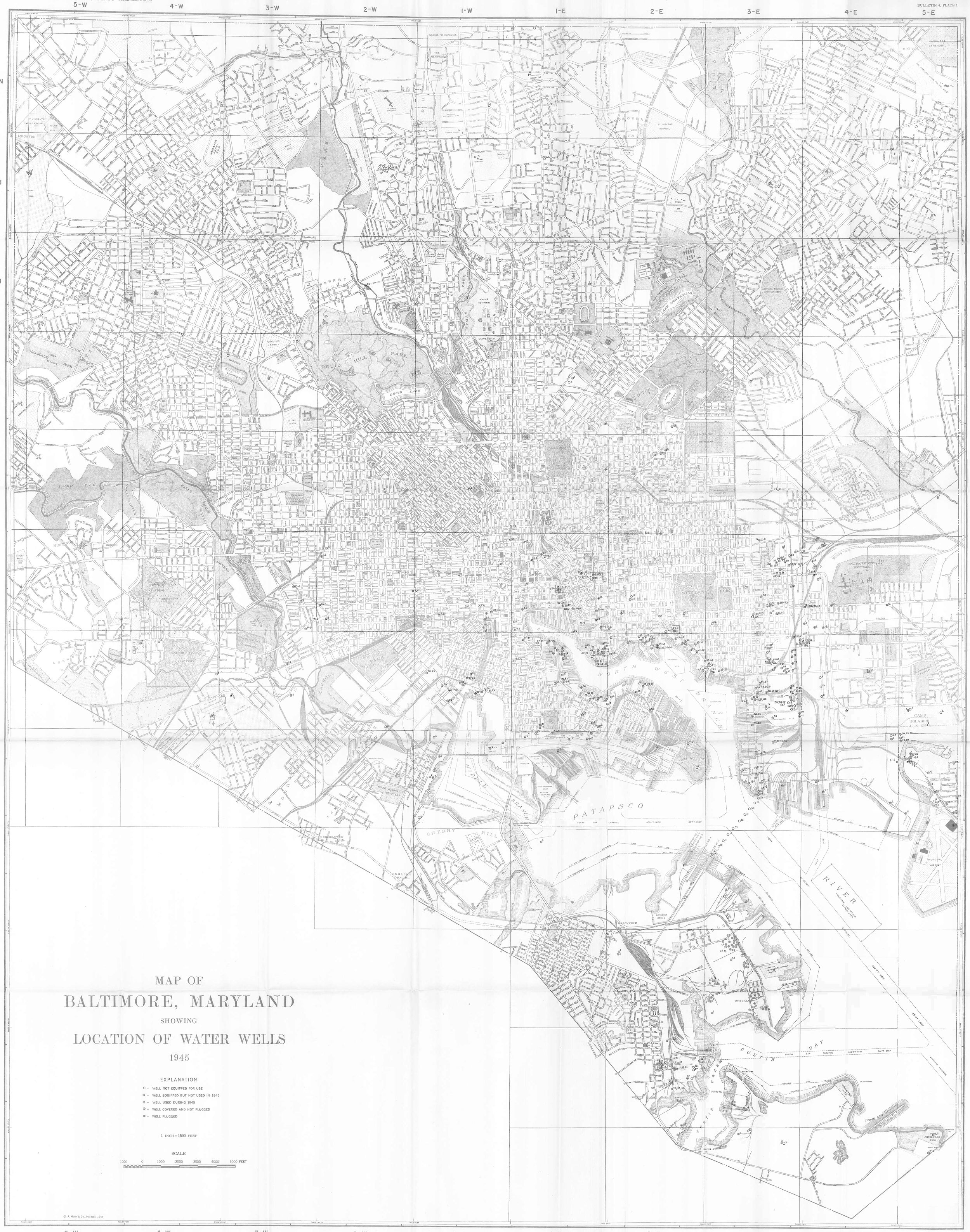
3 Strike and dip of bedding

○ 14 Diamond drill hole of U. S. Bureau of Mines Project 823. In the text the letters CB are suffixed to the numbers of holes drilled on this project.

Base from U. S. Geological Survey topographic maps.

A. Hoen & Co., Inc.

Geology by K. M. Waage assisted by H. P. Bangs, Jr.


5-W
4-W
3-W
2-W
1-W
1-E
2-E
3-E
4-E
5-E
5-N
4-N
3-N
2-N
1-N
1-S
2-S
3-S
4-S
5-S
6-S
7-S
MAP OF
BALTIMORE, MARYLAND
SHOWING
LOCATION OF WATER WELLS
1945
EXPLANATION
WELL NOT EQUIPPED FOR USE
WELL EQUIPPED BUT NOT USED IN 1945
WELL USED DURING 1945
WELL COVERED AND NOT PLUGGED
WELL PLUGGED
1 INCH = 1500 FEET
SCALE
1000 0 1000 2000 3000 4000 5000 FEET
© A. Hoen & Co., Inc.-Dec. 1946
PATAPSCO
RIVER
NORTH WEST BRANCH
MIDDLE BRANCH
CURTIS BAY
CURTIS CREEK
DRUID HILL PARK
DRUID LAKE
LAKE MONTEBELLO
LAKE CLIFTON
LEAKIN PARK
CARLINS PARK
HILLSDALE PARK
CARROLL PARK
LOUDON PARK CEMETERY
CATHEDRAL CEMETERY
MOUNT AUBURN CEMETERY
ST. JOSEPH'S HOSPITAL
JOHNS HOPKINS
UNIVERSITY
BALTIMORE CITY HOSPITALS
PATTERSON PARK
CAMP HOLABIRD U.S.-QM
MUNICIPAL AIRPORT
FORT ARMISTEAD PARK
BRIGHTON
HUNTINGTON RIDGE
NORTHWOOD
DORCHESTER
ENGLISH CONSUL
CHERRY HILL
MASONVILLE
BROOKLYN
BROOKLYN HEIGHTS
BRIDGEWATER
TWOMILE COVE
QUARANTINE PT.
FERRY BAR CHANNEL 400-FT. WIDE 35-FT. DEEP
CURTIS BAY CHANNEL 400-FT. WIDE 36-FT. DEEP