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OF
Kentucky

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GEOLOGY AND FORESTRY
OF
KENTUCKY

SERIES FIVE, BULLETIN TWO

J. E. BARTON,
Commissioner

W. R. JILLSON,
State Geologist


UNITED WE STAND DIVIDED WE FALL

FALLS OF THE CUMBERLAND
Photograph owned by the Cincinnati Southern Railway

THE GEOLOGY OF KENTUCKY

A Classified Compend of State Reports and Other Publications, With Critical Comment Based on Original Investigations

BY ARTHUR McQUISTON MILLER
Professor of Geology in the University of Kentucky

ILLUSTRATED WITH 114 PHOTOGRAPHS
MAPS AND DIAGRAMS

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PREFACE

The project of preparing a work on Kentucky geology, which should be comprehensive in its scope, had been in the mind of the writer for some time. A year's release from exacting executive duties, at the end of continuous service in the University of Kentucky for a quarter century, afforded the opportunity of putting this project into effect. During all this period as head of the Department of Geology in the institution, and part of the time as member of the staff of the State Geological Survey, he had been a student of Kentucky geology.

He has been encouraged in his undertaking by the reception accorded a work of similar scope for Tennessee by Professor J. M. Safford, who, a native of the same State (Ohio) as the writer, felt qualified for the task after a resident in the State of his adoption for a period of twenty-one years.

An examination of Part Five of the present work will show that the bibliography of Kentucky geology is varied and large. Much valuable information is contained in the reports, monographs and papers there listed, which is now difficult of access. In the case of the older publications many are out of print and copies are rare. A large number of these publications have been consulted and an attempt has been made to cull from them their important contributions to the geology of the State, and to give credit therefor.

It is the hope of the author that this work may prove acceptable to the practical man of affairs desiring information on Kentucky's natural resources. He has also had in mind in the preparation its possible use in the class room of the colleges and high schools of the State. To facilitate this latter use, the text has been given chapter groupings with paragraph sub-headings.

In the compilation of this work I am under many obligations to Professors August F. Foerste and Ray S. Bassler for valuable suggestions—none the less valuable though not in every instance adopted. In some cases these came too late to be incorporated in this edition. I owe much to my brother, Dr. Marion Mills Miller, whose experience in book editing enabled him to render much appreciated assistance, especially in the compilation of the index. This last, but by no means least, department of the book is calculated to render the work valuable as a dictionary of reference no less than as a treatise. It is designed to meet the wants not only of the practical man of affairs in search of information concerning the useful products of the State, but also of teachers and students of Kentucky geology and of geology in general, looking for illustrations of geological phenomena and principles.

The preparation of this index led to the discovery of a number of textual errors which had escaped previous proof reading, and which it was too late to correct in this edition. The following are the most important errors.

A. M. Miller

University of Kentucky
Lexington, Ky.

ERRATA

Page

16. Table: drop rule to include Cynthiana in Cincinnatian.
19. Picture legend: change "Woodford" to "Jessamine."
32. Line 1: change "*maria*" to "*parksensis;*" line 12: "upper" to "lower."
34. Lines 17, 18: change "*sericeous*" to "*sericeus*" and "Hall" to "Sowerby.
41. Line 4: change "*vetusta*" to "*richmondensis.*"
46. Fossil 6: change "*maria* (Billings)" to "*parkensis* Foerste."
54. Line 2: change "Britains" to "Britons;" line 5: "Cayagan" to "Cayugan;" table: drop rule to include Laurel under E. side of Arch.
59. Lines 10 and 13: transpose "Madison" and "Powell."
78. Line 9: change "Bands" to "Banks," and "page ——" to "page 308;" fourth line from bottom: change "Indian Oil Fields" to "Indian Old Fields."
95. Line 5: enclose "Pennsylvania" in parentheses.
105. Line 20: change "Franklin" to "Simpson."
110. Picture legend: change "Lithosthotion" to "Lithostrotion."
125. Fossil 20-21: change "*Composite*" to "*Composita.*"
144. Line 2: change "Western" to "Eastern."
147. Table: in Conemaugh, Eastern Field, read "stones (L. Cambridge and Ames)."
155. Close of middle paragraph: read "No. 1-B, Bell (Battery Rock); No. 2 (unnamed); No. 3, Ice House; No. 4, Curlew, and No. 5, Davis."
157. Table, first column, No. 9: change "High Split" to "High Splint."
165. Line under "Tertiary System": change "Brougnairt" to "Brongniart."
214. Line 3: read "plate 74 on page 188."
284. Table of Tradewater Coals: read "Dekoven, No. 6," and "Davis, No. 5."
291. Line 9: change "Livingston" to "Smithland."
356. Line 2: change "serolite" to "aerolite."

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ILLUSTRATIONS

[Plates not otherwise designated are photographs.]

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Geological books, being alphabetically listed by authors in the Bibliography (Part V) are not indexed here, nor are the minerals which are found only in Chapter XVIII on Mineralogy, since they are there arranged in alphabetical order.

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INTRODUCTION

Geology is a study of the physical and chemical composition of rocks, of the minerals, oils and gases which they contain, and of the availability of the latter for commercial purposes. It seeks the source of the materials forming rocks, investigates the methods of transportation of these materials from their source to their present location, and attempts to reconstruct the physical geography of the country while the deposition of rock was going on. It traces the development of seas and land areas, of hills and valleys, of those foldings of rocks which result in mountains, and of that long continued weathering which ends in the peneplain. It records the presence of remains of life, animal and plant, and seeks to reconstruct the faunas which were characteristic of particular seas or branches of seas, and attempts to follow the former migrations of these faunas from one area to another. It records the first evidence of plant life, and notes each recurrence of evidence of land conditions.

Kentucky offers a wonderful opportunity for such study. The sum of the maximum thicknesses of all strata found exposed within the limits of the State equals 9,300 feet; of this, 8,000 feet were deposited in the Palaeozoic era. It must have taken a long time to deposit this much rock. Evidently the history of rocks deposited in the sea begins long before that of the earliest rocks now exposed in Kentucky. Deep bore-holes, sunk in that area along the Kentucky River where now the oldest rocks exposed within the State are found, would probably reach the basal granite at a depth of several thousand feet.

All of the earlier history of the rocks of Kentucky is connected with marine life. The first remains of land plants actually found within the State occur in the Ohio Black shale, overlying 1,900 feet of exposed marine strata. Evidently land plant life had originated long before this, but no evidence of its former presence has been discovered so far within the limits of the State.

The presence of thick argillaceous deposits at the top of the Eden, in the upper part of the Maysville, and throughout the greater part of the Richmond division of the Cincinnatian series, especially in Southern and Southeastern Kentucky, suggests the proximity of land conditions at some point in that direction not far removed.

Although fern-like plants are found in Kentucky coals, and some occur in the Tar Springs member of the Chester, plants closely resembling modern forms are not known in Kentucky before the Cretaceous strata.

At different stages in its history the North American continent has been invaded by the sea from every direction. In Cambrian and Lower Ordovician times the chief embayments in the eastern half of the continent extended inward from the Mexican and St. Lawrence Gulfs, these two embayments sometimes connecting with each other. Later, during early Trenton and Richmond times, the Hudson Bay embayment became a prominent factor. From this time on, the history of the marine sediments of the eastern half of the North American continent is dominated by a succession of invasions of marine life from Gulf, Arctic and Atlantic seas, a more southern connection between the Central States and the Atlantic being sometimes established across areas in New Jersey.

The Trenton, Richmond and Niagaran include faunas of northern origin. The Utica, Lorraine, Rochester, Lockport, Helderbergian and Oriskany are typical examples of Atlantic invasions. Gulf invasions include such faunas as Brassfield, Osgood, Waldron and Louisville.

Owing to its central position Kentucky was sometimes affected by more than one invasion at the same time, this producing an intermingling of faunas—from the Gulf of Mexico and Hudson Bay in the Mohawkian, Richmondian, and Osgood, and from the Gulf of Mexico and the Atlantic in the Chazyan, Niagaran and Onondagan.

Numerous illustrations of the fossil life of the geologic past of Kentucky are offered in the following pages. The diagnostic fossils, lithological characters, and economic products of each geologic group of rocks are fully discussed. In preparing this treatise, Professor Miller has performed a labor of love, following twenty-seven years of service to the State as Professor of Geology in its University, and as member of its Geological Surveys. The volume indicates the great progress of recent years in knowledge of geology in general and of Kentucky geology in particular, in much of which he took a prominent part. And in making known the economic resources of Kentucky he has rendered valuable service not only to its citizens, but to a large and increasing number of persons throughout the country who are interested in the subject.

AUGUST F. FOERSTE

PART ONE

Stratigraphic Geology

CHAPTER I

GENERAL SURVEY

Present Surface of Kentucky; Its Age and History. —Kentucky is a part of a very old land surface. That portion of it lying east of the Tennessee River came up out of the sea virtually for the last time at the close of the period once known as Lower Carboniferous, but now called Mississippian. Since then it has oscillated considerably in level, having been worn down nearly to sea level by the beginning of the coal-making period for the eastern United States. During this period, which is called Pennsylvanian, it underwent aggradation by river sedimentation and wash from neighboring higher lands. There may also have been brief incursions of a shallow sea.

Since the close of Pennsylvanian time, commonly estimated at from 10,000,000 to 20,000,000 years ago—according to J. Barrel (1917) from 215,000,000 to 285,000,000 years ago—the surface of Kentucky has been exposed to continued action of the weathering and denuding agencies, with the result that it has become overlaid with a deep covering of residual soil. This is thicker in the limestone regions, where the rocks decompose with great rapidity, causing the soil material to form more rapidly than it can be removed by rain and stream erosion; and thinner in the sandstone regions, where the rock is more resistant to weathering, and where the products of disintegration tend to wash away about as quickly as they form.

That portion of Kentucky which lies west of the Tennessee River, or the "Purchase Region" as it is commonly called, from the nature of its acquisition by the State (see page 206), was not finally raised above sea level until late geologic time (Tertiary period), but remained for at least a portion of post-Mississippian time (late Cretaceous and Tertiary periods) as the head of an embayment extending northward from an ancient Gulf of Mexico, and received estuarine deposits.

Very little of the State felt the effects of glaciation—only a narrow strip along the Ohio River from Campbell to Trimble Counties having deposits ascribed to such agency. These consist of an imperfectly consolidated dust deposit called *loess,* with which are mingled pebbles and occasional boulders of northern origin. Glacial outwash deposits are also recognizable along the Ohio River from Campbell to Jefferson Counties.

CHARACTER OF THE BED ROCK.—The rocks of Kentucky belong to the stratified and igneous series. The igneous rocks are of very limited extent in areal outcrop. They are of the very basic variety known as *peridotite,* which constitutes the dikes of Elliott and Crittenden Counties —the former in the northeastern and the latter in the southwestern portion of the State.

The stratified rocks consist of the usual sedimentary sandstones, shales and limestones which make up the consolidated members of that series, along with some that are unconsolidated.

The sandstones, or the siliceous rocks, vary in color and texture. Classified according to their *texture,* they may be *fine grained*—such as *freestones* and *siliceous mudstones,* or *coarse grained*—such as *grits and quartz-pebble-conglomerates.* The latter are known as *hailstone grits, pudding stones,* or simply as *conglomerates.*

The shales are the argillaceous rocks which show a marked cleavage parallel to the bedding. These vary in color from light to dark, the former often being called soapstones and the latter slates. The dark color is due to incorporated carbonaceous or bituminous matter. The term "slate" is inappropriately applied, as the rocks so called have never been metamorphosed, and they lack the hardness and durability of true slates.

The limestones are those rocks composed largely of carbonate of lime. They exist in great variety, and may be classified in a number of ways: In accordance with *composition* they are pure and impure, magnesian, ferruginous, siliceous, etc. As regards *color,* they are light, dark, blue, gray and yellow limestones. According to *texture,* they are fine grained, coarse grained, crystalline, non-crystalline, etc. In accordance with their *chief fossil content,* we have crinoidal, coral, bryozoal, brachiopodal and molluscan limestones. Chert is an impure flint which frequently accompanies limestone in the form of nodules and layers, or has resulted from the decay of siliceous limestones and is then found in the soil.

Besides the foregoing older and more consolidated sediments there are the imperfectly consolidated forms known as sands, gravels, clays, loams, silts and loess. Loess is a fine grained buff colored clay-like deposit, the origin of which is in dispute. It is generally considered to owe its deposition in its present position mainly to the action of wind.

Origin of Present Topography.—The variety of topography in the State is due more to the different degrees of resistance which the various rock formations offer to the eroding agents than to stages of development that have been reached in the erosion cycle; though certain physiographic features may be best explained as an inheritance from past base-level conditions.

Influence of Structure on Areal Geology.—The present areal geology of Kentucky is largely controlled by a broad low arch, the *Cincinnati Anticline,* or, as some prefer to call it because of its great extent, the *Cincinnati "Geanticline."* This arch stretches north and south across the central portion of the State, and rises to a culminating point in Jessamine County, giving to this portion of it the name *Jessamine Dome.* The average dips of the strata on the flanks of this broad earth flexure are quite gentle, ranging from ten to fifteen feet per mile near the crest to twenty-five to fifty, or even seventy-five feet, further down the slopes; and hence they are not detected by the eye. However, this arching and doming of the strata have so invited erosion that nearly complete truncation has taken place, exposing strata on the surface of the dome which are the oldest in the State, because they were formed in the sea before their bowing up, and so became deeply buried underneath later formed sediments.

Westward the strata sink in a broad syncline to their lowest level underneath the Kentucky-Indiana-Illinois Coal Field, the axis of the syncline extending from northeast to southwest near the middle of this. An examination of a geological map, showing the concentric arrangement of the formations from Champlainian to Pennsylvanian inclusive in the order of their age from the Jessamine Dome outward as a center, strongly suggests that the Pennsylvanian once covered all or nearly all of the State; that this and the other formations back to the Champlainian first wore through on the Jessamine Dome to the next one below, and then had their series of areal outcrop retreat outward in enlarging circles like fairy rings in the grass. The outer circle finally became broken into two separate areas or patches—the Eastern and Western Coal Fields.

Table of Geological Formations

Groups (Eras)	*Systems (Periods)*
Cenozoic	Quaternary Tertiary
Mesozic	Cretaceous Comanchian Jurassic Triassic
Paleozoic	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian
Proterozoic	Keweenawan Animikean
Archeozoic	Algoman Timiskamian Laurentian Loganian

TABLE OF GEOLOGICAL FORMATIONS FOR KENTUCKY
With Their Thicknesses, Characteristic Fossils and Economic Products

Group	System	Series	Stage	Sub-Stage	Character of Deposits and Economic Products	Characteristic Fossils	Thickness in feet
			Recent	Alluvium	Loam, sand, gravel.		0–200
Cenozoic	Quaternary		Pleistocene		Brown loam and loess in Jackson Purchase and along lower Ohio R. Glacial outwash sands, clays and gravels and some loess farther north along the river. True glacial till and boulders near the river from Trimble to Campbell Counties. Foundry sand (loess). Brick clays.	Bones and teeth of Mastodon, Mammoth, Tapir and other mammals now extinct (at least in this region).	0–75
				Columbia—in the Purchase.	Gravel. Road material.		0–10
	Tertiary.		Pliocene.	Lafayette. (Irvine?)	Ferruginous gravel, sand, in the Purchase. Gravel, sand and clay as high level river deposits elsewhere. Road materials, Paducah gravels:—Tenn.-Cumb. R.—Iron ore (Limonite). Pottery clay.		0–45
			DISCONFORMITY				
			Eocene. In the Purchase.	LaGrange.	Sand and clay. Pottery clay. Lignite. Well water.	Leaf impressions of oak, willow, walnut, etc.; some of them of extinct species.	430
				Porters Creek.	Dark clays and green sand. Well water.	Shells of mollusks—species mostly extinct: Crassatella productus, Venericardia alticostata, Turritella mortoni.	100–160
Mesozoic.	Cretaceous.			Ripley. In the Purchase.	Variegated sands with intercalated dark clays. Pottery clay.	Leaf impressions.	200–400
		PRONOUNCED DISCONFORMITY					
	Comanchian.				Wanting in Kentucky.		
	Jurassic.				Wanting in Kentucky.		
	Triassic.						
	Permian.						

Table of Geological Formations for Kentucky—Continued

Group	System	Series	Stage	Sub-Stage	Character of Deposits and Economic Products	Characteristic Fossils	Thickness in feet
Paleozoic.	Pennsylvanian.	Monongahela, wanting in E. Ky. Present in Union Co., W. Ky.			Shale and sandstone. Coal from Geigers Lake seam, 3½ feet thick.	Land plant remains.	130
		Conemaugh. (Mc Leansboro of the W. Field.) Greatest exposure in W. Field: Limited to Lawrence and Boyd Cos. in E. Field.			Red and purple shales, sandstones, thin limestones (L. Cambridge and Ames), thin coal seams; Nos. 9 to 12 of E. Field—Nos. 13 to 18 in W. Field.	Land plant remains. Marine fossils in the limestones.	400–1000
				Mahoning in E. Field, Anvil Rock in Western.	Sandstone.		50–100
		Allegheny. (Carbondale of the W. Field).			Mostly shales. **In E. Field**, coal from about 7 seams of workable thickness: Old Survey Nos. 5-9. Iron ore—"red kidney"—between coals 7 and 8; "yellow kidney" between coals 6 and 7; and "ferriferous limestone" between coals 5 and 6. **In W. Field**, coal from 8 workable seams–Owen's Nos. 5 to 12, with Nos. 9 and 11—about 4 feet thick— most persistent and valuable. Iron mining once attempted on a black band ore just above coal 9.	Land plant remains. Marine fossils in the limestones.	100–400
		Pottsville.		Homewood in E. Field, Curlew in Western.	Sandstone.		25–100
			Breathitt in E. Field		Mainly shales. Coal from four seams. Old Survey Nos. 1-4 (Lily to Dean); mostly 3-4 feet thick. Elkhorn seam reaches 9 feet in thickness.	Land plant remains.	500
				Corbin in E. Field, Caseyville in Western. Sharon? of Pa.	Sandstone, usually conglomeritic. Cliff forming.		0–150
					Mainly shales. Coal from one seam—Barren Fk. 3-4 feet.	Land plant remains.	300–600
				Rockcastle in S. E. Ky.	Sandstone, usually conglomeritic. Cliff forming.		0–150
			Lee	Beattyville in E. Ky.	Mainly shales; S. S. Coal from two seams 3 to 4 feet thick—Beaver Creek. (Beattyville and Hudson.) Bituminous S.S. of Carter Co; and some of that of W. Ky. Beaver, Horton, Pike and Salt oil sands of Floyd and adjacent counties. Wages, Jones and Epperson	Land plant remains.	40–150

Table of Geological Formations for Kentucky—Continued

Group	System	Series	Stage	Sub-Stage	Character of Deposits and Economic Products	Characteristic Fossils	Thickness in feet
Pal-eozoic		Pottsville.	Lee.	Beattyville.	oil sands of Knox County, (Some of these oil sands may be higher in the Lee Formation.) At base. Fire clay of Carter Co. Limonite ore, especially the Red River iron ore of Estill and Powell Cos.		
		PRONOUNCED DISCONFORMITY					
					Traversed in Crittenden and Livingston Cos. by fluospar veins carrying some galena and sphalerite:—also by peridotite dikes.		
	Mis-sissip-pian.	Chester (Kaskaskia.)	Birdsville in W. Ky. Pennington represents upper part in S. E. Ky.	Clore (Buffalo Wallow).	Shale l. s., and s. s. macadam amd Agr. lime.		150–200
				Palestine.	Sandstone.		75
				Menard.	Limestone, Macadam, Agr. lime.	Sulcapinna missouriensis.	50–100
				Tar Springs.	Sandstone. Bituminous s. s.	Sigillaria Lepidodendron Cardiopteris.	30–50
				Glen Dean (Sloans Valley).	Limestone, Macadam Agr. lime.	Prismonora serulata, Archimedes laxus Pentremites godoni	40–80
				Hardinsburg.	Sandstone		30–40
				Golconda.	Limestone, s. s. and shale.	Pterotocrinus capitalis, Pentremites obesus.	30–90
				Cypress (Big Clifty, Garfield.)	Sandstone, Bituminous s. s. quarried in W. Ky.		40–85
		Mammoth Cave. Best developed in W. Ky. (Newman in part in E. Ky.)	Ste. Genevieve.	Gasper (Tribune).	Limestone (oolitic). Building stone (Bowling Green), Agr. lime.	Talarocrinus patei, Pentremites godoni, P. pyriformis.	0–60
				Bethel.	Sandstone.		
				O'Hara.	Limestone, Macadam Agr. lime.		
				Rosiclare.	Sandstone.	Platycrinus huntsvillae, Lithostrotion hermodites.	0–245
				Fredonia.	Limestone (oolitic). Building stone, Agr. lime.	Lithostrotion hermodites.	
			SLIGHT DISCONFORMITY				
			St. Louis	St. Louis	Limestone. Building stone, Macadam, R. R. ballast, Agr. lime.	Lithostrotion canadense and proliferum.	0–500
		DISCONFORMITY IN EAST KENTUCKY					
Paleo-zoic.		Waverly.	Warsaw.	Spergen. (Salem), E. of Cin. Arch.	Limestone. Crinoidal. Macadam. Agr. lime.	Zaphrentis elliptica, Pentremites conoideus.	0–20

Table of Geological Formations for Kentucky—Continued

Group	System	Series	Stage	Sub-Stage	Character of Deposits and Economic Products	Characteristic Fossils	Thickness in feet
	Mis-sissip-pian.		Warsaw. Mainly on summit and W. side of Cin. Arch.	Harrodsburg, (Ind.)	Limestone (siliceous). W. of Cin. Arch. Impure, yellow; E. of Cin. Arch. in Estill, Powell, and Menefee Cos.	Spirifer lateralis, Productus magnus.	0–80
		Waverly (Knob-stone).	Logan.	Vinton N. E. Ky. Allens-ville N. E. Ky. Byer N. E. Ky. / Holts-claw. N. W. Ky. Rose-wood N. W. Ky.	Sandstone and shale. Building stones as far south as Rockcastle Co. on E. side of Cin. Arch. "Big Injun" oil sand at top under cover in N. E. Ky.		160–530
				Berne N. E. Ky. Black Hand N. E. Ky. / Ken-wood N. W. Ky.			
		Outcrops in a semi-circle from Vanceburg to Louis-ville and in S. Central Ky.	Cuyahoga.	New Provi-dence, Ind: Raccoon of Ohio.	Shale, To the N. E. it contains sandstone (Lewis and Rowan County building stone). To the south and west it contains limestones. One of these is the Beaver oil sand of Wayne Co. Phosphatic concretions at the base.	Cyathaxonia cyn-odon. Taonurus cauda-galli. Frag-ments of large crinoid stems.	100–200
				Sunbury. South of C. & O. R. R. in its E. outcrop it rests directly on the Ohio.	Black shale. Oil formerly distilled from this shale at Vanceburg.	Lingula melie and Ctenacanthus fish remains.	5–10
			Kinder-hook.	Berea. E. side of Cin. Arch. N. of C. & O. R. R.	Sandstone, usually strongly ripple marked. Fine building stone near the Ohio R. in Lewis Co. The Berea Grit of the oil well driller in Ohio, Pa. and N. E. Ky. where struck under cover.		0–22
				MINOR DISCONFORMITY			
Paleo-zoic.				Bedford, East side of Cin. Arch. N. of C. & O. R. R.	Shale.		0–95
	DISCONFORMITY						
		U. Devon-ian.	Genesee.	Ohio. (New Albany and Chattanooga in part.) Outcrops in a semicircle from Vanceburg to Louisville and in S. Cen. Ky. in patches on summit of Arch.	Black shale. Bituminous, and probably the original source of the oil and gas in the formations just above or below. The horizon of the gas in the Meade County Field. The contained pyrites the source, as the result of oxidation, of the sulphur and the iron in the spring water of reputed medicinal value found along its outcrop.	Lingula spatulata, Dinichthys, Silicified wood. (Dadoxylon, a Cordiates genus.)	25–245

Table of Geological Formations for Kentucky—Continued

Group	System	Series	Stage	Sub-Stage	Character of Deposits and Economic Products	Characteristic Fossils	Thickness in feet
					DISCONFORMITY		
	Devonian		Hamilton.	Delaware (Sellersburg) Only on W. side of Cin. Arch.	Limestone: Divided in Jefferson Co. into two members. Beechwood above and Silver Creek below. The latter the "cement rock" quarried and calcined at Louisville.	Spirifer granulosus, Tropidoleptus carinatus. Dolatocrinus tuberculatus and many corals.	0–24
		M. Devonian.	Onondaga.	Columbus. (Jeffersonville on W. side of Cin. Arch).	Limestone: magnesian, cherty and frequently porous—the oil sand of the Estill, Ragland and Campton Pools: probably that of the Scottsville and Glasgow; and the gas sand of the Menefee Field. By replacement it furnished the oolitic carbonate iron ore of the Preston Ore Banks of Bath Co.	Spirifer acuminatus, Spirifer gregarius, Stropheodonta hemispherica and most of the corals constituting the coral reef at the Falls of the Ohio at Louisville.	0–25
					PRONOUNCED DISCONFORMITY		
Paleozoic.	Silurian.	Niagaran.	Only on W. side of Cin. Arch.	Louisville.	Limestone: magnesian. Building stone.	Strombodes pentagonus, Caryocrinus, indianensis, Conchidium knappi Pentamerus oblongus.	0–100
					MINOR DISCONFORMITY.		
			Alger (E. of Cin. Arch.) Osgood (W. of Arch.)	Waldron.	Shale.		0–15
				Laurel.	Limestone: dolomitic, Building stone.	Whitfieldella nitida.	0–40
				Estill (E. of Arch.)	Shale.	Chonetes venustus.	0–100
				Waco E. of Arch.)	Limestone: magnesian.	Favosites gothlandica.	0–10
			Indian Fields (Only on E. side of Cin. Arch.)	Lulbegrud, E. of Arch.	Shale.		0–15
				Oldham.	Limestone: magnesian.	Strictlandina norwoodi.	0–15
				Plum Cr.	Shale.		0–5
					MINOR DISCONFORMITY		
		Oswegan.	Medina (Cataract).	Brassfield (Ky. and O. Clinton).	Limestone: magnesian. Oolitic hematite (flaxseed iron ore) of Bath Co. Possibly the oil sand of Allen Co.	Fluted crinoid stem plates. Cyathophyllum calyculum Whitfieldella subquadrata.	0–20
					MINOR DISCONFORMITY		
	Ordovician.	Cincinnatian.	Richmond.	Saluda.	Sandstone and clayey limestone.	Columnaria, Calapoecia, Tetradium.	0–40
				Liberty.	Limestone, Macadam, Agr. lime.	Beatricia, Streptelasma rusticum, Hebertella insculpta.	50

Table of Geological Formations for Kentucky—Continued

Group	System	Series	Stage	Sub-Stage	Character of Deposits and Economic Products	Characteristic Fossils	Thickness in feet
		Cincinnatian. In N. Cen. Ky on Flanks of Jessamine Dome of Cin. Arch., constituting Outer Blue Grass Region.	Richmond. (Red Medina of Canada. N. Y. & S. along Apalachians.)	Waynesville.	Limestone, Macadam, Agr. lime.	Cyphotrypa clarksvillensis, Catazyga headi, Dalmanella jugosa, Strophomena planumbona.	40–50
				Arnheim.	Limestone, Macadam, Agr. lime.	Dinorthis carleyi, Leptaena rhomboidalis.	50–100
			MINOR DISCONFORMITY				
			Maysville.	Mt. Auburn.	Limestone, Macadam, Agr. lime.	Platystrophia lynx (globose form).	20
				Corryville.	Limestone, Macadam, Agr. lime.		60
	Ordovician.			Bellevue.	Limestone, Macadam, Agr. lime.		20
Paleozoic.				Fairmount.	Limestone, Macadam, Agr. lime.		80
				Mt. Hope.	Limestone, Macadam, Agr. lime.	Strophomena maysvillensis.	50
			Eden.	Garrard (Paint Lick).	Sandstone (siliceous mudstone of Owen).		60
				Million.	Shale, with some limestone.	Plectambonites rugosus, Ectenocrinus simplex.	160–200
				Fulton (Utica).	Shale.	Triarthus becki.	5
					Limestone.	Trinucleus concentricus.	10
			MINOR DISCONFORMITY				
			Cynthiana	Point Pleasant.	Limestone, Macadam, Agr. lime.	Cyclonema varicosum, Hebertella maria, Allonychia flanaganensis, Eridotrypa briareus.	40-100
				Greendale.	Limestone, Macadam, Agr. lime.		
		DISCONFORMITY					
		Champlainian.	Lexington (Trenton).	Perryville. Almost exclusively on W. side of Axis of Cin. Arch.	Limestone. Divided in descending order into three beds: a more shaly (Cornishville), a compact fine grained	Stromatocerium in a reef. Isochilina jonesi, Bellerophon troosti.	25

Table of Geological Formations for Kentucky—Continued

Group	System	Series	Stage	Sub-Stage	Character of Deposits and Economic Products		Characteristic Fossils	Thickness in feet
		Cham-plainian.		Perryville.	"bird's-eye" limestone (Salvisa), and a gastropod, shell limestone (Faulconer). Macadam, building stone, Agr. lime.	Traversed by veins filled mostly with barite, but with some lead and zinc ore.		
			Lexington. (Trenton.) On summit of Jessamine Dome of Cin. Arch. in Central Ky.	Bigby.	Limestone: in descending order in three beds; cross bedded granular-phosphatic (Woodburn), Siliceous-bouldery (Brannon) and a grayish-crystalline (Benson). Phosphate rock, Foundation stone, Macadam, Agr. lime, Lowest oil horizon of Cumberland Co.		Columnaria halli, Cyclora minuta, Brachiospongia digitata, Pattersonia aurita, Stromatocerium reef, Strophomena vicina, Dinorthis ulrichi Herbertella frankfortensis.	125
Paleo-zoic.	Ordo-vician			Wilmore.	Limestone, Macadam, Foundation stone, Agr. lime.		Dalmanella bassleri, Prasopora simulatrix.	80
				Hermitage.	Limestone, fine grained, siliceous and shaly.		Heterorthis clytie, Modiolodon oviformis.	30
				Curdsville.	Limestone, massive cherty and fossiliferous. Macadam, Agr. lime.		Dinorthis pectinella, Plectambonites sericeus.	10
			PRONOUNCED DISCONFORMITY					
			Highbridge (Stones River, Black River and Chazy.)	Tyrone.	Limestone, a fine grained, non crystalline, white or dove colored stone, marked on fracture surfaces by specks of calcite—"bird's-eye limestone." Fine building stone, Macadam, R. R. ballast, Agr. lime.	Traversed by veins filled mostly with calcite, one of these—The Chinn—mined.	Heliocotoma verticalis, Strophomena incurvata.	90
			In gorges of Ky. R. and Main tributaries where they trench the Jessamine Dome.	Oregon.	Limestone, magnesian. Fine building stone. (Ky. R. marble.)		Non fossiliferous.	15-25
Paleo. zoic.	Ordo-vician	Cham-plainian.		Camp Nelson.	Limestone, massive fine grained, mottled with magnesian streaks. Building stone, Macadam, Agr. lime. Wells passing below this reach the Calciferous sandrock at between 200 and 300 feet. It yields a sulphurous brine.		Fossils rare—a few large Endocerata and some Maclurias.	285

CHAPTER II

ORDOVICIAN SYSTEM

The stratigraphic series in the State begins in the Ordovician (Lapworth, 1879)-Lower Silurian of some authors. As has been mentioned, the oldest rock exposed within its boundaries are those on the summit of the Jessamine Dome. The very lowest layers are those lying at low water on the Kentucky River at Camp Nelson, where the river trenches the crest of the Jessamine Dome. These are not, however, the lowest layers of the Ordovician, as deep drilling elsewhere in the State shows that the Canadian—the bottom member of this formation—is still beneath.

Classification of the Ordovician (Lower Silurian) in Kentucky

Series	*Stage*	*Sub-stage*	*Thickness in Feet*
Cincinnatian	Richmond	Saluda Liberty Waynesville Arnheim	0—40 50 40—50 50—100
	Maysville	Mt. Auburn Corryville Bellevue Fairmount Mt. Hope	20 60 20 80 50
	Eden	Garrard (Paint Lick) Million Fulton	60 160—200 5
Champlainian	Cynthiana	Point Pleasant Greendale	40—90
	Lexington (Trenton)	Perryville Bigby Jessamine (Wilmore) Hermitage Curdsville	0—25 125 80 30 10
	Highbridge (Stone's River Black River Chazy)	Tyrone Oregon Camp Nelson	90 15—25 285

CHAMPLAINIAN SERIES

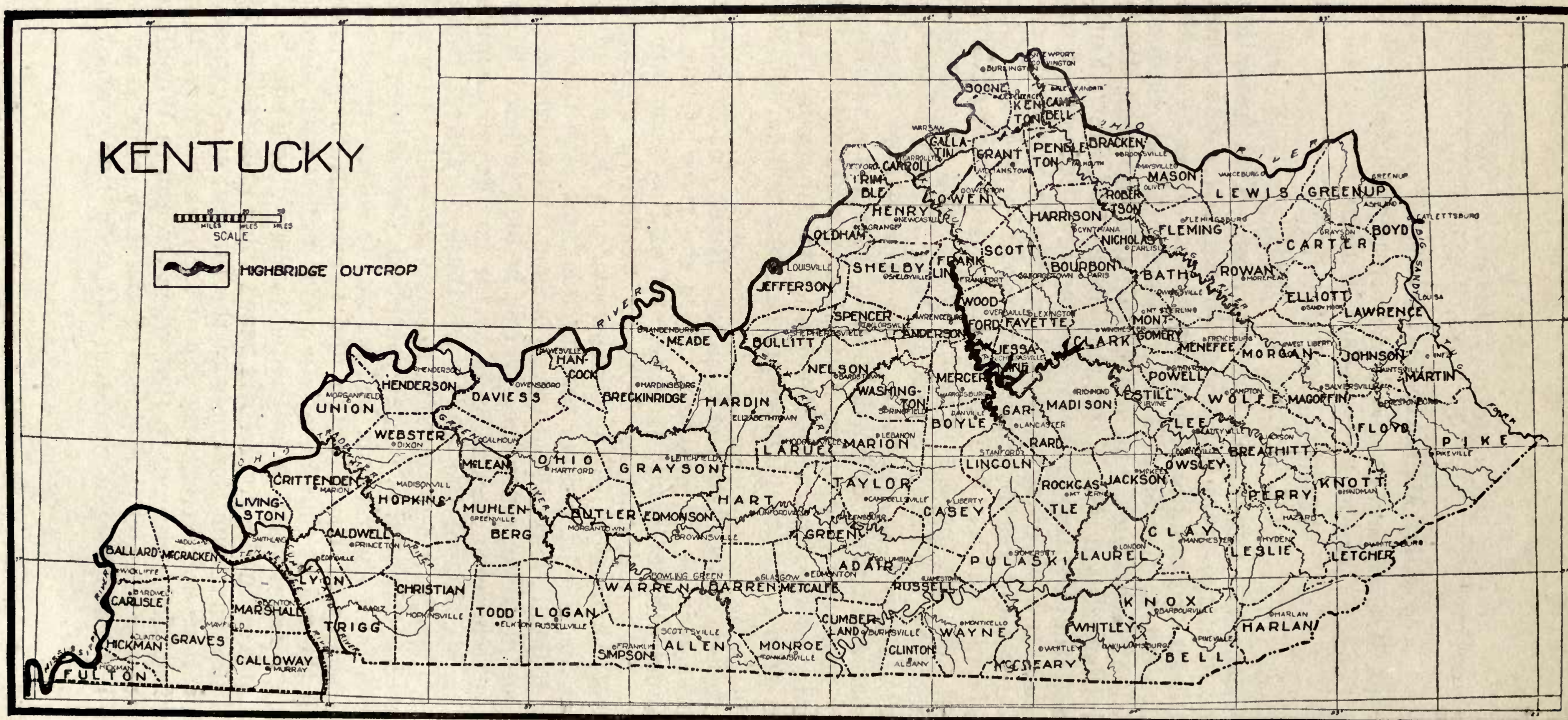
(J. M. Clark and Charles Schuchert, 1899; redefined by Charles Schuchert in 1915)

HIGHBRIDGE STAGE

(M. R. Campbell, 1898)

Character and Areal Distribution.—This formation takes its name from the bridge by which the Cincinnati Southern crosses the Kentucky River. It is about the equivalent of the Stone's River Group (J. M. Safford, 1851) of Tennessee, and the Chazy (E. Emmons, 1842) and Black River (L. Vanuxem, 1842), of New York. Where the Kentucky River cuts across the axis of the Cincinnati arch, about 400 feet of this formation is exposed without reaching the bottom of the series. Judging from what has been revealed by deep well drilling, about 200 feet more of this formation may be expected to lie below the lowest layers at Camp Nelson before the "Calciferous" is reached. The Highbridge consists almost exclusively of thick-bedded, compact limestones very resistant to erosion, so that where exposed in the vicinity of the Kentucky River and its tributaries it has been trenched into picturesque canyons 300 to 400 feet deep.

By one descending the Kentucky River this formation is first seen at Boonesboro. Here the river strikes the Kentucky River Fault (see account of this structure on page 234) and, turning from its prevailing northwest course, is diverted to the southwest for a distance of 41 miles, in which the river crosses the fault nine times before it finally leaves it at Camp Nelson. Throughout this serpentine divergence the river is bedded in hard Highbridge wherever its course is on the northwest (relative upthrow) side of the fault. On these northwest meanders, therefore, a gorge with precipitous walls is formed. Where the course is on the southeast (downthrow) side of the fault the river is bedded in the softer limestones and shales of the Trenton and Cincinnati formations; with the result that here is a wider valley with sloping sides, often wooded or cultivated to the water's edge. At Camp Nelson the river cliffs reach their greatest height, and the maximum thickness of the formation is exposed. From here downstream the dip of the rock is steeper than the fall of the stream, so that when Oregon in Woodford County is reached (a distance of about 16 miles in an air line) the magnesian limestone (Oregon Bed), which at

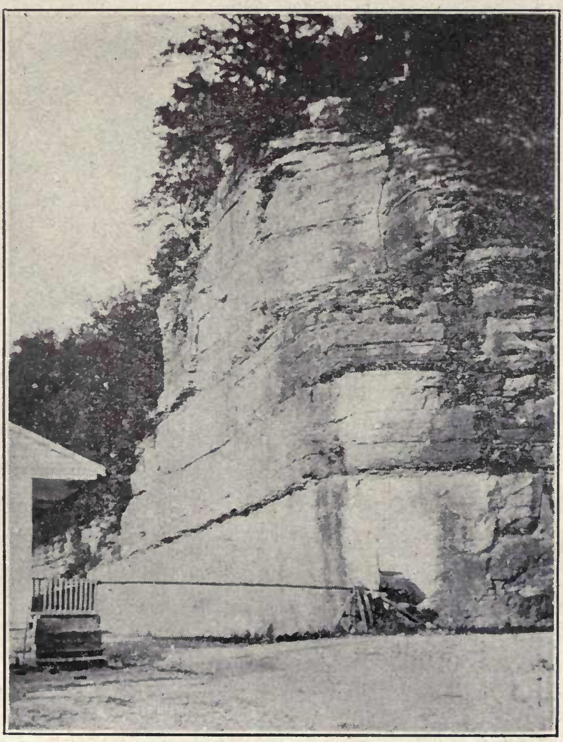


1. LOCATION OF HIGHBRIDGE LIMESTONE OUTCROPS

Camp Nelson is 285 feet above the river, is here at water level. This indicates a north-45-degree-west dip of eighteen feet per mile. From here onward the course of the river is more northerly, and, the dip of the rocks not being so steep in this direction, the river has only sunk to the top of the formation at the mouth of Steele Branch, eleven miles below Frankfort and about thirty miles in an air line from Oregon. This would give in this distance a drop of only 100 feet, or an average of about 3.3 feet per mile.

Subdivisions.—The Highbridge may be divided in ascending order into three members—the Camp Nelson, Oregon and Tyrone.

The *Camp Nelson* (A. M. Miller, 1905) is the division William Linney called the Chazy (Emmons, 1842), correlating it with that formation in New York. The layers of this bed are for the most part quite thick. They are marked on their surfaces by "sea weed" like designs



2. CAMP NELSON BED, SHOWING CHARACTERISTIC THICK BEDDING
Brooklyn Bridge, Woodford County

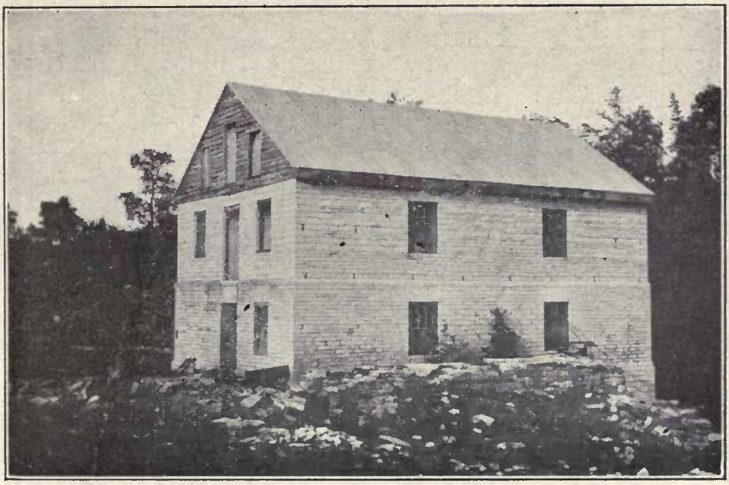
which, weathering into relief on the bedding planes, resemble the tracks of crows. On the joint plane surfaces these markings are apt by weathering to give a honeycomb appearance to the exposures, and a mottled look to freshly fractured surfaces. They are more magnesian than the rest of the rock, and probably algal in origin—more directly so than the material of the limestone itself, which may have been originally a secretion of marine algae. Fossils are rare in the Camp Nelson. They consist mainly of occasional casts of the gastropod genus *Macluria* and of the cephalopod genus *Endoceras*.

The *Oregon Bed* (A. M. Miller, 1905) is a magnesian limestone. It is the bed described as the "Kentucky

3. OREGON BED
Quarry near Clay's Ferry, Fayette County. Photograph by A. M. Miller

River marble" by William Linney in his various reports for the Shaler Survey. It was formerly prized in Kentucky as a material for monuments and pillars. Daniel Boone's monument in the Frankfort Cemetery, Henry Clay's monument in the Lexington Cemetery, and the columns of the old State House at Frankfort are built of this stone. It runs as high in carbonate of magnesia as 33 per cent. This percentage, associated with a cream color in the stone, was reached in the layers quarried from near Grimes Mill on Boone's Creek in Fayette County. According to report, the Grimes Mill Quarry was the source of most of the material used in the structures above referred to. The rock is non-fossiliferous.

The *Tyrone* (A. M. Miller, 1905) is the "Birdseye" limestone of Sidney Lyon, 1861. It appears also to be about the equivalent of the Lowville (Clark and Schuchert, 1899) of New York. It is a fine grained, compact, light-colored stone, weathering toward white. It has conchoidal fracture, and the fractured surfaces exhibit facets of calcite, which sparkle like the eyes of birds; hence the lithologic name, "birdseye limestone." These facets appear to be sections of calcitic fillings of minute tubes penetrating the rock. The tubes were probably the molds of seaweed stems, and hence it is likely that these limestones too were algal. This stone is also sometimes called "Kentucky marble." It furnishes an excellent building stone. From it many old distilleries and mills along the Ken-



4. MORTON'S MILL, BOONE'S CREEK, FAYETTE COUNTY
A structure with walls built of Tyrone limestone. Photograph by A. M. Miller

tucky River, in the stretch where it is exposed, were constructed, as well as many residences and public structures in Frankfort.

The Tyrone is not very fossiliferous. As most characteristic may be mentioned the gastropod *Helicotoma verticalis,* and the brachiopods *Strophomena incurvata,* and *Rafininesquina minnesotensis.* These fossils would indicate a Black River age for the formation.

5. LOCATION OF LEXINGTON AND HIGHBRIDGE OUTCROPS

LEXINGTON STAGE

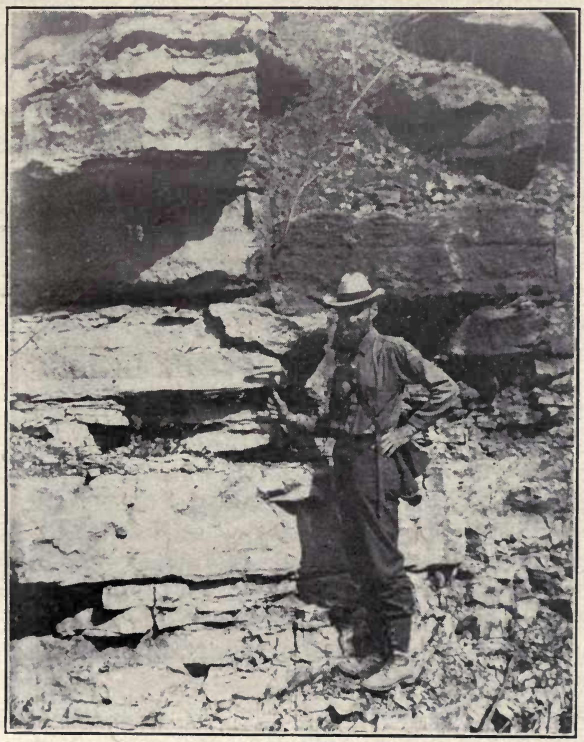
(M. R. Campbell, 1890)

This is the formation which earlier writers on Kentucky geology, e. g., William Linney, called the *Trenton,* correlating it with that formation in New York originally named and described by Vanuxem in 1840.

Linney was approximately correct in his determination. The formation closely corresponds both lithologically and in fossils with that known as Trenton in New York.

E. O. Ulrich would include in this division the next overlying formation—the *Cynthiana.* The writer, however, follows previous Ohio and Kentucky geological survey usage in placing the Cynthiana in the Cincinnatian.

CHARACTER AND AREAL DISTRIBUTION.—The Lexington is for the most part a grayish, granular to crystalline



6. TRENTON (CURDSVILLE) LIMESTONE RESTING DISCONFORMABLY ON TYRONE LIMESTONE NEAR FRANKFORT

Hammer is held by author at line of contact limestone contrasting strongly with the underlying light-colored compact Tyrone of the Highbridge series, on which, in every exposure in Kentucky, it rests disconformably. Sometimes the basal layer of the formation contains fragments of Tyrone incorporated in the general grayish mass, constituting a contact breccia. Deep drilling in other parts of Kentucky and in neighboring States confirms the evidence yielded by natural exposures. Everywhere there is this strong contrast in texture and color in passing from one formation to the other. Yet the two beds are perfectly accordant in dip, and are often so completely cemented together that there is no tendency for a plane of cleavage to develop between them. There is evidence, from the presence of ripple marks and sun cracks in the Tyrone, that shallow water and even subaerial conditions prevailed during a portion of the time in which it was being deposited. The evidence, however, is inconclusive that the disconformity here represented marks a period of prolonged subaerial denudation between Tyrone (Lowville) and Trenton time.

The Lexington limestone outcrop forms two main areas in North Central Kentucky—one in the Kentucky and the other in the South Fork of the Licking drainage. These are separated by a narrow strip of Cynthiana along the watershed which forms the boundary between Bourbon and Fayette Counties. The Kentucky River area—including the inlier of Highbridge and outliers of Cincinnatian—has an extent of 875 square miles, and the South Fork of the Licking area has an extent of 190 square miles, making 1,065 square miles in all. There are also some linear outcrops of the Lexington along Salt River in Mercer and Anderson Counties, and perhaps along the Main Licking in Nicholas, Robertson, Harrison and Pendleton Counties, and along the Ohio from near Foster in Bracken County, to near California in Campbell County. According to Mr. E. O. Ulrich, all of this Ohio and Main Licking outcrop should be included in the Cynthiana. To the writer the evidence seems to point to a Lexington age for the lower portion of these exposures.

The Kentucky River and South Fork of the Licking areas combined constitute the Inner Bluegrass Region—of exceptional fertility.

Subdivisions and Fossils.—The *Lexington* is divided into five beds partly on the basis of the vertical range of certain species of fossils and partly on lithological differences. These divisions, named in ascending order, are as follows: Curdsville, Hermitage, Jessamine, Bigby and Perryville.

The *Curdsville* (A. M. Miller, 1905) is a grayish crystalline limestone about ten feet in thickness. It takes its name from an old station on the Cincinnati Southern Railroad in Mercer County, from which locality many of its most characteristic fossils have been collected. It has yielded a rich fauna of lower Trenton age. Crinoids of limited vertical range are a characteristic feature of this horizon. Among these are representatives of the general *Carabocrinus, Hybocrinus* and *Edrioaster*. A very characteristic fossil of this bed is the brachiopod *Dinorthis pectinella*. A small cup coral *Streptelasma profundum* is also abundant.

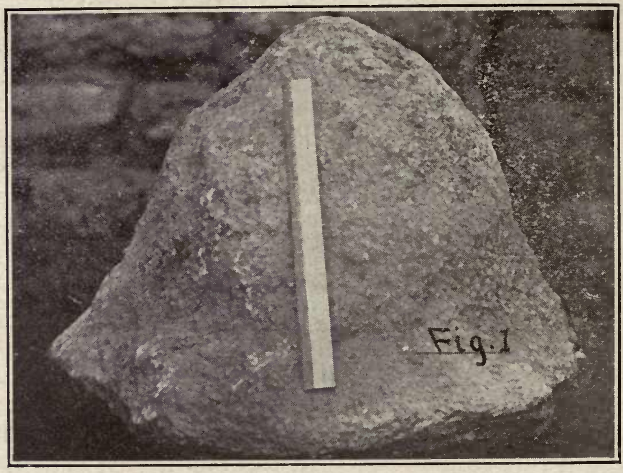
The *Hermitage* (E. O. Ulrich, 1903), named from the old Andrew Jackson home in Tennessee, is a bed of siliceous limestone and shale thirty feet thick. The rock is fine-grained and non-crystalline. It carries as a characteristic fossil the brachiopod *Heterorthis clytie. Dalmanella bassleri* is distributed through the bed, and is crowded in a confused mass in the top layers, but as the same fossil ranges through the next formation above it is not characteristic.

The *Jessamine* is a bed about eighty feet thick, for which the name *Wilmore* was proposed by the writer in 1905. Later, however, he discovered that this appellation was preoccupied, having been applied in the same year to a sandstone in Pennsylvania, and hence he proposes as a substitute the name "Jessamine," from Jessamine Creek in Jessamine County.

The bed is composed of rather thin-bedded grayish crystalline limestone with occasional thin shaly layers intercalated. The "chocolate drop" bryozoan, *Prasopora simulatrix*, and the brachiopod *Dalmanella bassleri* range through it; so these two in association may be considered characteristic of it.

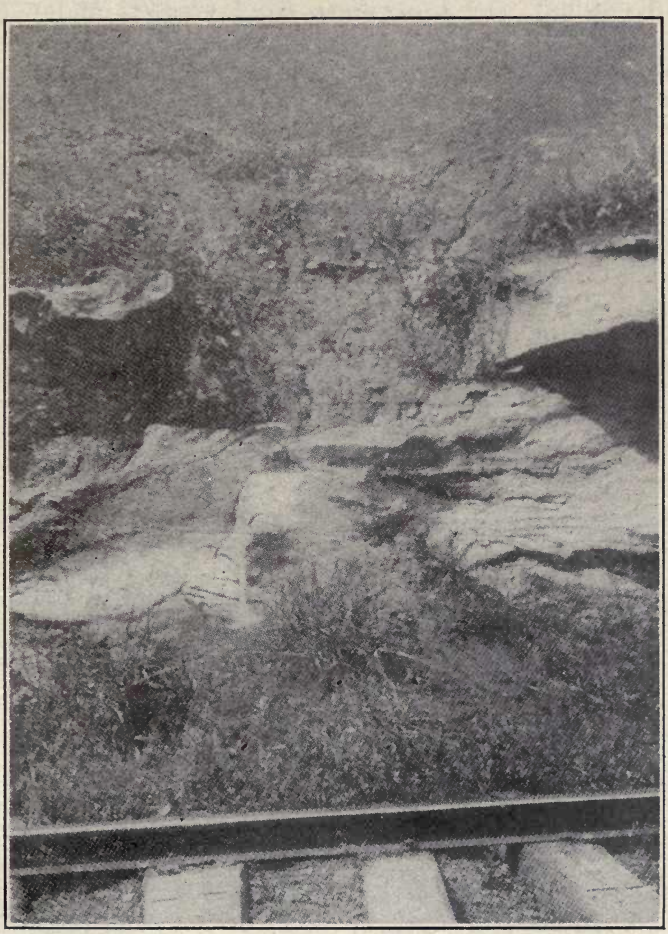
The *Bigby* (E. O. Ulrich, 1903), named from a locality in Tennessee, is about 125 feet thick. It may be divided again into three beds.

These in ascending order are as follows: The Benson, Brannon and Woodburn. The *Benson* (August Foerste, 1913), named from Benson Creek in Franklin County, is similar lithologically to the Jessamine. It is about seventy feet thick. Characteristic fossils distributed through it are the brachiopods *Rhynchotrema increbescens* and *Hebertella frankfortensis.* The latter also extends down into the Jessamine. At the top, and limited to a few feet vertical range, are the brachiopods *Strophomena vicina* and *Dinorthis ulrichi.* Here also is the problematic fossil



7. STROMATOCERIUM PUSTULOSUM
A characteristic fossil at the top of the Benson Bed

Stromatocerium pustulosum. The latter, having conical forms, and showing internal concentric structure, are often found so thickly crowded together at this horizon that they must have constituted a reef in the ancient Trenton sea. The bryozoan, *Cyphotrypa frankfortensis* is also abundant and characteristic at this horizon. The *Brannon* (A. M. Miller, 1913), named from Brannon Station in Jessamine County, is a siliceous limestone about fifteen feet in thickness. Certain layers present a contorted or bouldery appearance. On weathering this bed gives rise to chert in the soil. Where outcropping on hillsides under a sufficient covering of overlying rock this horizon is marked by springs. It is frequently found forming the throat of sinks. It is a fossil sponge horizon, yielding at two localities in Franklin County the rare sponge *Brachiospongia digitata,* and at one in Fayette (the Peter farm) the equally rare sponge *Strobilospongia aurita.* The *Woodburn* (A. M. Miller, 1913) is a highly phosphatic limestone with a maximum thickness of forty feet. It receives its name from Woodburn, the famous Alexander estate in Woodford County. M. R. Campbell in his Geology of Richmond Quadrangle, 1898, included this bed with the siliceous Brannon bed below in his Flanagan chert, apparently not realizing that it was only the siliceous bed which by weathering produced the chert.

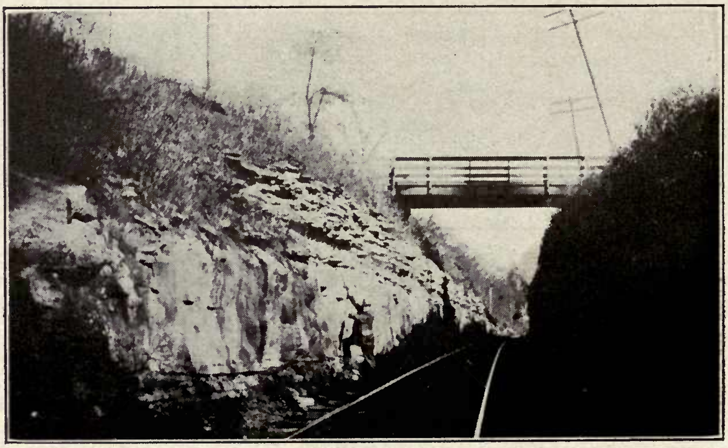


8. BRANNON CHERTY LIMESTONE SHOWING IRREGULAR BEDDING
Near Virginia Avenue Bridge, Lexington, Ky. Photograph by W. C. Phalen

The Woodburn together with the Brannon below are much pitted with sinks, the Woodburn forming the bowl and the Brannon the throat of these. The most characteristic fossils of the Woodburn are the honeycomb coral *Columnaria halli,* the bryozoan *Constellaria teres,* and the minute gastropod *Cyclora minuta.* The latter may be called the "phosphate fossil," as it universally accompanies the more phosphatic layers. Indeed the phosphate seems to have been deposited originally in some relationship to the organism, as the casts of the shell—the only form in which the fossil occurs—are pure phosphate of lime. For a discussion of the origin of phosphate of lime in association with this fossil in Central Kentucky, see *Phosphate Rock* treated under Economic Geology, page—.

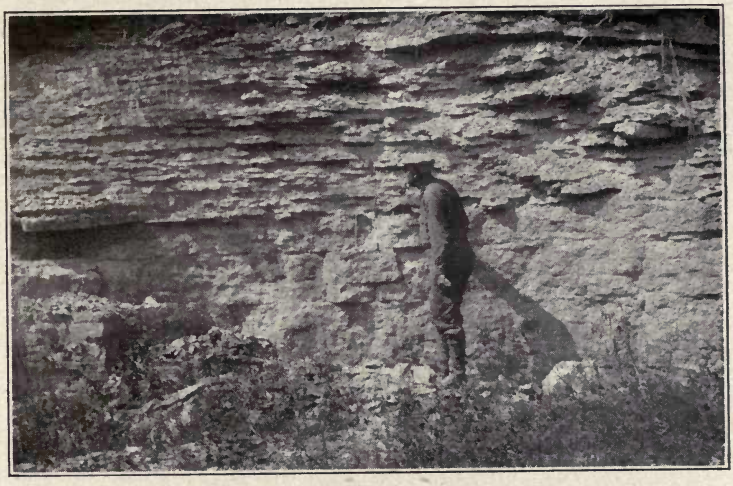
While all the limestones of the Trenton and Cincinnatian area are relatively high in phosphate, it is this Woodburn Bed which is especially rich in that preeminently important element of plant food, and hence it is not surprising that where this bed has entered most largely into soil formation the soil should be of such surpassing fertility. The Ordovician of Kentucky, relatively high in phosphate of lime, has given us in its weathered outcrop the rich Bluegrass Region in general; the Trenton, still higher in this mineral ingredient, has given us in the same way the richer and more circumscribed Inner Bluegrass Area; while highest in phosphorus content, the Woodburn Bed, of the Bigby, of the Trenton, of the Ordovician, has given us, where thickest in a still more restricted area, the richest portion of all—the far-famed "Asparagus Bed" of the Bluegrass in northern Woodford County.

The *Perryville* (J. M. Nickles and A. M. Miller, 1905) receive its name from a village in Boyle County. It is in the main the "Upper Birdseye" of William Linney. It exhibits its maximum development on the western flank



9. MASSIVE FAULCONER BED OF PERRYVILLE
Louisville and Nashville Railroad cut, between Duckers and Spring Station, Woodford County. Photograph by A. M. Miller

of the Cincinnati Anticline in Mercer County, where it attains a thickness of about twenty-five feet. It has been divided in ascending order into three subordinate beds—the Faulconer, Salvisa and Cornishville. The *Faulconer* (August Foerste, 1912), named from a station on the Cincinnati Southern Railroad, is a shell limestone five to eight feet thick. Gastropods predominate among these shells, and it has therefore been called the "gastropod bed." The most conspicuous species among these are *Belerophon troosti* and *Lophospira sumnerensis*. The



10. CONTACT BETWEEN SALVISA BED OF PERRYVILLE AND CYNTHIANA
Head of Devil's Hollow, Franklin County. Hammer is held by Mr. E. O. Ulrich at line of contact. Photograph by A. M. Miller

Salvisa (Foerste and Miller, 1913), named from a station on the Southern Railroad between Lawrenceburg and Harrodsburg in Mercer County, is a fine-grained limestone having much the same appearance as the Tyrone where seen in its typical localities in Mercer County. It was this appearance which led William Linney to give to the whole formation, here called Perryville, the name *Upper Birdseye*. Its thickness is about ten feet. Its most characteristic fossils are ostracods—among which *Isochilina jonesi* is a conspicuous form. The brachiopod *Orthorhynchula linneyi* is also common. The *Cornishville* (August Foerste, 1912) is named from a village in Mercer County. It is lithologically similar to the Benson or Woodburn. A Stromatocerium reef is a prominent feature of it. It is also marked by the recurrence of the top of the Benson fauna in other respects—the brachiopod *Strophomena vicina* being found here. Northward along the western flank of the Cincinnati Anticline these beds of the Perryville tend to drop out in descending order, the next overlying formation, the Cynthiana, resting on successively lower beds till, in the furthest northward exposures along the Kentucky River north of Franklin County, it lies on the Woodburn or some lower bed of the Lexington. On the east side of the Arch there is only one locality where any Perryville has been found. This is a place about one mile northeast of Paris, where a small patch of Faulconer and Salvisa is exposed. Everywhere else on the eastern flank of the Arch the lower contact of the Cynthiana is with the Woodburn member of the Lexington.

CINCINNATIAN SERIES

(Cincinnati Limestone, Mather, 1859)

CYNTHIANA STAGE

(August F. Foerste, 1906. Named from the County Seat of Harrison)

Lithological Character and Fossils.—The Cynthiana is mainly a limestone; but more shaly than the Lexington—at least in the southern exposures. It ranges in thickness from forty feet in the southern part of the area to upwards of a hundred feet toward the Ohio River. On fresh exposure it is generally blue in color. Weathered outcrops are reddish, and generally present a rubbly appearance. It does not, as a rule, form as good soil as the underlying Lexington, yet it is of similar character and but little inferior in fertility. It outcrops in a belt surrounding the Inner Trenton Bluegrass Area, and forms outliers within it. Towards the north along the Licking and Ohio, where the formation thickens, it includes beds of diverse lithological composition and fossil content.

The Cynthiana limestone in general is very fossiliferous, especially that which is rubbly on weathering. Probably the most characteristic fossil of the formation is *Cyclonema varicosum,* a gastropod.

Other characteristic fossils are the lamellibranch *Allonychia flanaganensis,* the bryozoan *Eridotrypa briar-*

11. LOCATION OF CYNTHIANA LIMESTONE OUTCROP

eous, and the brachiopods *Hebertella maria* and *Rafinesquina winchesterensis.*

The Cynthiana has been subdivided by Professor August F. Foerste into two members—the Greendale and the Point Pleasant.

The *Greendale* (August F. Foerste, 1906) is the lower bed found in the more southern exposures, the one which on weathering exhibits the characteristic rubbly phase. It was named from a station on the Cincinnati Southern Railroad in Fayette County.

The *Point Pleasant* bed (Edward Orton, 1873), according to Professor Foerste, is the upper Cynthiana as seen exposed along the Ohio in Bracken and Campbell Counties. The name was originally applied to the exposures along the Ohio River at Point Pleasant, Ohio, extending from low water up to fifty feet above.

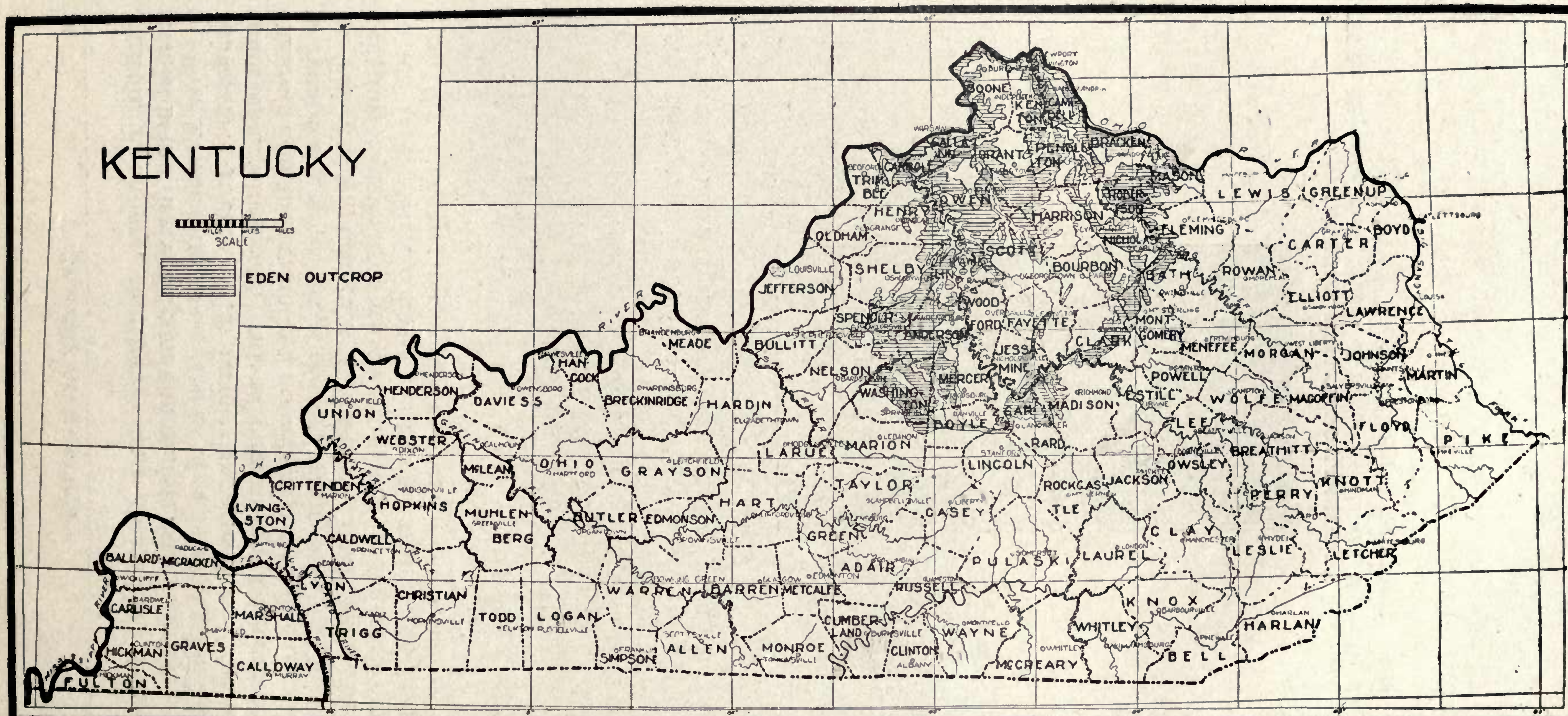
EDEN FORMATION

(Edward Orton, 1873. The Middle Hudson in Part, of William Linney)

General Characteristics and Areal Outcrop.—This formation was named "Eden shale" from Eden Park, Cincinnati. It there consists largely of shale. With this thin limestone layers are intercalated. This shale, like similar shale in the Cincinnatian, is commonly called "blue clay" and "soapstone." In reality it is properly a *marlite.* Professor Orton placed the lower limit of the Eden in the vicinity of Cincinnati at fifty feet above low water mark and assigned to it a thickness of 250 feet. Southward in Kentucky the formation becomes siliceous at the top, forming the "siliceous mudstone" of David Owen.

On account of its prevailing shaly and siliceous character the Eden gives rise in outcrop to rather poor agricultural land. It forms that belt of hilly country five to fifteen miles wide which one must cross in passing from the outer margin of the Bluegrass Region in general to the inner Bluegrass Region, central about Lexington.

Subdivisions and Fossils.—In ascending order the formation may be divided into the *Trinucleus concentricus* Bed, the Fulton, the Million, and the Garrard. E. O. Ulrich divides the Eden in the same order into the



12. LOCATION OF EDEN SHALE OUTCROP

Fulton, Economy, Southgate and McMicken Beds, the names being derived from Cincinnati and vicinity.

The *Trinucleus concentricus Bed* is about ten feet in thickness. It has at its base "wave marked" layers of limestone, which are full of comminuted fragments of crinoids and the trilobite *Trinucleus concentricus.* There is recorded here a slight disconformity.

The *Fulton* (August F. Foerste, 1909) is a shale in Cincinnati exposures which ranges in thickness from five to ten feet. On the basis of its containing the trilobite *Triarthrus beckii,* it is correlated with the Utica of New York.

The *Million* (August F. Foerste, 1909), 160 to 200 feet thick, is the great shale member of the Eden. It is about the equivalent of the Southgate of E. O. Ulrich. As a diagnostic fossil may be mentioned the brachiopod *Plectambonites rugosus* (*Plectambonites sericeous* of Meek, non Hall). It may be seen completely covering the limestone slabs which are intercalated with the shale. Also very common and characteristic is the bryozoan *Dekayella*

13. EDEN SHALE AND LIMESTONE
Cut on Maysville-Paris Branch of the Louisville and Nashville Railroad, Nicholas County. Photograph by A. M. Miller

ulrichi and the crinid *Ectenocrinus simplex.* The stem plates of the latter often make up nearly the whole mass of the limestone layers, thus forming a crinoidal limestone.

The *Garrard* (M. R. Campbell, 1898), named from Garrard County, has been called a sandstone. It is a siliceous limestone, which on weathering loses its calcareous content and comes to resemble a fine-grained sandstone, the "siliceous mudstone." This is the Paint Lick formation of Foerste. Mr. M. R. Campbell, in his

14. GARRARD SANDSTONE, SHOWING TYPICAL CONCRETIONARY LEDGE

Hills of Jessamine County. Photograph by A. M. Miller

description in the Richmond (Kentucky) Folio, assigned to it a thickness of sixty feet. Certain of the freshly exposed layers have a bouldery or concretionary structure, resembling closely layers of similar composition in the Brannon bed of the Lexington.

MAYSVILLE STAGE

(August F. Foerste, 1909. Upper Hudson in Part, of William Linney)

Characteristics.—The Maysville, the third member from the bottom of the Cincinnatian, resembles very much in appearance the Cynthiana, being mainly a limestone with some shale intercalated, and very fossiliferous, the fossils recalling those of the Cynthiana. Among brachiopods are *Hebertellas, Strophomenas, Rafinesquinas* and characteristic large *Platystrophias,* the *Playstrophias* of the Cynthiana being small; among bryozoa are *Constellarias* and rugose *Calloporas;* among gastropods are several varieties of *Cyclonemas,* which are smaller than the one species, *varicosum,* in the Cynthiana. These forms are for the most part wanting in the intervening Eden.

Areal Distribution.—The Maysville is found mainly in a belt encircling the Eden. There is also a narrow exposure along the Cumberland River near the Tennessee line. It gives rise to a better agricultúral country than does the Eden, resembling in topography and in soil the Inner (Lexington) Bluegrass Region.

Subdivisions.—There are five divisions of the Maysville, all taking their names from suburbs of Cincinnati; in ascending order they are as follows: Mt. Hope, Fairmount, Bellevue, Corryville and Mt. Auburn.

The *Mt. Hope* (J. M. Nickles, 1902) is about fifty feet in thickness. A very characteristic fossil is the brachiopod *Strophomena maysvillensis.*

The *Fairmount* (J. M. Nickles, 1902) is about eighty feet thick. The large form of *Playstrophia* and the rugose bryozoan *Callopora dalei* make their appearance.

The *Bellevue* (J. M. Nickles, 1902) is twenty feet thick. Large forms of *Platystrophia lynx* are abundant.

The *Corryville* (J. M. Nickles, 1902) is sixty feet thick.

The *Mt. Auburn* is twenty feet thick. The presence in it of a very globose form of *Platystrophia lynx* is characteristic.

15. LOCATION OF MAYSVILLE AND RICHMOND OUTCROP

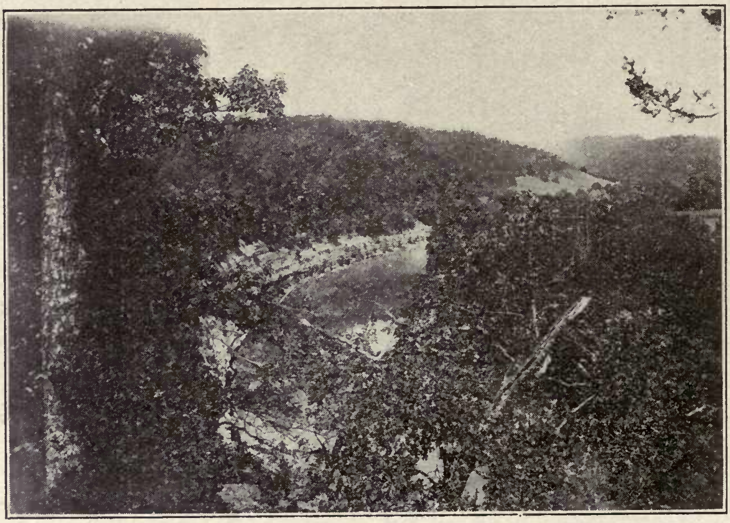
RICHMOND STAGE

(E. O. Ulrich. Upper Hudson in Part, of
William Linney)

Characteristics.—The Richmond receives its designation from the city of that name in Indiana. This top member of the Cincinnatian in places rests disconformably upon the Maysville, the Mt. Auburn, and even the Corryville, of the latter being sometimes wanting. In harmony with this is its more argillaceous and shaly character testifying to changing physiographic conditions. In its Cumberland River exposures it is ripple marked. Its strata may aggregate 220 feet in thickness.

Areal Distribution.—The Richmond forms the outer margin of the general Bluegrass Region from the Ohio River in Mason County to the same river again in Trimble County. It does not inclose the region on the north.

It is also found along the Cumberland River in Wayne,



16. UPPER CINCINNATIAN (RICHMOND) UNDERLYING OHIO SHALE
View taken from top of ridge above the natural bridge near Creelsboro, Cumberland River, Russell County. Photograph by A. M. Miller

Russell, Clinton, Cumberland and Monroe Counties, and in isolated patches (inliers) in a few other places—as on Fishing Creek in Pulaski, Damron Creek in Adair, and upper Robinson Creek in Taylor County. In the Cumberland River exposures it is covered disconformably by the

Ohio black shale of the Devonian. On account of its prevailing argillaceous character it does not as a rule give rise to as good agricultural land as the Maysville.

Subdivisions.—The divisions of the Richmond are four—in ascending order, the Arnheim, Waynesville, Liberty and Saluda.

The *Arnheim* (August F. Foerste, 1905) receives its names from an Ohio locality. It is a limestone and shale about eighty-five feet thick. Professor Foerste inclines to the view that the fossils of this bed should place it in the Maysville as the top member. Ulrich and Butts, however, place it in the Richmond. Fossils, which it possesses in common with the Maysville, are large *Platystrophias, Hebertellas* and *Rafinesquinas.* As good index fossils of the bed are the brachiopods *Rhychotrema dentata, Leptaena rhomboidalis* and *Dinorthis carleyi* (re-

17. EXPOSURE OF WAYNESVILLE LIMESTONE
Quarry on Brush Run, two and one-quarter miles east of Seatonsville, looking southeast. The middle layer is about sixteen feet thick.
Photograph by Charles Butts

trorsa). Another characteristic fossil is the large ribbed shelled lamellibranch *Anomalodonta gigantea*.

The Arnheim has been correlated with the Queenston (Red Medina) shale of Canada and New York.

The *Waynesville* (J. M. Nickles, 1903) is an argillaceous, thick-bedded limestone with shale, aggregating forty-five feet in thickness. It was named from an Ohio locality. It is rather poor in fossils. The most characteristic are the globular bryozoan, *Cyphotrypa clarksvillensis,* the gastropod *Lophospira bowdeni,* and the brachiopods *Catazyga headi, Dalmanella jugosa* and *Stro-*

18. LIBERTY FORMATION IN RAILROAD CUT AT EASTWOOD
Lower five feet or so of formation not exposed. Top just above top of cut above portal of tunnel. Looking east. Photograph by Charles Butts

phomena planumbona. We also find here the honeycomb coral *Columnaria alveolata*—a recurrence from the Cynthiana.

The *Liberty* (J. M. Nickles, 1903) was named from Liberty, Indiana. It is composed of shale and thin-bedded limestone—in all fifty feet in thickness. Corals are still more characteristic of the Liberty than of the Waynesville. The same compound head coral *Columnaria alveolata* occurs here, and in addition the "calves horn" coral *Streptelasma rusticum,* and the encrusting form *Protarea vetusta.* The most characteristic brachiopods are *Hebertella insculpta* and *Rhynchotrema capax.* Here also occurs that most widespread and characteristic fossil of the Richmond in North America, the problematic root-shaped fossil *Beatrica,* represented by two species, *undulata* and *nodulosa.*

The *Saluda* (August F. Foerste, 1902), the topmost member of the Richmond, forty feet thick, consists of argillaceous limestone and fine-grained flaggy sandstone (Cumberland River standstone) often beautifully ripple-marked and sun-cracked. It is named from a locality in Indiana. Except for the corals *Columnaria, Calapoecia* and *Tetradium,* which are frequently massed together so as to form a reef, the Saluda is not rich in fossils.

19. SALUDA AND LIBERTY FORMATION

The overhanging bed is the heavy sandy magnesian limestone thirty feet thick, below which is thirty feet of coarse mud rock with thin limestone layers and the Columnaria reef in the middle. This mud rock rests upon the Liberty formation, which is marked by the beginning of the thin limestone layers. North cut of railroad at Madison, Ind., looking southwest. Photograph by Charles Butts.

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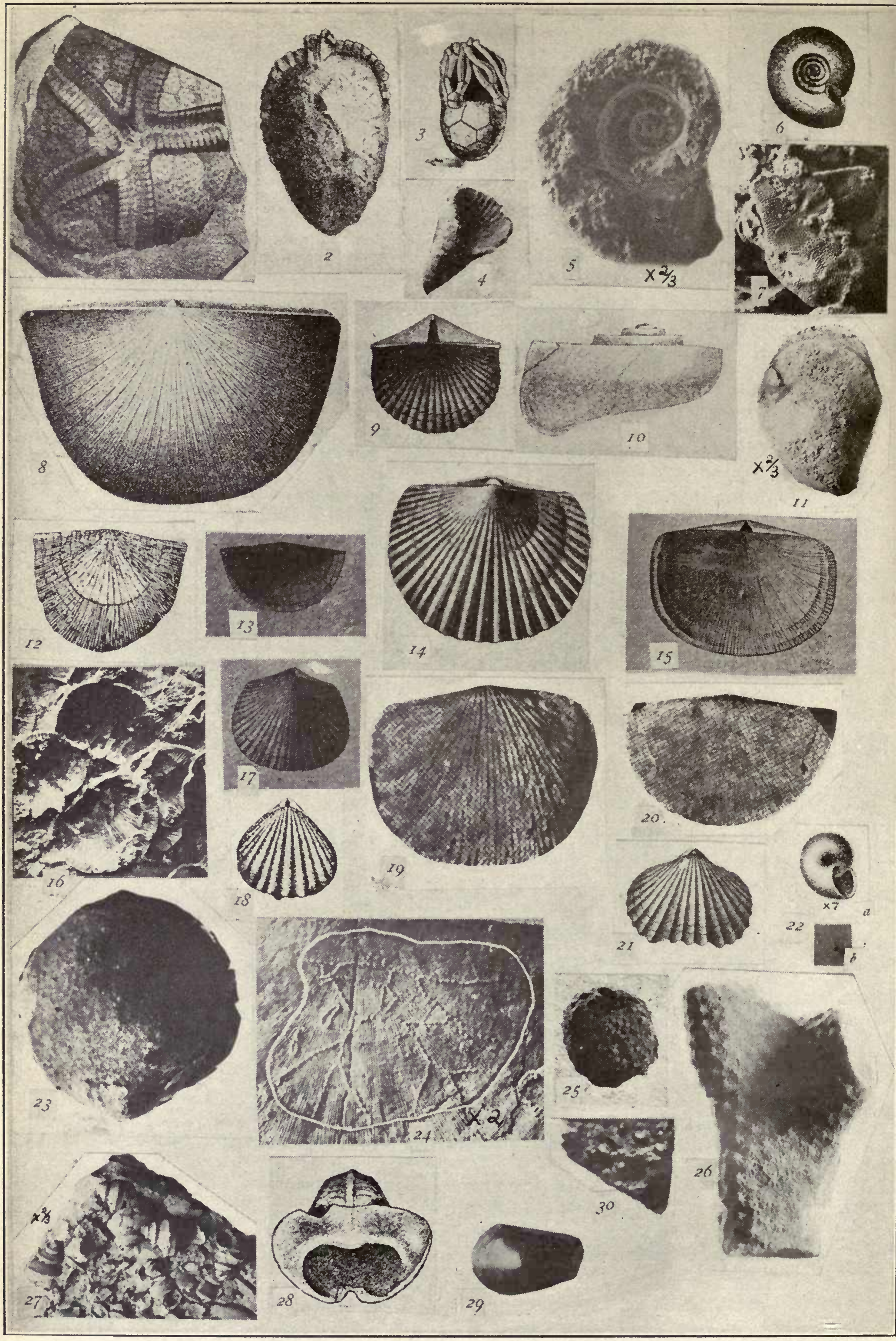
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PLATE 20

20. FOSSILS FROM THE HIGHBRIDGE AND LEXINGTON LIMESTONE

1. *Edrioaster bigsbyi* Billings, after Billings: a cystid from the Curdsville bed of the Lexington.

2. *Amygdalocystites florealis* Billings, after Billings: a cystid from the Curdsville bed of the Lexington.

3. *Carabocrinus ovalis* Miller and Gurley, after Miller and Gurley: a crinid from the Curdsville bed of the Lexington.

4. *Streptelasma profundum* Conrad: a horn coral from the Curdsville bed of the Lexington. Photograph by A. M. Miller.

5. *Maclurites bigsbyi* Hall, X⅔: a gastropod from the Camp Nelson bed of the Highbridge. Photograph by A. M. Miller.

6. *Liospira angulata* Ulrich: a gastropod from the Tyrone bed of the Highbridge. Photograph by A. M. Miller.

7. *Phyllodictya frondosa* Ulrich: a bryozoan from the Tyrone bed of the Lexington. Photograph by A. M. Miller.

8. *Strophomena incurvata* (Shepard), after Hall and Clarke: brachial valve of a brachiopod from the Highbridge.

9. *Orthis tricenaria* Conrad after Hall and Clarke: brachial valve and hinge of a brachiopod from the Tyrone and Curdsville.

10. *Helicotoma verticalis* Ulrich, after Ulrich and Schofield: a gastropod from the Tyrone bed of the Highbridge.

11. *Vanuxemia dixonensis* Meek and Worthen: right valve of a lamellibranch from the Curdsville bed of the Lexington. Photograph by A. M. Miller.

12. *Rafinesquina minnesotensis* Winchell, after Winchell and Schuchert: brachial valve of a brachiopod from the Tyrone bed of the Highbridge.

13. *Plectambonites sericeus* Sowerby, after Hall; brachial valve of a brachiopod from the Curdsville bed of the Lexington.

14. *Dinorthis pectinella* Emmons, after Hall and Clarke: a brachial valve and hinge of a brachiopod from the Curdsville bed of the Lexington.

15. *Heterorthis clytie* Hall, after Hall and Clarke: brachial valve and hinge of a brachiopod from the Hermitage bed of the Lexington.

16. *Dalmanella bassleri* Foerste: a brachiopod from the Hermitage and Jessamine beds of the Lexington. Photograph, showing inside of the valves, by A. M. Miller.

17. *Hebertella frankfortensis* Foerste: brachial valve of a brachiopod from the Jessamine and Benson beds of the Lexington. Photograph by A. M. Miller.

18. *Rhynchotrema increbescens* Hall (*R. inaequivalve Castelnau*), after Winchell and Schuchert: brachial valve of a brachiopod from the Bigby bed of the Lexington.

19. *Dinorthis ulrichi* Foerste, after Foerste: pedicle valve of a brachiopod from the top of the Benson bed of the Lexington.

20. *Strophomena vicina* Foerste, after Foerste: pedicle value of a brachiopod from the top of the Benson bed of the Lexington.

21. *Orthorhynchula linneyi* (James), after Hall and Clarke: brachial valve of a brachiopod from the Perryville bed of the Lexington and from the Cynthiana.

22. (a) *Cyclora minuta* Hall, X7, after Meek and Worthen.

(b) *Cyclora minuta* Hall, natural size.

A very minute gastropod, found as phosphatic casts especially in the Woodburn bed of the Lexington, but ranging upward into the Cincinnatian. Photographs by A. M. Miller.

23. *Prasopora simulatrix* Ulrich: the "chocolate drop" bryozoan from the Jessamine bed of the Lexington. Photograph by A. M. Miller.

24. *Corynotrypa inflata* (Hall) on shell of *R. alternata*, X2: a bryozoan from the Lexington. Photograph by A. M. Miller.

25. *Hindia parva* Ulrich: a sponge from the Woodburn bed of the Lexington. Photograph by A. M. Miller.

26. *Constellaria teres* Ulrich and Bassler, X4/3: a "star cluster" bryozoan from the Woodburn bed of the Lexington. Photograph by A. M. Miller.

27. *Lophospira medialis* Ulrich, X⅔: a gastropod from the Woodburn and Perryville beds of the Lexington. Photograph by A. M. Miller.

28. *Bellerophon troosti* D'Orbigny, after Ulrich and Schofield: a gastropod from the Perryville bed of the Lexington.

29. *Leperditia caecigena frankfortensis* Ulrich: an ostracod from the Perryville bed of the Lexington. Photograph by A. M. Miller.

30. *Isochilina jonesi* Wetherby: an ostracod from the Perryville bed of the Lexington. Photograph by A. M. Miller.

21. FOSSILS FROM THE LEXINGTON, CYNTHIANA AND EDEN FORMATIONS

1. *Brachiospongia digitata* (Owen), X⅓: a rare sponge from the Brannon bed of Franklin County. Photograph by A. M. Miller.

2. *Pattersonia aurita* Beecher, X⅓: a rare sponge from the Brannon bed of Fayette County. Photograph by A. M. Miller.

3. *Columnaria halli* Nicholson, X4/9: a characteristic coral of the Woodburn bed of the Lexington. Photograph by A. M. Miller.

4. *Promopalaeaster prenuncius* Schuchert: a rare asteroid (starfish) from the Lexington (Hermitage?) of Franklin County. Photograph by A. M. Miller.

5. *Platystrophia colbyensis* Foerste, after Foerste: brachial valve of a brachiopod from the Cynthiana.

6. *Hebertella maria* (Billings): brachial valve of a brachiopod from the Cynthiana. Photograph by A. M. Miller.

7. *Heterotrypa parvulipora* Ulrich and Bassler, X⅔: a bryozoan from the Cynthiana. Photograph by A. M. Miller.

8. *Eridotrypa briareus* (Nicholson), X2: a bryozoan from the Cynthiana.

9. *Rafinesquina winchesterensis* Foerste, after Foerste: brachial valve of a brachiopod from the Cynthiana.

10. *Constellaria fischeri* Ulrich, X4/3: a bryozoan from the Cynthiana. Photograph by A. M. Miller.

11. *Peronopora milleri* Nickles, X4/3: a bryozoan from the Cynthiana. Photograph by A. M. Miller.

12. *Strophomena hallie* (S. A. Miller), after S. A. Miller: pedicle valve of a brachiopod from the Eden.

13. *Orthodesma subnasutum* (Meek and Worthen), after Ulrich and Schofield: right valve of a lamellibranch from the Cynthiana.

14. *Plectambonites rugosus* (James), after Meek: brachial valve of a brachiopod characteristic of the Eden.

15. *Cyclonema varicosum* Hall, after Ulrich and Schofield: a diagnostic gastropod of the Cynthiana.

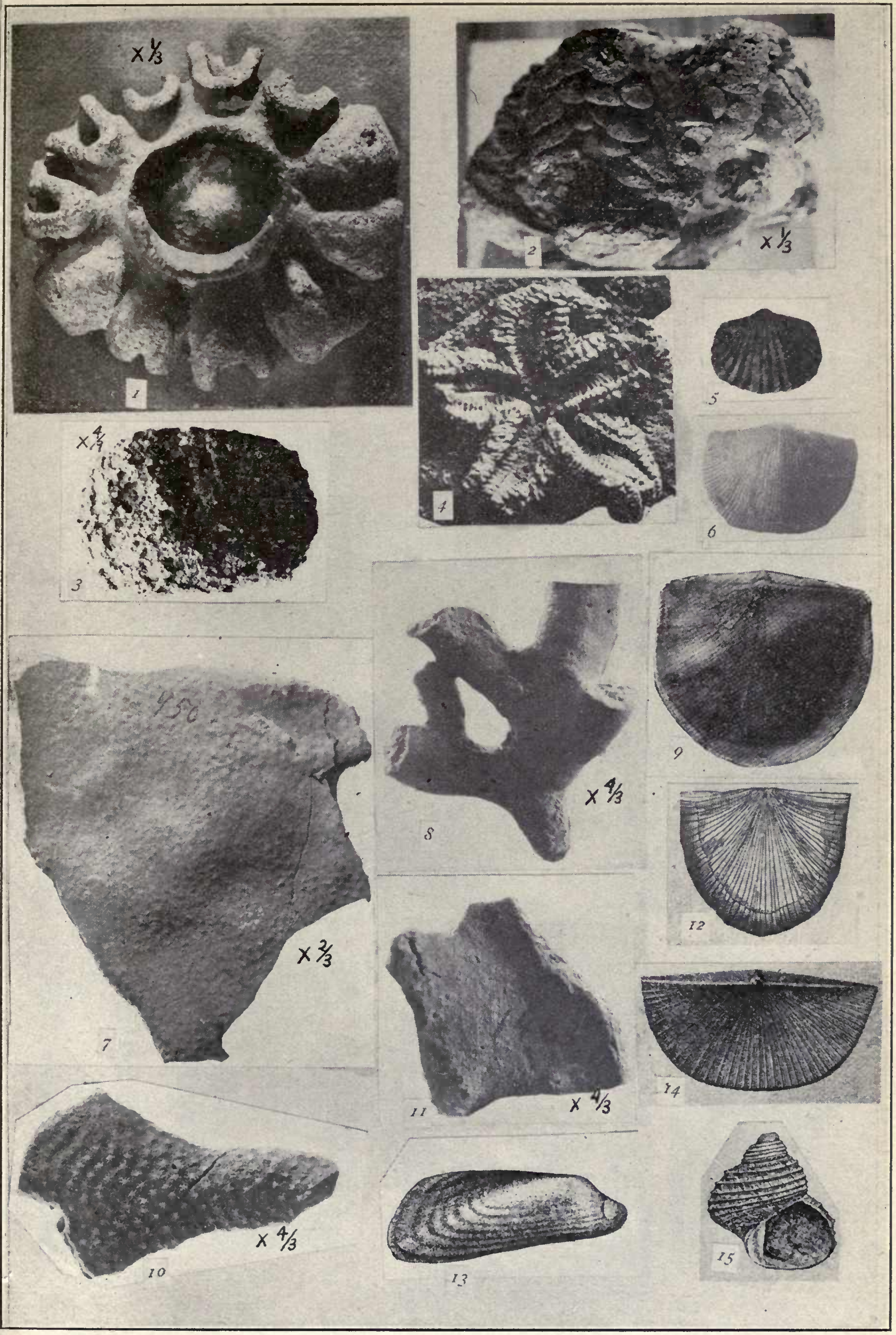


PLATE 21

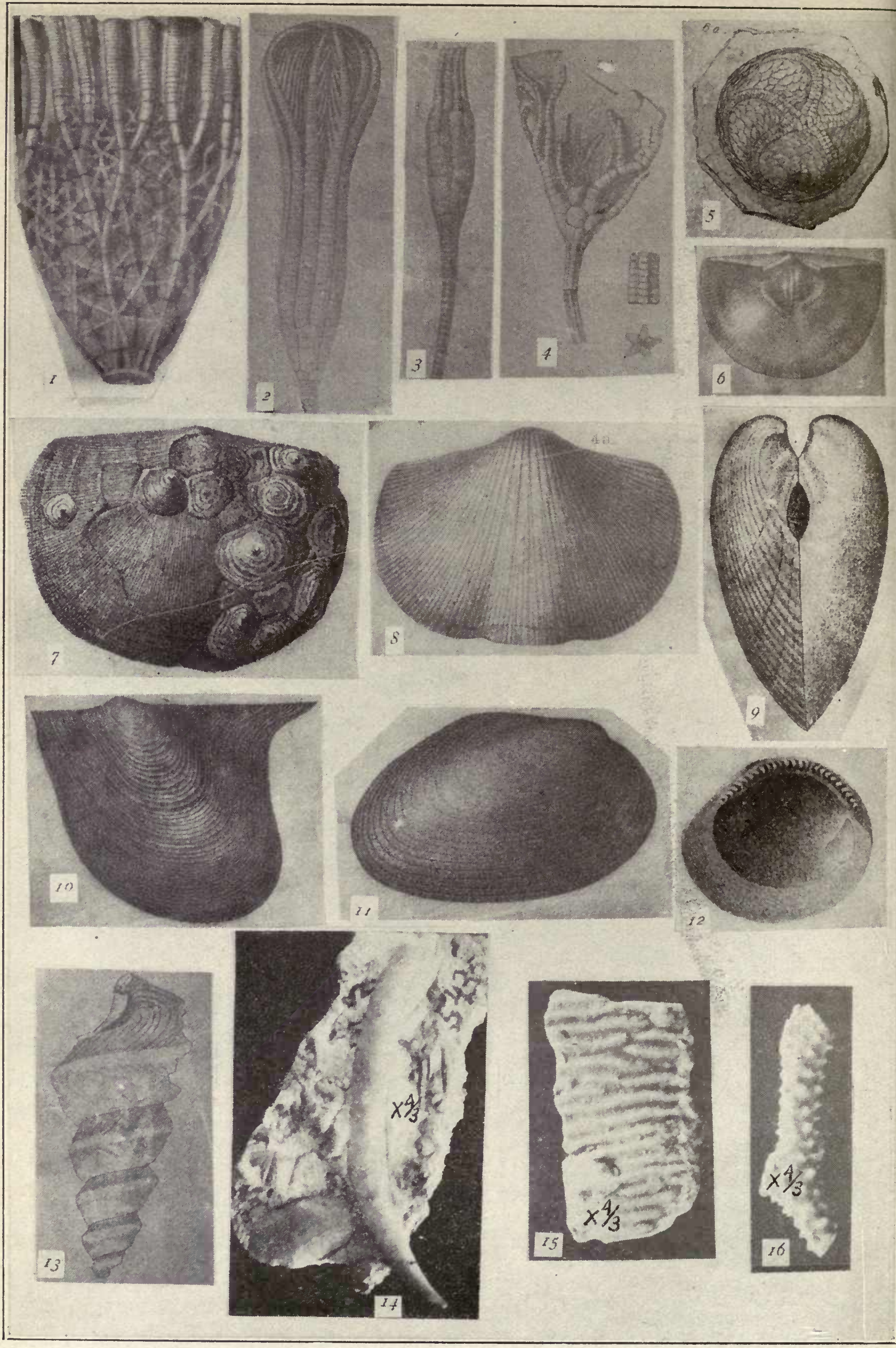


PLATE 22

22. FOSSILS FROM THE EDEN AND MAYSVILLE FORMATIONS

1. *Glyptocrinus decadactylus* Hall, after Meek: a crinid from the Fairmount bed of Maysville.

2. *Ectenocrinus grandis* Meek, after Meek: a crinid, Eden and Maysville.

3. *Ectenocrinus simplex* (Hall) after Meek: a crinid from the Eden. The stem plates of this species are very abundant in this formation, often forming crinoidal limestone.

4. *Dendrocrinas cincinnatiensis* (Meek), after Meek: a crinid, Fairmount bed of Maysville.

5. *Agelacrinites cincinnatiensis* (Roemer), after Meek: a cystid, Maysville formation.

6. *Strophomena planoconvexa* Hall, after Meek; interior of pedicle valve: a brachiopod from the Fairmount bed of the Maysville.

7. *Crania scabosa* Hall; on shell of another brachiopod, after Meek: a parasitic brachiopod, Eden and Maysville formations.

8. *Hebertella occidentalis sinuata* Hall, after Meek; brachial valve: a brachiopod, Maysville and Richmond.

9. *Byssonychia alveolata* Ulrich, after Ulrich; anterior end: lamellibranch from the Corryville bed of the Maysville.

10. *Pterinia demissa* (Conrad), after Meek; left valve: a lamellibranch from the Maysville and Richmond.

11. *Ischryodonta unionidae* (Meek) after Meek; right valve: a lamellibranch from the Bellevue bed of the Maysville.

12. *Ctenodonta pectunculus* Hall, after Meek; interior of left valve: a lamellibranch from the Fairmount bed of the Maysville.

13. *Lophospira bowdeni* (Safford), after Ulrich and Schofield: a gastropod ranging from the Trenton to the Richmond.

14. *Escharopora falciformis* (Nicholson); 4/3, on a piece of limestone: a bryozoan from the Maysville. Photograph by A. M. Miller.

15. *Escharopora hilli* (James); X4/3: a bryozoan from the Fairmount bed of the Maysville. Photograph by A. M. Miller.

16. *Hallopora* (*Callopora*) *ramosa* (D'Orbigny) X4/3: a bryozoan from the Maysville. Photograph by A. M. Miller.

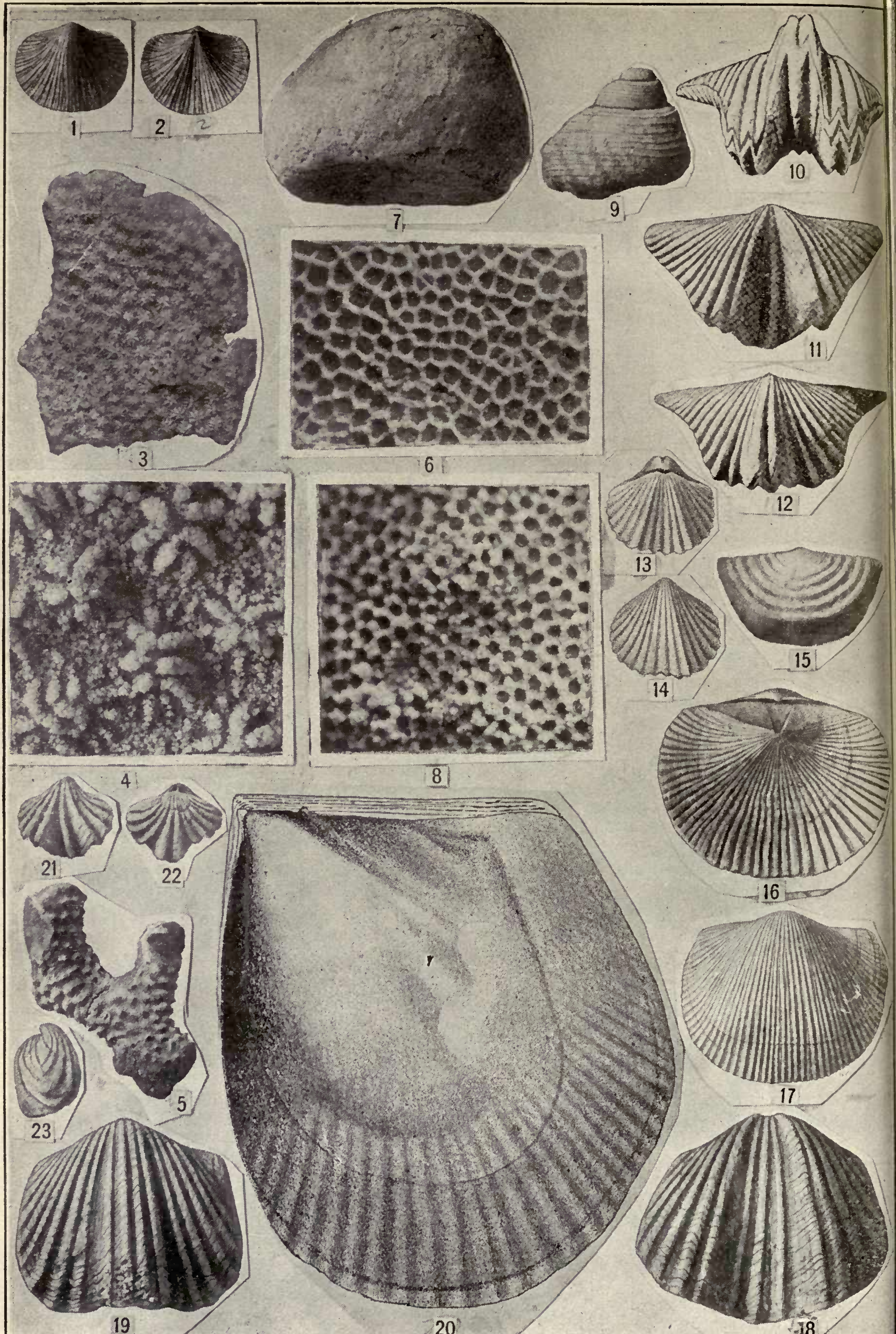


PLATE 23

23. FOSSILS FROM THE ARNHEIM AND WAYNESVILLE BEDS OF THE RICHMOND

A reproduction of Plate 8 in "Geology of Jefferson County," by Charles Butts.

1-2. *Dalmanella meeki* (S. A. Miller); 1, brachial; 2, pedicle valve: a brachiopod from the Arnheim bed.

3-4. *Constellaria polystomella* (Nicholson); 3, a zoarium, natural size; 4, a portion of the surface, X15: a bryozoan from the Arnheim bed.

5-6. *Hallopora* (*Callopora*) *subnodosa* (Ulrich); 5, a zooarium, natural size; 6, a portion of the surface, X15: a bryozoan from the Arnheim and Waynesville beds.

7-8. *Cyphotrypa clarksvillensis* Ulrich; 7, a zoarium, natural size; 6, a portion of the surface, X15: a bryozoan diagnostic of the Waynesville bed.

9. *Cyclonema bilix fluctuatum* James: a gastropod of the Arnheim bed.

10-12. *Platystrophia cypha* Foerste, after Foerste; 10, anterior side; 11, pedicle valve; 12, brachical valve: a brachiopod of the Arnheim bed.

13-14. *Zygospira kentuckyensis* James, after Nettelroth; 13, brachial; 14, pedicle valve: a brachiopod of the Arnheim bed.

15. *Leptaena richmondensis* Foerste; pedicle valve view: a brachiopod of the Arnheim bed.

16-17. *Dinorthis carleyi* Hall; 16, pedicle; 17, brachial valve: a rare brachiopod of the Arnheim bed.

18-19. *Platystrophia ponderosa* Foerste; 18, pedicle; 19, brachial valve: a brachiopod confined to the Arnheim bed.

20. *Anomalodonta gigantea* S. A. Miller, after Ulrich; left valve: a lammellibranch confined to the Arnheim bed.

21-23. *Rhynchotrema dentata arnheimensis* Foerste; 21, pedicle valve; 22, brachial valve; 23, profile: a brachiopod diagnostic of the Arnheim bed.

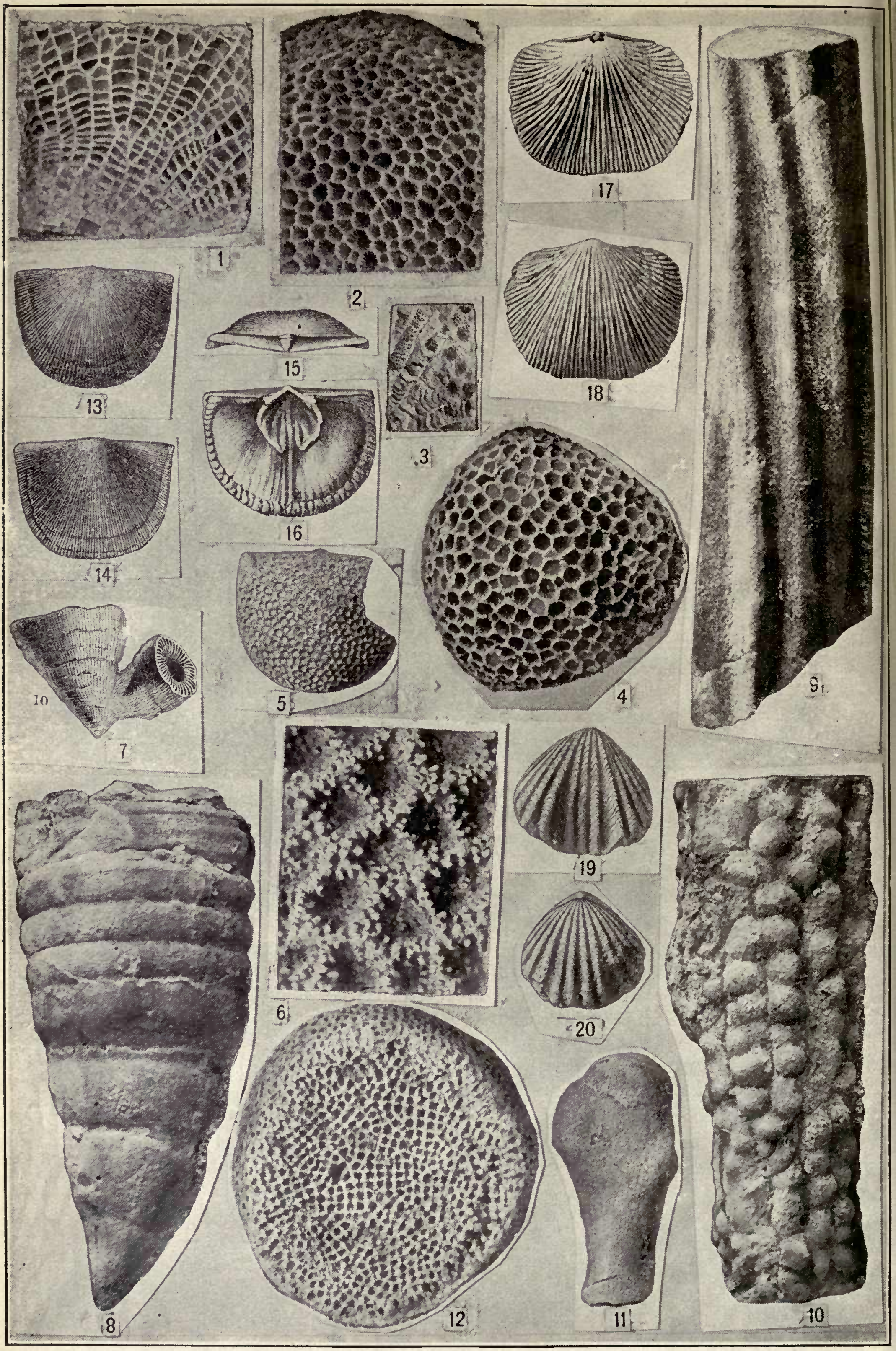


PLATE 24

24. FOSSILS FROM THE LIBERTY, WAYNESVILLE AND SALUDA BEDS OF THE RICHMOND

A reproduction of Plate 15 in "Geology of Jefferson County," by Charles Butts.

1-2. *Columnaria alveolata* Goldfuss, after Davis; 1, section showing tubes and tabulae; 2, outer surface showing mouths of tubes with radiating septa: a coral of the Waynesville bed.

3-4. *Calapoecia cribriformis* Nicholson, after Davis; 3, portion of the base; 4, upper surface: a coral of the Liberty bed.

5-6. *Protarea richmondensis* Foerste; 5, natural size, encrusting a brachiopod shell; 6, enlarged view of surface: a coral common in the Liberty bed.

7. *Streptelasma divaricans* (Nicholson), after Meek: a horn coral common in the Saluda bed.

8. *Streptelasma rusticum* (Billings): a horn coral characteristic of the Liberty bed.

9. *Beatricea undulata* Billings, after Foerste: a problematic fossil characteristic of the Richmond.

10. *Beatricea nodulosa* Billings: a problematic fossil characteristic of the Liberty bed.

11-12. *Rhombotrypa quadrata* Rominger; 11, a part of a zooarium, natural size; 12, end view of stem X6: a bryozoan characteristic of the Liberty bed.

13-16. *Strophomena planumbonum* Hall, after Meek; 13, brachial valve; 14, pedicle valve; 15, cardinal end; 16, interior of pedicle valve views: a brachiopod diagnostic of the Liberty bed.

17-18. *Dinorthis subquadrata* (Hall); 17, pedicle valve; 18, brachial valve: a brachiopod diagnostic of the Liberty bed.

19-20. *Rhynchotrema capax* Conrad; 19, pedicle valve; 20, brachial valve: a brachiopod abundant in and characteristic of the Liberty bed.

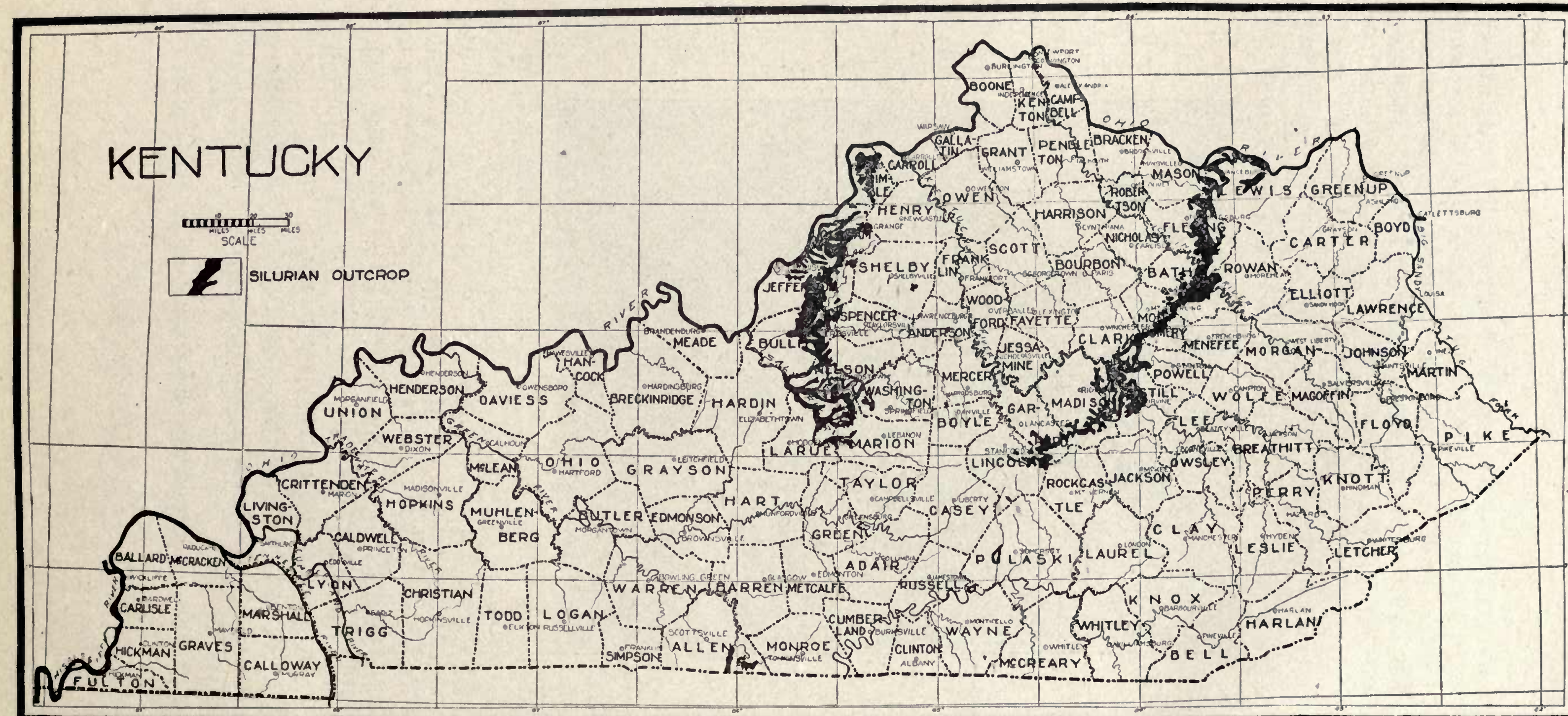
CHAPTER III

SILURIAN SYSTEM

The Silurian (Murchison, 1835; named after an ancient tribe of Britains—Upper Silurian of some authors) in Kentucky is relatively thin, being represented only by the Niagaran division. The lower part of the upper Oswegan (unless ultimately the upper part of the Richmond and the whole of the Brassfield shall be placed in it) and the upper, Cayagan divisions, are wanting. The total maximum thickness is about 350 feet. It was at the close of Oswegan time that the Cincinnati Arch was first bowed up out of the sea. Between this time and the next submergence in the mid-Devonian this arch was extensively truncated by subaerial erosion. The evidence of this lies in the dropping out in descending order of the members of the middle and lower portions of the formation as the axis of the arch is approached, and in the absence from any portion of Kentucky of late Silurian and early Devonian strata.

Classification of the Silurian in Kentucky

Series	*Stage*	*Sub-stage*	*Thickness in Feet*
Niagaran	(Only on E. side of Arch)	Louisville	0—100
		Waldron	0— 15
	Alger (On E. side of Arch) Osgood (On W. side of Arch)	Laurel	0— 40
		Estill	0—100
		Waco	0— 10
		Lulbegrud	0— 15
	Indian Fields (Only on E. side of Arch)	Oldham	0— 15
		Plum Creek	0— 5
		Brassfield (Ky., Clinton)	0— 20



25. LOCATION OF SILURIAN OUTCROP

NIAGARAN SERIES

BRASSFIELD STAGE

(August F. Foerste, 1906. Named from a Village in Madison County, Ky.)

LITHOLOGICAL CHARACTERS, FOSSILS AND CORRELATIONS. —The Brassfield is the only bed of the Silurian which can be identified with certainty on both sides of the Cincinnati Arch. It is thinner on the western side, being in some places only three feet thick. On the eastern side it usually ranges from twelve to eighteen feet thick.

It is a magnesian limestone, somewhat sandy in ap-

26. SURFACE OF BRASSFIELD (KENTUCKY CLINTON) LIMESTONE, SHOWING FOSSILS

These are the coral *Enterolasma calyculum* (Hall) and the fluted "crinoid beads" so characteristic of this formation in Kentucky

pearance and rather reddish in color. In one place, in Kentucky, near Olympia, Bath County, it carries the characteristic ''flaxseed iron ore,'' originally an oolitic hematite, which is so prominently diagnostic of this formation from point to point along the western flank of the

Appalachians. The grains of this oolite are flattened, hence the name "flaxseed."

Its most characteristic fossils of easy identification are the brachiopod *Whitfieldella quadrangularis* and the bryozoan *Clathropora frondosa.* It also carries the crinoid stem-plates with peculiar fluted edges that make their recognition easy and serve most readily to identify limestone belonging to this formation.

The earliest name given to this formation in the Ohio Valley was the "Cliff limestone" by Dr. John Locke, of the Ohio Survey, in 1838. This name was continued in use for it by J. S. Newberry and Edward Orton, of the Ohio Survey, until 1873, when they substituted the name "Clinton" for it, correlating it with the formation of that name in New York, chiefly on the basis of its general geological position, and the occurrence in it in Ohio, as well as in New York, of the flaxseed or dye stone iron ore.

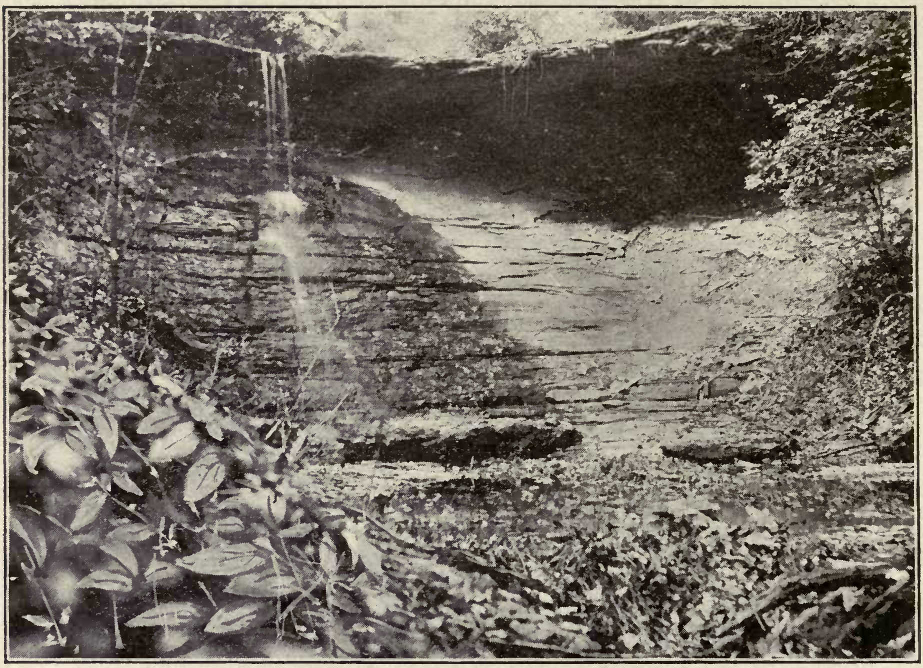
In 1906 August F. Foerste, by a careful comparison of fossils, concluded that this formation (for which he proposed the name "Brassfield" from a Madison County, Ky., locality) is the equivalent in the Ohio Valley of the Cataract formation of the Canada—New York section—which would, if the correlation shall stand, place it at a horizon next below the New York Clinton. It would appear to the writer, however, that the presence, from New York to Alabama, of an iron ore of such peculiar structure, in a formation admitted to be throughout at nearly the same geological horizon, is geological evidence which should not be lightly set aside. If the dyestone ore is Cataract in Alabama and Kentucky and Clinton in New York, then we have to postulate a shifting northward of peculiar iron ore forming conditions from Cataract into Clinton time—a theory which presents nearly as great difficulties as the postulating of a faunal migration from north to south in order to get into the Kentucky Clinton the same fossils as those which in Canada and New York are found in the underlying Cataract.

Areal Distribution.—The Brassfield has a narrow outcrop skirting the boundary of the Bluegrass, just outside of the Richmond outcrop, except it is for the most part absent where this boundary crosses the summit of the Cincinnati Arch. Smaller discontinuous areas of Brassfield outcrop exist on the Cumberland River near the mouth of Cub Creek and on Fishing Creek, west of Somerset. In these two places it intervenes between the

Saluda member of the Richmond and either the Devonian limestone or Devonian Black shale.

Its absence along the crest of the Cincinnati Arch, or if present, its being overlaid disconformably by Devonian, is accounted for by the bowing up and erosion of the Arch in the interval between the deposition of the Mid-Silurian and Mid-Devonian.

Economic Products.—Reference has already been made to the dyestone, or flaxseed iron ore, of the Brass-



27. EXPOSURE OF BRASSFIELD AND SALUDA FORMATIONS

Falls of a ravine two and one-half miles south-southeast of Fern Creek Station, on the railroad. The overhanging rock at the top is Brassfield, beneath which is the Saluda sandy limestone that shells off across the bedding and undermines the Brassfield. Photograph by Charles Butts

field. It occurs in Kentucky on Rose Run, northeast of Olympia, Bath County, Kentucky. It is an oolitic hematite. An account of this deposit is given on page— under the head of Iron Ore.

In Ohio the Clinton (Brassfield?) has been found to be a source of gas, as in the Lancaster Field. In Kentucky the rock has been found frequently to be bituminous in outcrop, but no productive oil or gas horizon has yet been located in it with certainty.

INDIAN FIELDS STAGE

(August F. Foerste, 1906)

The Indian Fields Formation, twenty feet in thickness, mostly whitish shale, next succeeds the Brassfield on the east side of the Cincinnati Arch. It has not yet been identified on the west side. It takes its name from the old Indian village in eastern Clark County.

Subdivision and Fossils.—There are two divisions of the Indian Fields, named in ascending order: Plum Creek shale and Oldham limestone.

The *Plum Creek* shale or clay (August F. Foerste, 1906) was named from a creek in Madison County. It is five feet thick.

The *Oldham limestone* (August F. Foerste, 1906) was named from a creek in Powell County. It has much shale intercalated with thin magnesian limestone. Its most characteristic fossil is the brachiopod, *Stricklandinia norwoodi*. This formation is probably about the equivalent of the Dayton limestone (Haymond, 1869) of Ohio. It varies from nothing to fifteen feet thick.

OSGOOD STAGE

(August F. Foerste, 1896)

Characteristics and Correlation.—The Osgood Formation takes its name from a locality in Indiana. It consists largely of a calcium-magnesium shale, with a range in thickness on the west side of the Cincinnati Arch of from fourteen to 100 feet. It has been correlated with the Rochester shale of New York. To approximately the same formation on the east flank of the Anticline Professor Foerste in 1906 gave the name *Alger*, from a station on the Louisville and Atlantic Railroad in Estill County. Mr. Charles Butts, in his report on Jefferson County for the Kentucky Geological Survey, 1915, is disposed to correlate the basal limestone of the Osgood with the Oldham limestone of Foerste's Indian Fields, and both with the Dayton limestone of Ohio.

If this be the correct view it would seem best to suppress the term "Indian Fields" and make the term "Osgood" include all the Niagara on both sides of the Cincinnati Arch up to the base of the Laurel limestone.

Subdivisions and Fossils.—The Osgood has been subdivided only on the east side of the Arch. These divisions in ascending order are three: Lulbegrud, Waco and Estill.

The *Lulbegrud* (August F. Foerste, 1906), named from Lulbegrud Creek, boundary of Clark and Powell Counties, is a shale from nothing to fifteen feet thick.

The *Waco* (August F. Foerste, 1906), named from a village in Madison County, is mingled limestone and shale. Over a considerable area in Madison, Estill and Powell Counties there is a persistent layer of limestone about two feet thick at the base of this formation. It has on its surface peculiar raised markings, radial in design, by which it may be identified. The Waco in this region has yielded a rich fossil fauna which is remarkable in having its closest resemblance to that of the Silurian in the Swedish province of Gotland and to the Wenlock of England and Wales. Characteristic fossils of this bed are the corals *Arachnophyllum mammillare distans, Arachnophyllum granulosum, Favosites gothlandica, Lindstroemia lingulifera* and *Heliolites spongiosa.*

The *Estill* (August F. Foerste, 1906), named from Estill County, is a very friable shale. It may reach a thickness of 100 feet. Fossils are almost wanting. Splendid exposures of this shale may be seen on the Irvine-Winchester branch of the L. & N. Railroad east of Howards Creek. Exposures erode rapidly and are often devoid of vegetation, giving rise to bare knolls, as at Blue Banks in Estill County. The soils bedded on this bed are especially poor, being "crawfishy."

The Estill on the east side of the Cincinnati Arch is the top member of the Niagaran. The Onondaga limestone of the Devonian rests directly on it where the exposures are far out on the flanks of the Arch. As the axis is approached the Niagara section thins rapidly in all its members and it becomes increasingly difficult to identify a number of these.

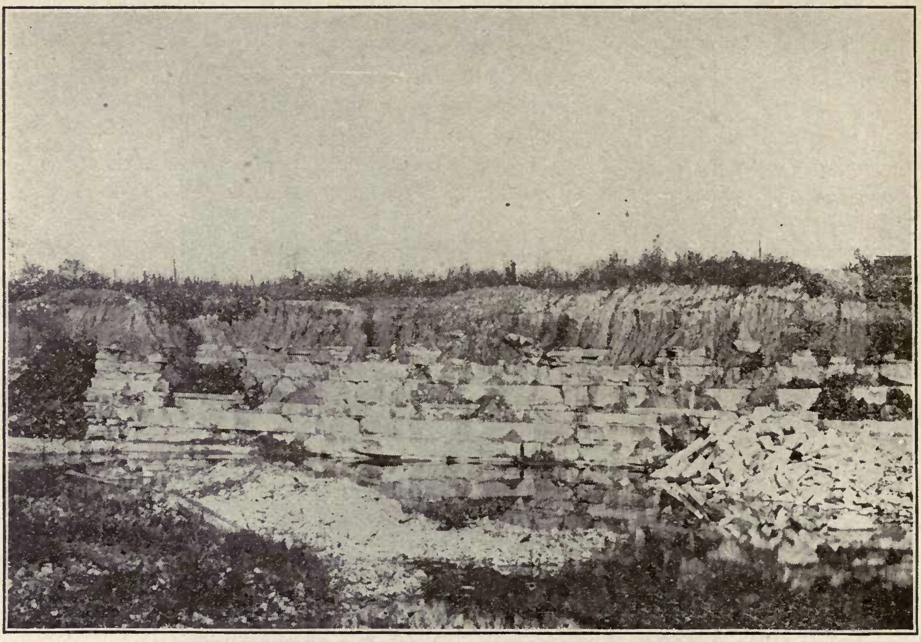
According to Professor Foerste this is evidence that the Cincinnati Arch was coming into existence at this time and affecting the deposition of the beds.

28. ESTILL SHALE UNDERLYING COLUMBUS LIMESTONE
Winchester-Irvine Branch of the Louisville and Nashville Railroad, Estill County. Photograph by A. M. Miller

LAUREL LIMESTONE

(August F. Foerste, 1896)

Characteristics, Correlation and Areal Distribution.—The Laurel limestone takes its name from a locality in Indiana. In Kentucky it is dolomitic and reaches a



29. QUARRY IN LAUREL DOLOMITE AT TUCKER, KENTUCKY
This shows the upper evenly bedded part of the Laurel which is quarried for building stone. Looking north. Photograph by Charles Butts

thickness of forty feet. Fossils are scarce, but the presence in it of a trilobite, *Dalmanites limulurus*, would tend to correlate it with the top of the Rochester or bottom of the Lockport of New York.

It is found well out on the west flank of the Cincinnati Arch from Trimble to Nelson County inclusive.

WALDRON SHALE

(Eldrod, 1882)

Characteristics, Fossils, Correlation and Distribution.—The name Waldron adopted by Professor Foerste from Eldrod is from an Indiana locality. It has a maximum thickness in Kentucky of fifteen feet. It is quite calcareous and magnesian, with a clay rather than a shale fracture. It is sparingly fossiliferous in Kentucky, yielding the brachiopods *Rhynchotreta cuneata, Dalmanella elegantula, Meristina maria, Spirifer radiatus, Spirifer crispus, Uncinulus stricklandi,* and the trilobite *Calymmene niagarensis.* These forms are also found in the overlying Louisville limestone. Characteristic forms which are known to occur in the Waldron of Indiana and Tennessee and which may be expected in the Waldron of Kentucky, are the sponge *Astylospongia praemorsa,* the crinid *Eucalyptocrinus crassus,* the gastropod *Platyostoma niagarense,* and the brachiopods *Whitfieldella nitida* and *Bilobites bilobus*—the latter possibly the smallest brachiopod known.

The above assemblage of fossils would seem to place the bed within the Lockport of New York. Its distribution in Kentucky is about the same as that of the Laurel limestone.

Disconformity at the Top of the Waldron in Kentucky and Indiana.—In Kentucky and Indiana there is a hiatus at the top of the Waldron which is supplied in Tennessee by about 270 feet of limestone intervening between this formation and the Louisville limestone.

LOUISVILLE LIMESTONE

(August F. Foerste, 1897)

Lithological Characters, Fossils and Correlation.—The name "Louisville" was given to this formation on account of the extensive quarries which are in it in the vicinity of that well known city. It is a fine-grained, thick-bedded, magnesian limestone from forty to 100 feet thick. It forms the top of the Silurian in northwestern Kentucky and neighboring portions of Indiana. The bed is highly fossiliferous, yielding in addition to those it has in common with the Waldron such characteristic forms as the sponge *Astraeospongia meniscus,* the brachiopods *Conchidium nisius, Pentamerus oblongus, Gypidula knotti, Spirifer foggi,* and a rich assemblage of corals belonging to the genera *Alveolites, Blothrophyllum, Cladopora, Cystiphyllum, Diphyphyllum, Favosites, Halysites, Heliolites, Lyellia, Ptychophyllum, Strombodes, Zaphrentis,* and others.

Characteristic trilobites are *Bumastic ioxus* and *Illaenus congerus.* This assemblage of fossils would correlate the Louisville with the upper part of the Lockport limestone of New York.

THE NIAGARAN AS A WHOLE IN KENTUCKY

Areal Distribution.—The Niagaran rocks in the State form two belts, converging and narrowing from Mason and Trimble Counties on the northeast and northwest respectively toward Boyle County on the south. These belts are from eight to ten miles across at their widest points. On the east side of the Cincinnati Arch the Niagaran passes through eastern Mason, Fleming, Bath, Montgomery, Clark, Madison and Garrard Counties. On the western side of the Arch it passes through western Trimble, central Oldham, eastern Jefferson and Bullitt, and southern Nelson Counties. From western Marion to eastern Lincoln—a distance of about fifty miles—it is virtually wanting where due in outcrop. In this fifty-mile stretch the Devonian with few exceptions rests directly on the Ordovician.

An interesting outlier of Niagaran well within the boundary of the Bluegrass is Jeptha Knobs in Shelby County, forming, according to Marius Campbell, "a monadnock on the Lexington Peneplain." It is a prominent elevation plainly seen to the south and east by a traveler on the Chesapeake and Ohio Railroad between Shelbyville and Christiansburg. It carries on top Niagaran with the chert waste of the Devonian scattered over it.

Soils of the Niagaran.—The Niagaran in Kentucky, on account of the magnesian character of its limestones and the predominance of clay, gives rise by decay to indifferent soils. They incline to be "sobby," being locally known as "crawfish land." The topography is rather flat.

Economic Products.—The Niagara shales (Crab Orchard shales of William Linney, 1882) contain on the east side of the Cincinnati Arch much secondary crystallized gypsum (selenite) and sulphate of magnesia (epsom salts). It is the latter which, by impregnation, gives the reputed medicinal value to the water from wells and springs in the vicinity of Crab Orchard, Lincoln County. By evaporation of this water the well-known Crab Orchard salts are made.

The limestones—especially those belonging to the Louisville member—furnish valuable building stone.

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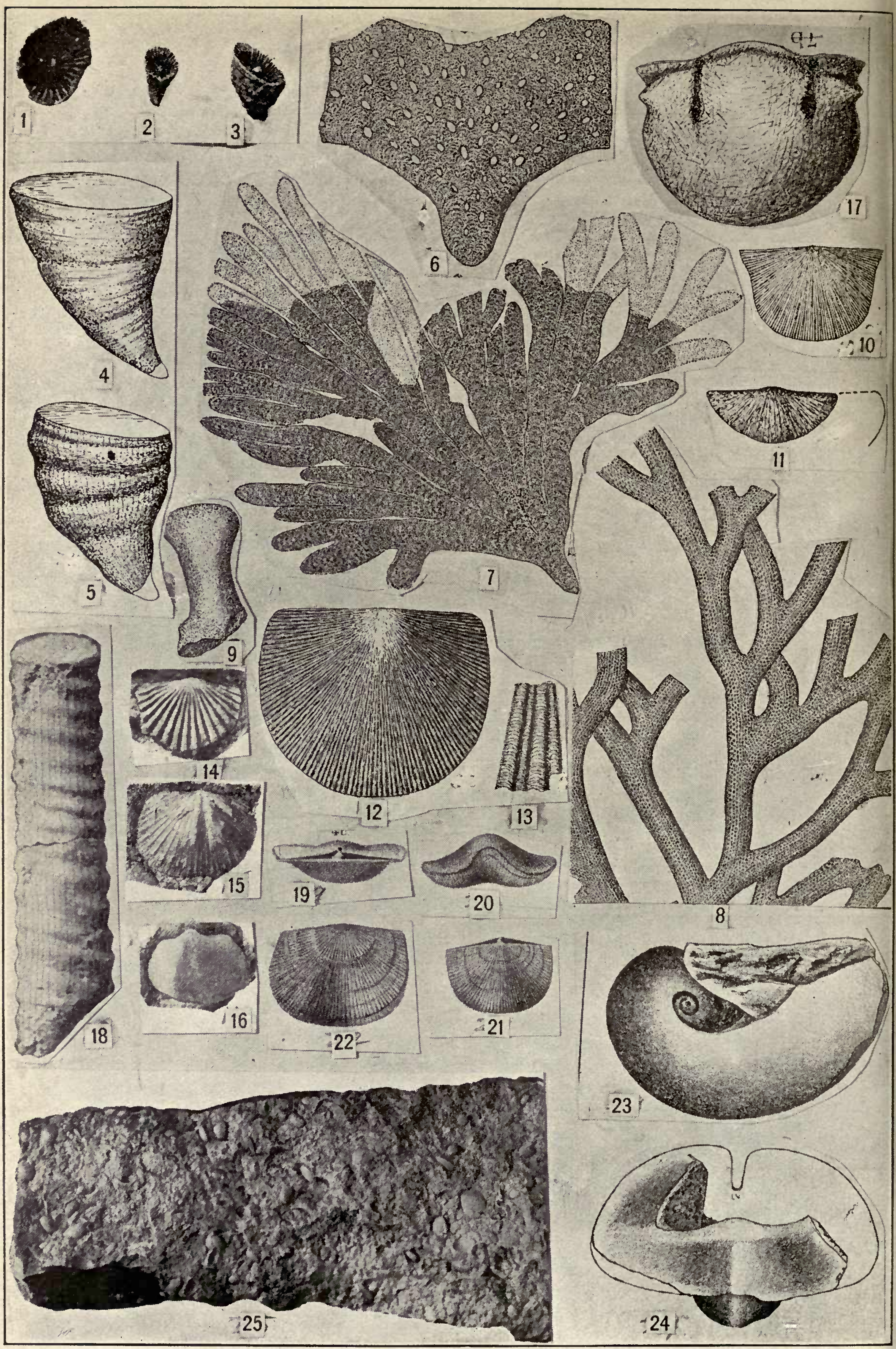

PLATE 30

30. FOSSILS FROM THE SALUDA AND BRASSFIELD BEDS

A reproduction of Plate 23 in "Geology of Jefferson County," by Charles Butts

1-3. *Lindstroemia gainsei* (Davis) after Davis: a horn coral characteristic of the Brassfield bed.

4-5. *Zaphrentis celator daytonensis* Foerste, after Foerste: a horn coral common in the Brassfield bed.

6. *Clathropora frondosa clintonensis* Hall and Whitfield, after Foerste: a bryozoan characteristic of the Brassfield bed.

7. *Phaenopora multifida* (Van Cleve) Hall after Foerste: a bryozoan common in the characteristic of the Brassfield bed.

8. *Pachydictya bifurcata* (Van Cleve) Hall, after Foerste: a bryozoan common in the Brassfield bed.

9. *Hallopora magnopora* (Foerste), after Foerste: a bryozoan common in the Brassfield bed.

10. *Strophonella striata* (Hall), after Foerste; brachial valve: a brachiopod common in the Brassfield bed.

11. *Plectambonites transversus prolongatus* Foerste, after Foerste: a brachiopod common in and characteristic of the Brassfield bed.

12-13. *Schuchertella tenuis* (Hall), after Foerste; 12, pedicle valve, natural size; 13, a few plications enlarged: a large brachiopod characteristic of the Brassfield bed.

14-15. *Orthis flabellites* Foerste; 14, exterior of a valve; 15, exfoliated valve: a brachiopod common in the Brassfield bed.

16. *Triplesia ortoni* Meek; exterior of pedicle valve: a brachiopod diagnostic of the Brassfield bed.

17. *Illaenus daytonensis* Hall and Whitfield, after Foerste; top-view of head: a trilobite common in and characteristic of the Brassfield bed.

18. *Dawsonoceras hammeli* Foerste: an orthoceratite of the Saluda bed.

19-22. *Strophomena sulcata* (Vernuel); 19, cardinal area; 20, front; 21, brachial valve; 22, pedicle valve: a brachiopod of the Saluda bed.

23-24. *Bellerophon mohri* Miller, after Ulrich: a gastropod of the Saluda bed.

25. Ostracods in limestone: a characteristic specimen from the Hitz member of the Saluda bed.

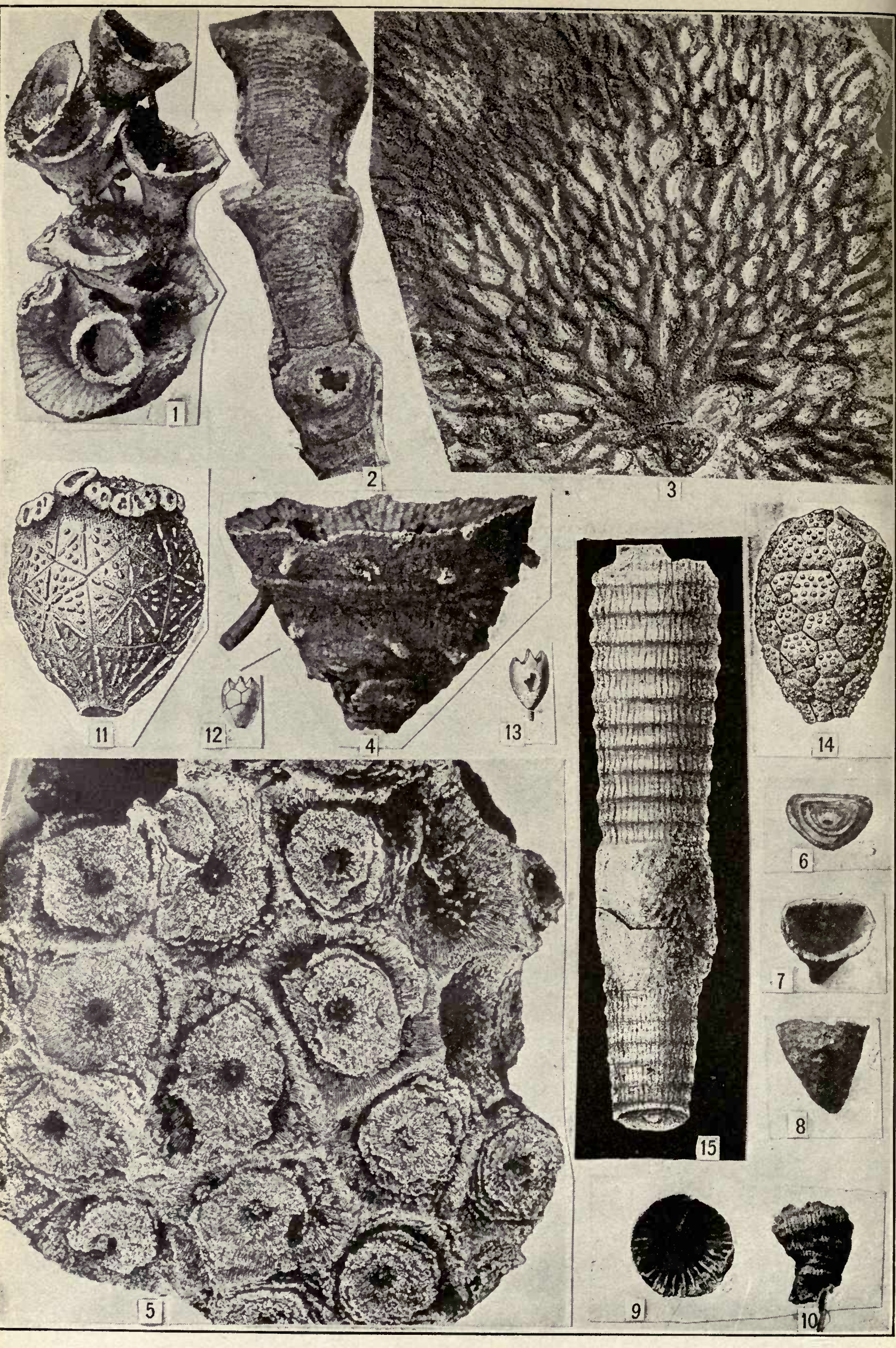

PLATE 31

31. FOSSILS FROM THE OSGOOD AND LOUISVILLE BEDS

A reproduction of Plate 29 in "Geology of Jefferson County," by Charles Butts

1. *Ptychophyllum stokesi* Edwards and Haime, after Davis: a horn coral of the Louisville bed.

2. *Amplexus shumardi* Edwards and Haime, after Davis: a horn coral of the Louisville bed.

3. *Cladopora reticulata* Hall, after Davis: a branching coral diagnostic of the Louisville bed.

4. *Omphyma verrucosa* Rafinesque and Clifford, after Davis: a horn coral common in and characteristic of the Louisville bed.

5. *Strombodes striatus* D'Orbigny, after Davis: a compound horn coral diagnostic of the Louisville bed.

6-8. *Calceola attenuatus* Lyon, after Davis: a horn coral of the Louisville bed.

9-10. *Cyathophyllum radicula* Rominger, after Davis: a horn coral of the Louisville bed.

11. *Caryocrinites indianensis* S. A. Miller, after S. A. Miller: a cystid characteristic of the Louisville bed.

12-13. *Stephanocrinus gemmiformis* Hall: a crinid rare in the Osgood bed.

14. *Holocystites parvulus* S. A. Miller, after S. A. Miller: a cystid rare in the Osgood bed.

15. *Dawsonoceras annulatum* Sowerby, after Clarke and Ruedemann: an orthoceratite, rare, but a characteristic fossil of the Osgood bed.

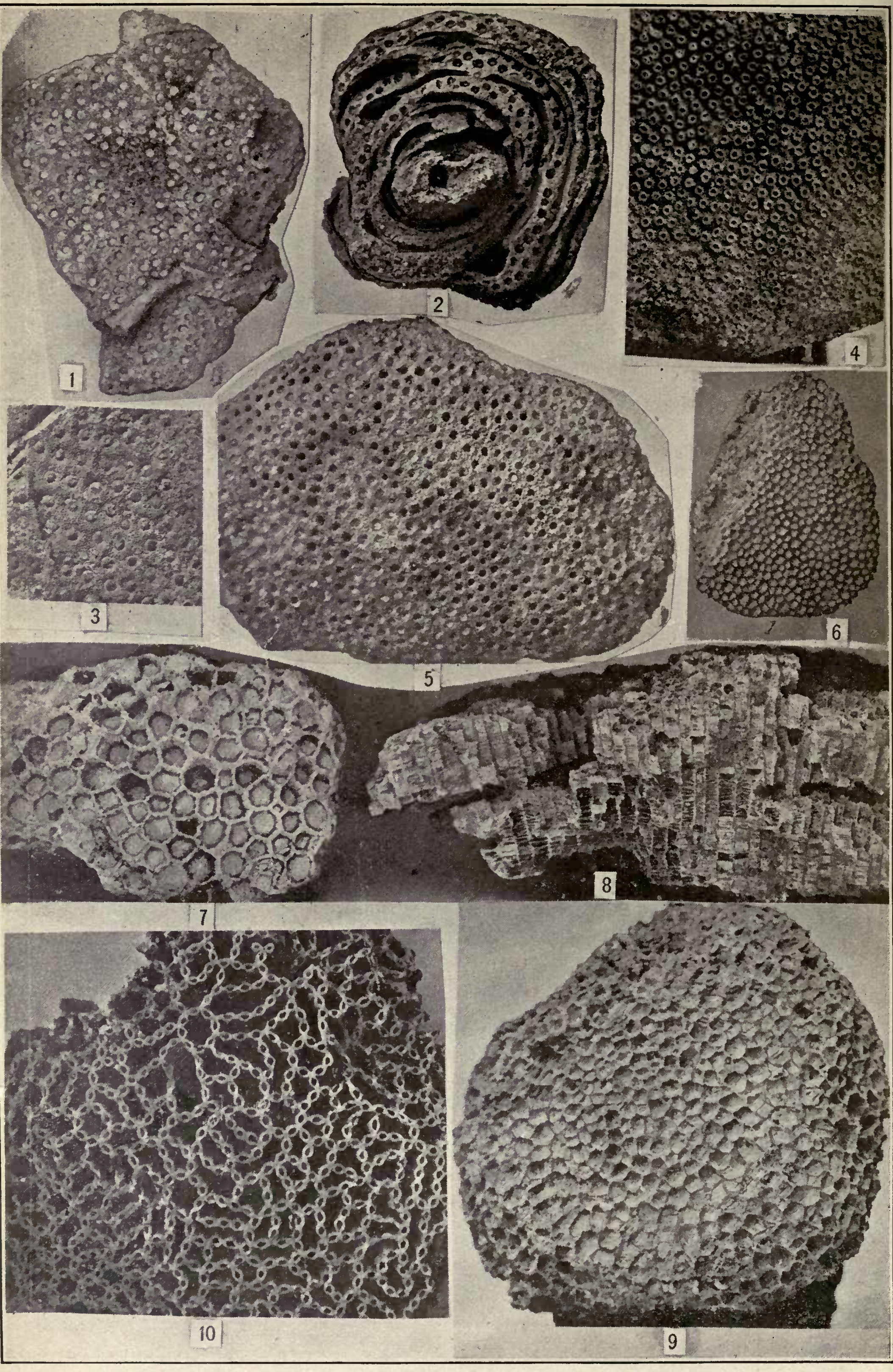

PLATE 32

32. FOSSIL CORALS FROM THE LOUISVILLE BED

A reproduction of Plate 30 in "Geology of Jefferson County," by Charles Butts

1-2. *Heliolites interstinctus* Linnaeus, after Davis; 1, top; 2, bottom: a compound coral (*Octocorala?*) common in the Louisville bed. Occurs also rarely in the Brassfield bed.

3. *Heliolites megastoma* McCoy, after Davis: a compound coral (*Octocorala?*) of the Louisville bed.

4. *Lyellia papillata* Rominger: a compound coral (*Octocorala?*) of the Louisville bed.

5. *Plasmopora follis* Edwards and Haime, after Davis: a compound coral (*Octocorala?*) characteristic of the Louisville bed.

6. *Thecia major* Rominger, after Davis: a compound coral (*Octocorala?*) characteristic of the Louisville bed.

7-8. *Favosites favosus* Goldfuss, after Davis; 7, top; 8, side: a honeycomb coral of the Louisville bed.

9. *Favosites forbesi* Edwards and Haime, after Davis: Louisville bed.

10. *Halysites catenulatus* Linnaeus, after Davis: a chain coral abundant in the Louisville bed and characteristic of the Silurian.

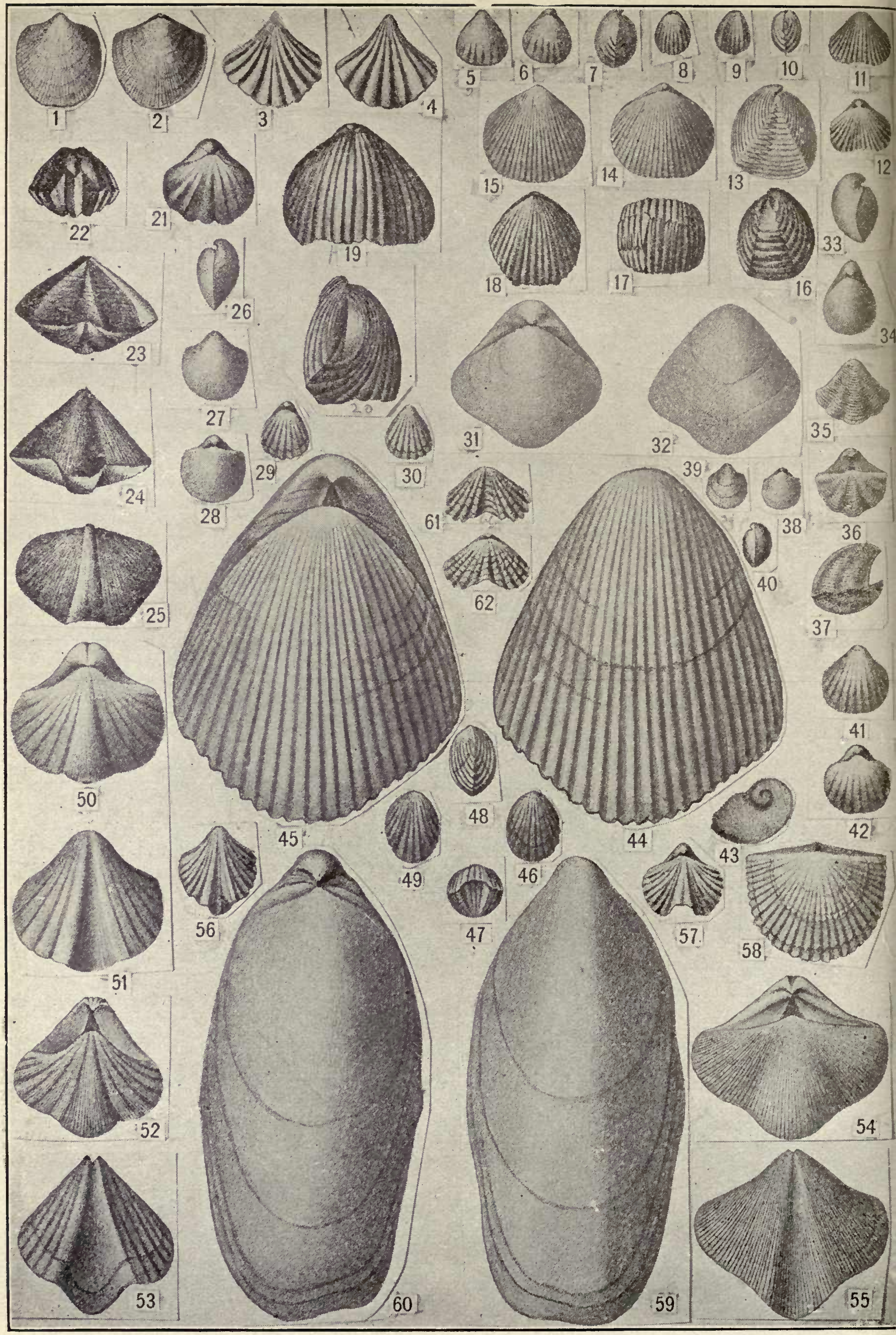
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PLATE 33

33. FOSSIL BRACHIOPODS FROM ROCKS OF NIAGARA AGE

A reproduction of Plate 31 in "Geology of Jefferson County," by Charles Butts

All the specimens figured except 58 are after Nettleroth

1-2. *Atrypa reticularis niagarensis* Nettelroth; 1, pedicle valve; 2, brachial valve: distinguished by its smaller size from the Devonian form.

3-4. *Rhynchotreta cuneata americana* Hall; 3, brachial valve; 4, pedicle valve: Louisville and Osgood beds.

5-7. *Camarotoechia (?) indianensis* Hall; 5, pedicle valve; 6, brachial valve; 7, side: Louisville bed.

8-10. *Camarotoechia (?) acinus* Hall; 8, brachial valve; 9, pedicle valve; 10, side: Louisville bed.

11-12. *Anastrophia internascens* Hall; 11, brachial valve; 12, pedicle valve: Louisville bed.

13-18. *Wilsonia saffordi* (Hall); side, brachial and pedicle views of two different forms: Louisville bed.

19-20. *Uncinulus stricklandi* Sowerby; 19, brachial valve; 20, side: Louisville bed.

21-22. *Gypidula nucleus* Hall and Whitfield; 21, brachial valve; 22, front: Louisville bed.

23-24. *Cyrtia exporrecta* Wahlenberg; 23, cardinal end; 24, pedicle valve; 25, brachial valve: Louisville bed.

26-28. *Dalmanella elegantula* Dalman; 26, profile; 27, pedicle valve; 28, brachial valve: Louisville bed.

29-30. *Rhynchospira (?) helena* Nettleroth; 29, brachial valve; 30, pedicle valve: Louisville bed.

31-32. *Meristina maria* Hall; 31, brachial valve; 32, pedicle valve: Louisville bed.

33-34. *Whitfieldella nitida* (Hall); 33, profile; 34, brachial valve: Louisville bed.

35-37. *Spirifer crispus* Hall; 35, pedicle valve; 36, brachial valve; 37, profile: Osgood and Louisville beds.

38-40. *Rhipidomella hybrida* Sowerby; 38, brachial valve, 39; pedicle valve; 40, profile: Osgood and Louisville beds.

41-42. *Gypidula knotti* Nettleroth; 41, pedicle valve; 42, brachial valve: Louisville bed.

43. *Diaphorostoma niagarense* Hall; top view of young or small specimen: Osgood and Louisville beds.

44-45. *Conchidium nysius* (Hall and Whitfield); 44, pedicle valve; 45, brachial valve: Louisville bed.

46-49. *Camarotoechia pisa* (Hall and Whitfield); 46, brachial valve; 47, front; 48, profile; 49, pedicle valve: Louisville bed.

50-51. *Spirifer (Eospirifer) foggi* Hall; 50, brachial valve; 51, pedicle valve: Louisville bed.

52-53. *Spirifer (Eospirifer) rostellum* Hall and Whitfield; 52, brachial valve; 53, pedicle valve: Louisville bed.

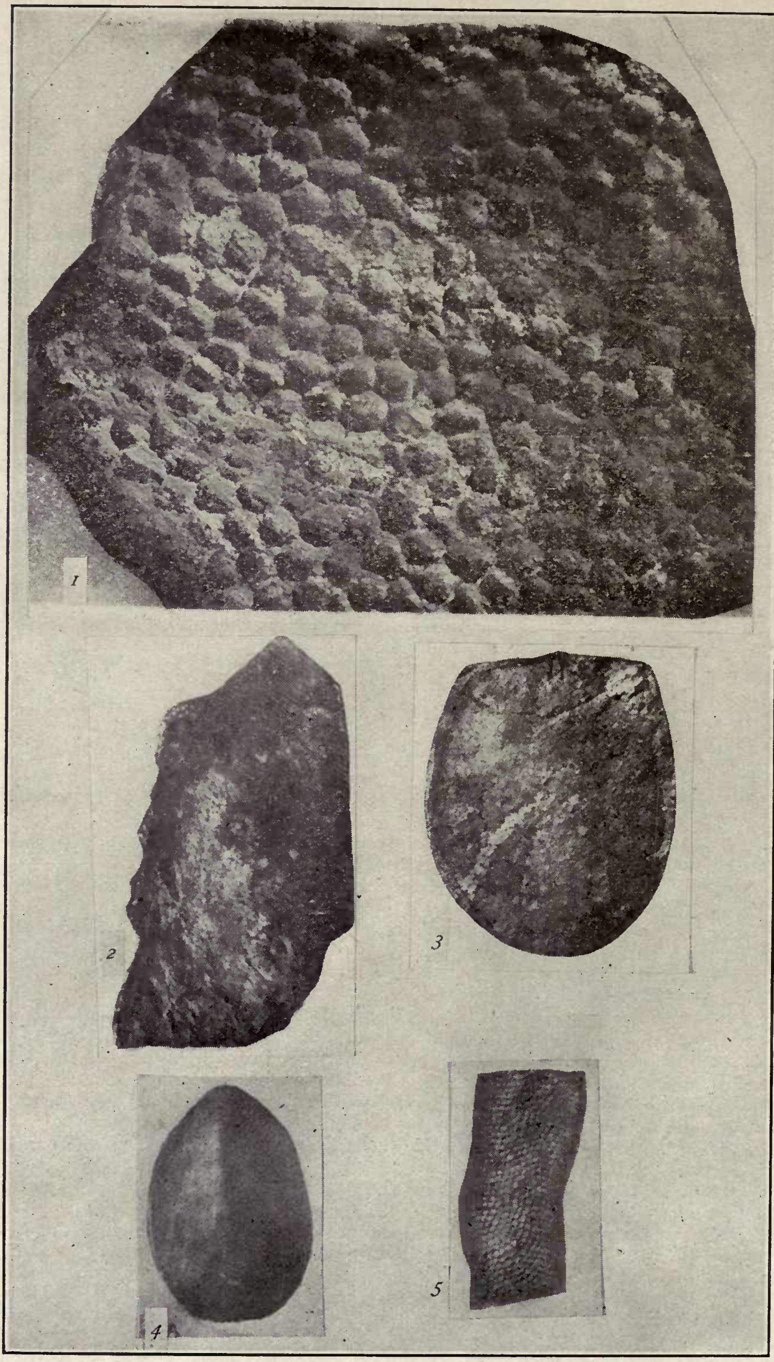
54-55. *Spirifer (Eospirifer) radiatus* Sowerby; 54, brachial valve and hinge; 55, pedicle valve.

56-57. *Atrypa calvina* Nettleroth; 56, pedicle valve; 57, brachial valve and hinge.

58. *Orthis nettelrothi* Foerste; brachial valve: Louisville bed.

59-60. *Pentamerus cylindrica* Hall and Whitfield; 59, pedicle valve; 60, brachial valve: common and characteristic of the Louisville bed.

61-62. *Orthis (?) rugiplicata* Hall and Whitfield; 61, pedicle valve; 62, brachial valve: a rare fossil in the Louisville bed.



34. FOSSILS FROM THE SILURIAN ON THE EAST SIDE OF THE CINCINNATI ARCH

34. FOSSILS FROM THE SILURIAN ON THE EAST SIDE OF THE CINCINNATI ARCH

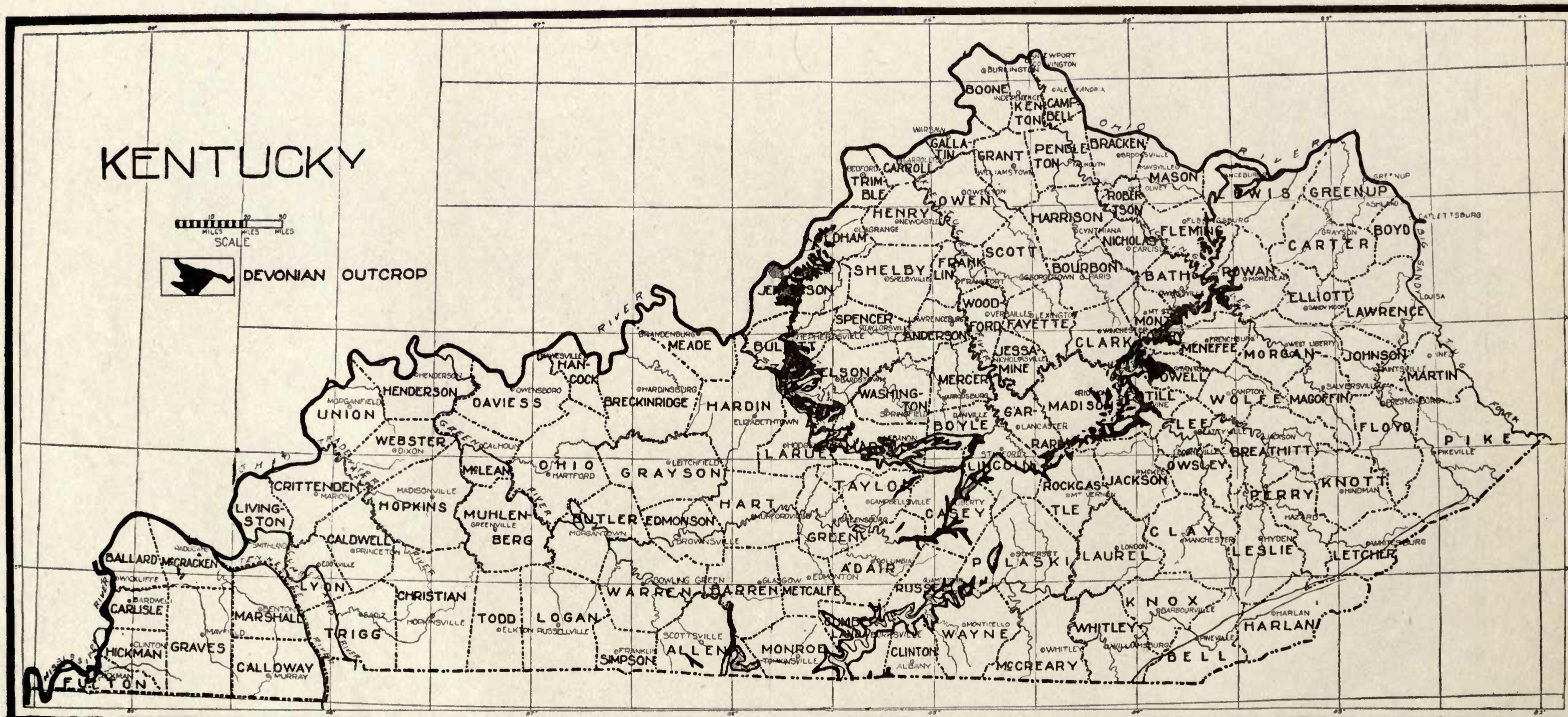
1. *Favosites gothlandica* Lamarck, after Foerste: a favosite coral from the Waco limestone.

2. *Strombodes mammilaris distans* (Foerste), after Foerste: a compound horn coral from the Waco limestone.

3. *Stricklandinia norwoodi* Foerste, after Foerste: the cast of a pedicle valve of a brachiopod diagnostic of the Oldham limestone.

4. *Whitfieldella subquadrata* Foerste, after Foerste: the cast of a pedicle valve of a brachiopod diagnostic of the Brassfield (Kentucky Clinton) limestone.

5. *Meekopora bassleri* Foerste, after Foerste: a bryozoan highly characteristic of the Waco limestone.



35. LOCATION OF DEVONIAN OUTCROP

CHAPTER IV

DEVONIAN SYSTEM

Disconformities.—The Devonian (Murchison and Sedgwick, 1829; named from Devonshire, England) in Kentucky is bounded by disconformities, and there is an inter-disconformity between its two principal members. The Niagaran strata of Mid-Silurian age is immediately overlaid by Onondaga strata of Mid-Devonian age, indicating a stratigraphic gap between, which must stand for a considerable time interval, since in Southern Pennsylvania this is represented by about 2,000 feet of strata. It was during this interval that an uplift of considerable extent took place in the Ohio Valley, accompanied by a bowing of the strata in the Cincinnati Geanticline. This caused the region to emerge from the sea and to undergo extensive erosion. The period of erosion terminated in a peneplaination which completely truncated the Cincinnati Arch, so that, in the succeeding Middle and Upper Devonian submergence, sediments were laid down unobstructedly and with great horizontality across the Arch.

Subdivisions and Correlations.—The Devonian in Kentucky consists of a lower limestone and an upper shale series with a disconformity between them. The limestone (Onondaga and Hamilton) is Mid-Devonian, while the shale (Genesse) is upper Devonian. The limestone was included by Marius Campbell, in his *Richmond Folio,* with the whole of the Silurian, under the name "Panola Formation." The name was derived from a station on the Louisville and Atlantic Railroad in Madison County.

Classification of the Devonian in Kentucky.

Series	*Stage*	*Substage*	*Thickness in Feet*
U. Devonian	Genesse	Ohio (New Albany and Chattanooga in part)	25—245
M. Devonian	Hamilton	Delaware (Sellersburg)	0— 24
	Onondaga	Columbus (Jeffersonville Boyle)	0— 35

MIDDLE DEVONIAN

COLUMBUS LIMESTONE

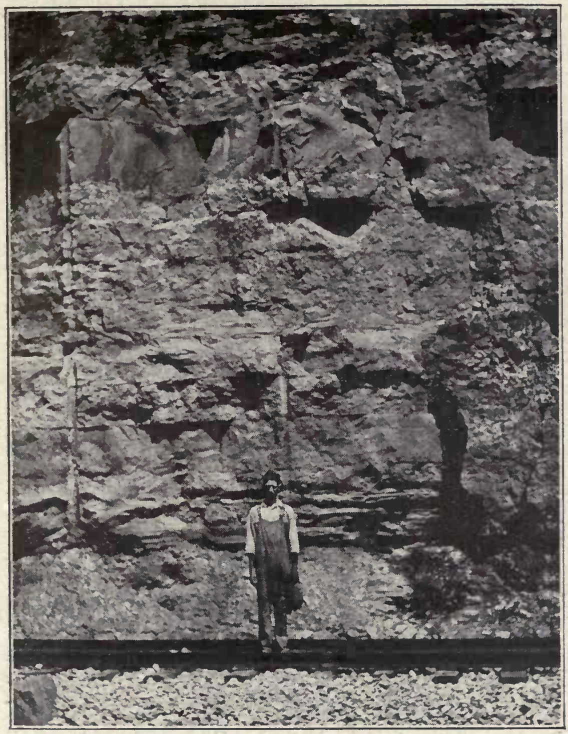
(W. W. Mather, 1859. Named from Columbus, Ohio)

Characteristics, Synonyms and Correlation.—The Columbus is a massive, cherty magnesian limestone having a maximum thickness in outcrop of about twenty-five feet. It is frequently quite porous and then under cover may form a reservoir for oil, as in the Irvine Oil Field. Near Preston Station, in Bath County, it has been formed by replacement into an oolitic siderite, which by weathering has been converted into a limonite—the famous iron ore of the Preston Ore Bands (see account on page —, under head of Iron Ore). This is the formation which E. M. Kindle in 1899 named "Jeffersonville" from that town in Indiana, and Professor August F. Foerste in 1906 named "Boyle" from Boyle County, Kentucky. It is the equivalent, at least in part of the Onondaga (James Hall, 1839) of New York.

Fossils.—Especially characteristic of this formation are the brachiopods *Spirifer gregarius, Spirifer (Delthyris) acuminatus, Stropheodonta hemispherica,* and a large form of *Atrypa reticularis;* also the gastropods *Turbo shumardi, Platyceras dumosum,* and the lamellibranch *Conocardium cuneus.* In number and perfection of preservation, however, the corals outrank all other fossils in this formation. At the Falls-of-the-Ohio at Louisville, especially, they crowd the strata, forming, indeed, what must have been in the Devonian Sea at that point a veritable coral reef. According to Mr. Charles Butts, species especially characteristic are: *Zaphrentis prolifica, Blothrophyllum cinctutum, Favosites hemisphericus* and *Cladopora bifurca.*

Areal Distribution.—The Columbus appears to be the only Devonian Limestone represented on the east side of the Cincinnati Arch. Here it may be found outcropping in vertical cliffs underlaid by the Estill shale of the Niagara. It does not as a rule form a good soil district: There is, however, one notable exception, the good land known as "Indian Fields" or "Indian Oil Fields" in Clark County—an exceptionally level and fertile tract—being bedded on this limestone.

On the crest of the Cincinnati Arch, where south of the Bluegrass the Devonian outcrop crosses from one flank to the other, the Columbus is generally unaccompanied by any Silurian. The Columbus is found in Taylor, Adair and Pulaski Counties in isolated patches, con-



36. COLUMBUS LIMESTONE (COMPLETE SECTION) UNDERLYING BASE OF OHIO SHALE
On Winchester-Irvine Branch of the Louisville and Nashville Railroad, Estill County. Photograph by A. M. Miller

stituting *inliers*. It is absent, where due, in the Cumberland River Devonian outcrop.

On the western flank of the Arch it is found as far north as Oldham County. In Jefferson County it has extensive development, the outcrop crossing the Ohio at Louisville and forming there the main portion of the ledge which has produced the Falls-of-the-Ohio. It was the obstruction offered to navigation by this ledge which, by necessitating the transfer of cargoes, resulted in the rise here of a populous city. South of the Bluegrass encircling outcrop of Devonian on the west flank of the Arch no outcrops of Columbus limestone are met with until

37. **CONTACT OF LOUISVILLE AND COLUMBUS (JEFFERSONVILLE) LIMESTONES**

Quarry on Beargrass Creek in the eastern part of Louisville, showing these formations. The line of contact is near the middle of a massive layer close to the top of quarry. Photograph by Charles Butts.

southeastern Allen County is reached. Here, on Big Barren River and Long Creek, the rise of the strata again brings up massive cliff-forming ledges of this and possibly of the next overlying limestone. It is here underlaid by Niagara. It is, where under cover, the chief oil-bearing sand of this region, as it is of other sections of the State.

38. BASAL CORALIFEROUS LAYERS OF COLUMBUS (JEFFERSONVILLE) LIMESTONE IN BED OF OHIO RIVER

This bare expanse of limestone extends for several hundred yards west of the J. M. and I. (middle) bridge, and its surface is covered with a mat of fossil corals. Looking north. Photograph by Charles Butts.

39. MIDDLE AND LOWER PART OF THE COLUMBUS (JEFFERSONVILLE) LIMESTONE

A man is sitting on the top of the lower especially coraliferous layers. Find the man. The heavy layers above are largely made up of Stromatopora. Indiana shore of Ohio River, one mile northwest of J. M. and I. (middle) bridge, looking west. Photograph by Charles Butts.

DELAWARE LIMESTONE

(Edward Orton, 1888. Named from Delaware, Ohio)

Synonym and Correlation.—The Delaware limestone occurring at the Falls-of-the-Ohio was separated from the rest of the Devonian limestone there by Kindle in 1899 and called by him the "Sellersburg," from a town of that name in the vicinity. Its fossils show it to be of Hamilton (Lardner Vanuxem, 1840), New York age.

Fossils.—Characteristic fossils of the Sellersburg are the brachiopods *Spirifer oweni* (*granulosus*), *Spirifer fornacula* (*euruteines*), the coral *Heliophyllum juvene*, and the lamellibranch *Paracyclas lirata*.

Subdivisions.—Charles Butts in his "Report on Jefferson County," divided the Sellersburg in ascending order into two members—Silver Creek and Beechwood.

The *Silver Creek* (Charles Butts, 1915), named from a creek in Jefferson County, is a thick-bedded, aluminous, magnesian limestone, reaching in some cases a thickness of eight or ten feet. It is the "cement rock" which is calcined and ground to make natural cement known by

40. EXPOSURE OF SILVER CREEK LIMESTONE MEMBER

This is about eighteen inches thick, with the *Spirifer acuminatus* zone of the Columbus (Jeffersonville) limestone below the Beechwood limestone members above. Hammer rests upon the *Spirifer acuminatus* bed. Electric railway cut on Payne Street near Sturgus, looking northwest. Photograph by Charles Butts.

the trade name "Louisville cement." The Silver Creek is moderately fossiliferous.

The *Beechwood* (Charles Butts, 1915), named from a station on the Louisville & Nashville Railroad in Jefferson County, is a crinoidal limestone, about five feet thick. The crinoid which has contributed most stem-plate material to the formation of the rock is *Dolatocrinus tuberculatus*.

UPPER DEVONIAN

OHIO SHALE

(N. S. Shaler, 1877. Named from the Ohio Valley)

Synonyms and Correlations.—The name "New Albany shale" was applied by E. T. Cox in 1875, and the name "Chattanooga shale" was applied by C. W. Hayes in 1890, to what was then thought to be the Devonian black shale of Indiana, Tennessee and Kentucky. It is now known that for the region where the terms were applied some at least of the black shale at the top is the Sunbury of Ohio—a Mississippian bed. At Chattanooga all this bed may be Sunbury. The term *Ohio shale*, as here used,

41. OHIO-SUNBURY SHALE
Neatsville Ford of Green River, Adair County. Photograph by A. M. Miller

is meant to cover only the Devonian portion of the bed, even where the two shales are united.

This Devonian shale is about the equivalent of the Genessee (Lardner Vanuxem, 1842) of New York.

Characteristics and Fossils.—The shale of this bed is very black and fissile. The black color is due to bituminous matter. On account of its black color and marked cleavage it is commonly known as the "black slate."

The percentage of oil in it is so high—approaching four or five per cent.—that it burns somewhat readily. For this reason it often catches fire in railroad cuts and smoulders away for weeks or months, frying out the oil by a natural distillation process, and suggesting thereby that the time may come when oil will be obtained from this shale commercially by distillation in retorts.

It is highly probable that most of the oil obtained from wells in Kentucky was once incorporated in this shale and has been driven from it to closely adjacent porous strata above or below by differential capillary attraction of small and large pore spaces acting upon oil and water. The shale contains considerable iron pyrites, and the oxidation of this mineral and subsequent other chemical reactions of its products mineralizes the water issuing from it. The belt of outcrop surrounding the Bluegrass Region can be pretty well traced by enumerating mineral springs of greater or less medicinal repute situated on or at the base of this formation. In thickness the shale varies from about 240 feet in the northern part of the State to less than twenty-five feet thick in the southern part.

Fossils are rare in the formation. These consist of plant remains (minute spores throughout the shale), of brachiopods, a pteropod, and a fish.

Altogether the evidence for a fresh water origin of the shale is quite strong. The brachiopods are *Lingulas*, which are rather brackish water forms. Besides the spores of plants other evidence of plants, and in this case of land plants, exist in the presence in the shale of silicified trunks of trees—*Dadoxylon* being the most common genus represented. The fish which is characteristic of this formation is *Dinychthys*, usually classed as a Dipnoian or lung fish. Remains of some unusually large specimens of this genus were found a number of years ago at Eastin's Mill in Clark County, at the Powell line.

Disconformities.—There is a pronounced disconformity at the bottom of this formation and usually a lesser one at the top. Evidence of the disconformity at the top is best seen in the more southern exposures—especially those on the saddle of the Cincinnati Arch between the Jessamine Dome in Kentucky and the Rutherford Dome in Tennessee.

In this region the shale frequently rests on the upper bed of the Ordovician, the hiatus here recorded representing all of Silurian and a portion of Devonian time. The writer has seen in the bottom layer of Black shale in the Cumberland River region an imprint of *Platystrophia lynx*, an upper Cincinnatian fossil. The imprint, a fossil of a fossil, was taken by the laying down disconformably Devonian mud on already thoroughly consolidated Ordovician fossiliferous limestone.

The disconformity at the top is evidenced by the thinning in a southward direction from Vanceburg of the interval between the Ohio shale and the Sunbury shale, until at a point in about the latitude of the Chesapeake and Ohio Railroad the two black shales (Sunbury and Ohio) come together and lithologically are indistinguishable. The hiatus here represents a portion of early Mississippian time. In these more southern situations the part of the Black shale which should be assigned to the Sunbury is about five feet. The plane of juncture between the Devonian and Mississippian is here within a bed which from top to bottom is a lithological unit.

Areal, Distribution, Topography and Soils.—In its outcrop surrounding the Bluegrass, a little outside the Silurian-Devonian limestone strip, the Ohio shale forms a belt of decidedly poor agricultural land. The formation constitutes the whole of a series of low knobs and the bases of higher knobs which are yet capped with the next formation above—the Waverly. These knobs and slopes support only a scrubby growth of timber, which to a traveler passing out from the Bluegrass is seen for the first time to be taking on the aspects of the mountains. Here will be seen small pines, and the first chestnut trees, also a great variety of oaks.

The main streams, such as the Licking, Red, and Kentucky Rivers, in crossing this strip have excavated wide valleys, but these bottoms are wet and "crawfishy." Unless drained they do not produce well.

South of the Bluegrass-encircling-Ohio-shale strip, the main outcrop of the Ohio shale is along the Cumberland River from Mill Springs south to the State line. In this region on account of its being so thin—not over twenty-five feet thick—and because it is exposed in the river valley walls, it has very little lateral surface extent. Other places in Southern Kentucky, where there are Ohio shale exposures, are in Allen County in the upper Big Barren River drainage; in Adair County in the upper Green River drainage; in Pulaski County—Fishing Creek area; in Taylor County—upper Robinson Creek.

There are also some exposures of Ohio shale along the western foot of the Pine Mountain Range where they constitute inliers on the upthrow side of the Pine Mountain thrust fault.

REFERENCES

Those listed at the end of the last chapter which treat of the Devonian in addition to the Silurian as follows: One each by Messrs. Butts, Campbell and Davis, two by Foerste and all of those by Linney.

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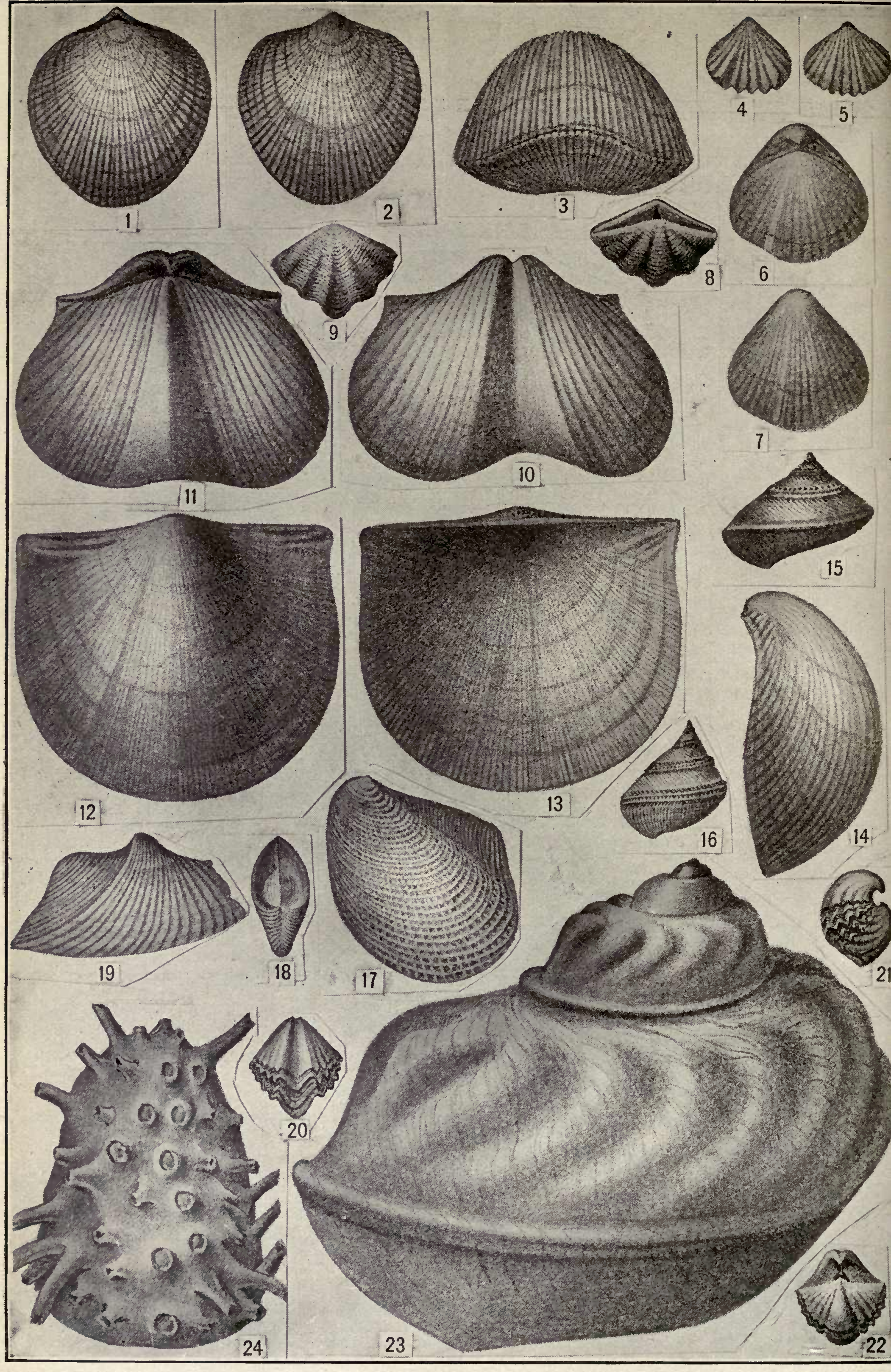

PLATE 42

42. FOSSILS FROM COLUMBUS (JEFFERSONVILLE) LIMESTONE

A reproduction of Plate 39 in "Geology of Jefferson County," by Charles Butts

All the specimens figured were taken from "Kentucky Fossil Shells," by Henry Nettleroth

1-3. *Atrypa reticularis Linnaeus;* 1, brachial valve; 2, pedicle valve; 3, front: a brachiopod which also ranges into the overlying Delaware (Sellersburg) limestone. Distinguished from the Niagara form by its larger size.

4-5. *Camaroteechia tethys* Billings; 4, pedicle valve; 5, brachial valve: a common brachiopod in this formation.

6-7. *Pentamerella pavillionensis* Hall; 6, brachial valve and hinge; 7, pedicle valve: a brachiopod.

8-9. *Spirifer raricosta* Conrad; 8, brachial valve and hinge; 9, pedicle valve: a rather rare brachiopod.

10-11. *Spirifer acuminatus* Conrad; 10, pedicle valve; 11, brachial valve and hinge: a common brachiopod in this formation especially near the top.

12-14. *Stropheodonta hemispherica* Hall; 12, pedicle valve; 13, brachial valve; 14, profile: a common brachiopod in this formation.

15. *Pleurotomaria sulcomarginata* Conrad: a gastropod confined to this formation.

16. *Pleurotomaria proceteri* Nettleroth: a gastropod confined to this formation.

17. *Actinopteria boydi* Conrad; left valve: a lamellibranch confined to this formation.

18-19. *Conocardium cuneus* Conrad; 18, hinge line side of both valves of a small specimen; 19, left valve: an odd shaped lamellibranch common in this formation.

20-22. *Spirifer gregarius* Clapp; 20 pedicle valve; 21, profile; 22, brachial valve with hinge: a brachiopod with pedicle valves commonly preserved in this formation.

23. *Turbo shumardi* Verneuil: a gastropod found occasionally in this formation.

24. *Platyceras dumosum* Conrad: a gastropod.

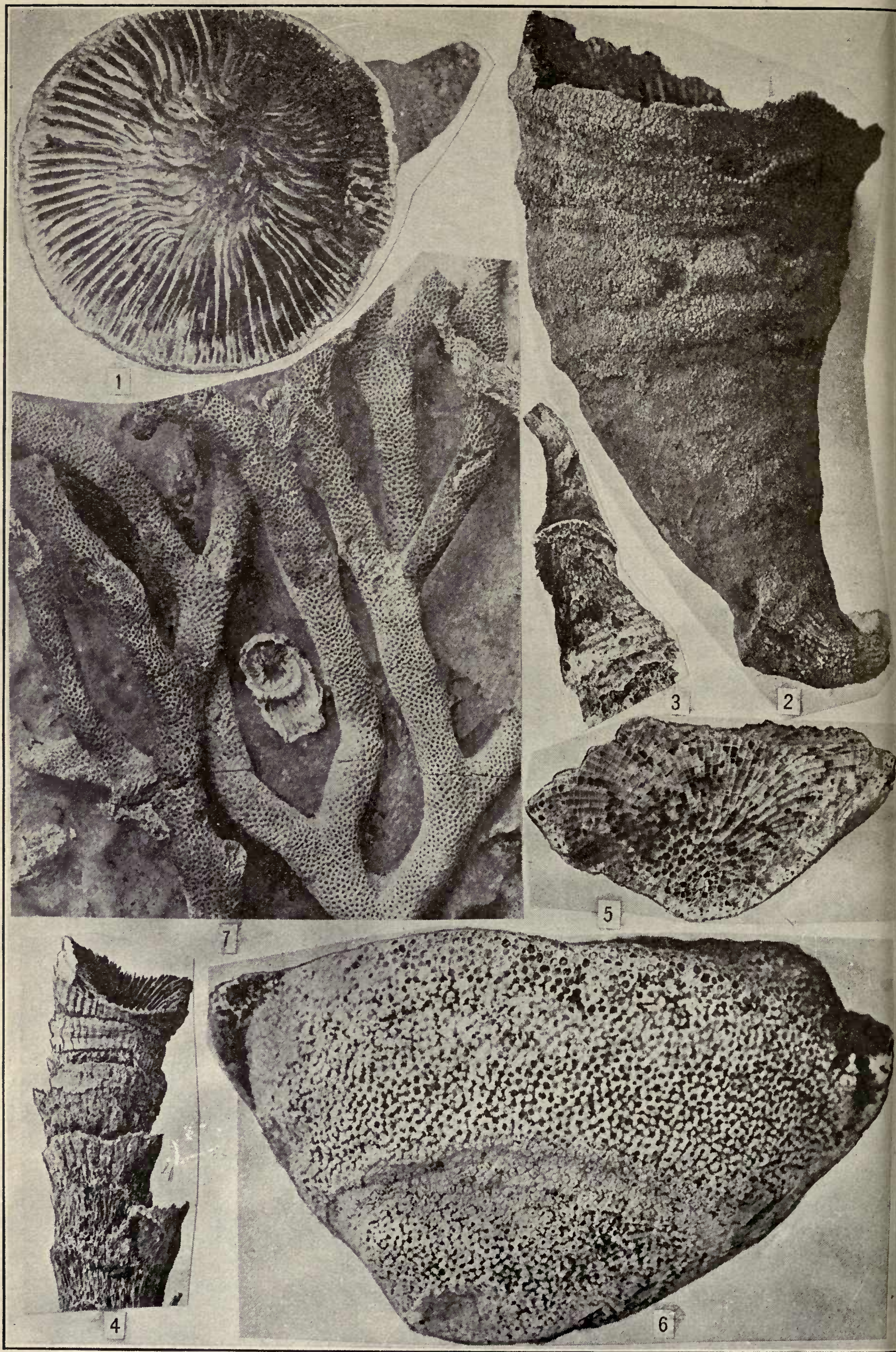

PLATE 43

43. FOSSIL CORALS FROM THE COLUMBUS (JEFFERSONVILLE) LIMESTONE

A reproduction of Plate 40 in "Geology of Jefferson County," by Charles Butts

All the specimens figured were taken from "Kentucky Fossil Corals," by W. J. Davis

1-2. *Zaphrentis prolifica* Billings; 1, top; 2, side: a horn coral.

3-4. *Blothrophyllum cinctutum* Davis; 3, lower end; 4, upper end, both from the side: a horn coral confined to this formation.

5-6. *Favosites hemisphericus* Troost; 5, a sectional view showing honeycomb structure; 6, view from the side in the position of growth: a common honeycomb coral.

7. *Cladopora bifurca* Davis: a branching coral very abundant in this formation.

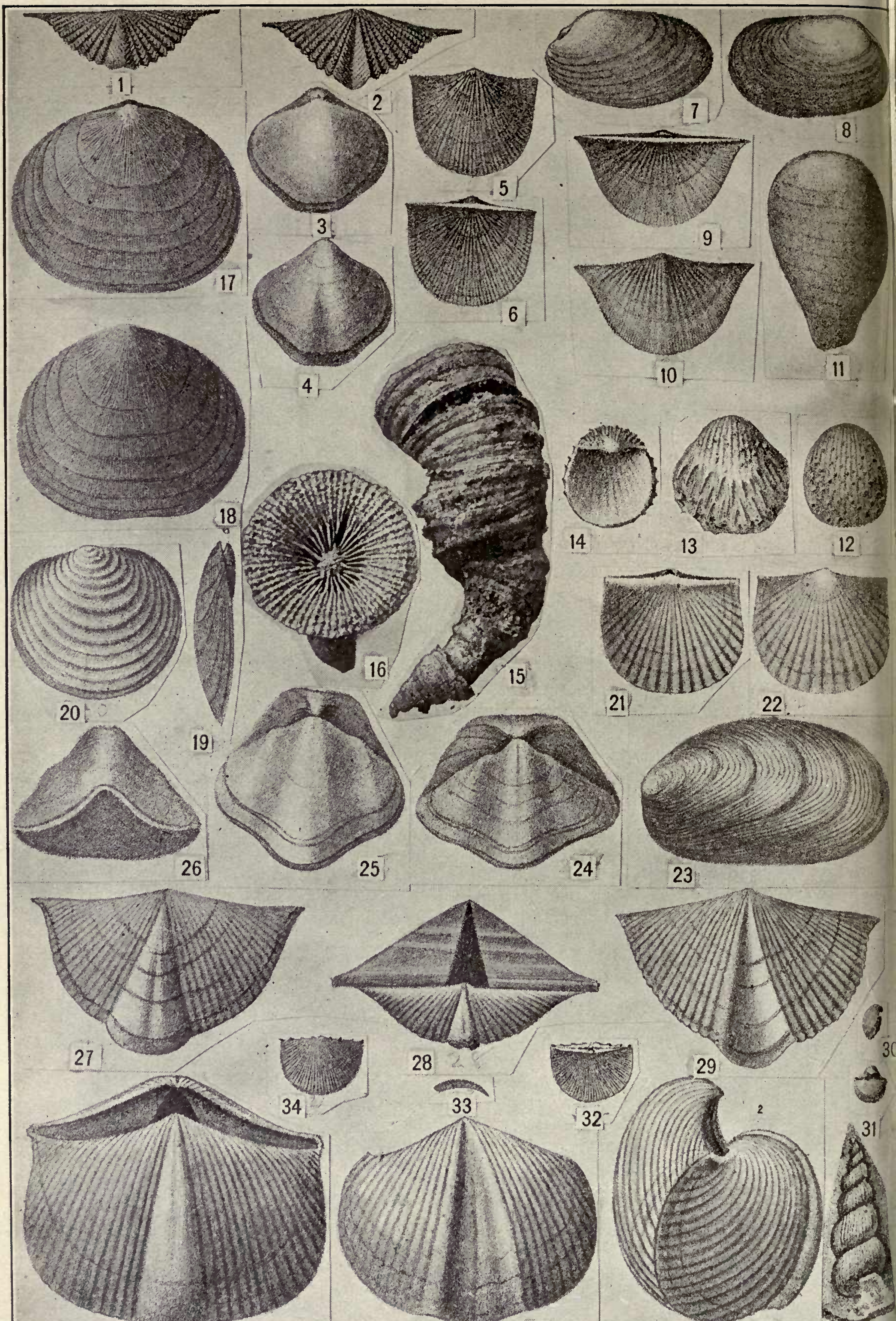
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PLATE 44

44. FOSSILS FROM THE DELAWARE (SELLERSBURG) LIMESTONE

A reproduction of Plate 45 in "Geology of Jefferson County," by Charles Butts

All the specimens figured except 15 and 16 were taken from "Kentucky Fossil Shells," by Henry Nettleroth

1-2. *Spirifer hobbsi* Nettelroth; 1, brachial valve; 2, pedicle valve: a brachiopod from the Beechwood member.

3-4. *Athyris fultonensis* Swallow; 3, brachial valve; 4, pedicle valve: a brachiopod common in both the Columbus and Delaware limestones.

5-6. *Stropheodonta demissa* Conrad; 5, pedicle valve; 6, brachial valve: a brachiopod common in both the Columbus and Delaware limestones.

7-8. *Clinopistha antiqua* Meek; 7, left valve; 8, right valve: a lamellibranch found in the Beechwood limestone member.

9-10. *Chonetes acutiradiatus* Hall; 9, brachial valve; 10, pedicle valve: a brachiopod common in the Beechwood member.

11. *Gomphoceras turbiniforme* Meek and Worthen: a cephalopod from the Beechwood member.

12-14. *Productella subculeata cataracta* Hall and Whitfield; 12 and 13, pedicle valve; 14, brachial valve: a brachiopod common in the Beechwood member.

15-16. *Heliophyllum juvene* Rominger, after Davis: a horn coral from the Beechwood member.

17-19. *Rhipidomella vanuxemi* Hall; 17, brachial valve; 18, pedicle valve; 19, profile: a common brachiopod in this formation.

20. *Paracyclas lirata* Conrad; left valve: a lamellibranch from the Silver Creek member.

21-22. *Tropidoleptus crinatus* Conrad; 21, brachial valve; 22, pedicle valve: a brachiopod from the Silver Creek member.

23. *Modiomorpha concentrica* Conrad; left valve: a lamellibranch from the Beechwood member.

24-26. *Pentagonia unisulcata* Conrad; 24, pedicle valve; 25, brachial valve; 26, front: a brachiopod from the Beechwood member.

27-29. *Spirifer fornacula* Hall; 27, brachial valve; 28, area and hinge; 29, pedicle valve: a brachiopod common to the Columbus and Delaware limestones.

30-31. *Ambocoelia umbonata* Conrad; 30 profile; 31, brachial valve: a brachiopod from the Beechwood member.

32-34. *Chonetes yandellianus* Hall; 32, brachial valve; 33, profile; 34, pedicle valve: a brachiopod abundant in the Silver Creek member.

35-37. *Spirifer oweni* Hall; 35, brachial valve; 36, pedicle valve; 37, profile: a brachiopod rather abundant in the Silver Creek member.

38. *Loxonema hydraulicum* Hall and Whitfield; a gastropod confined to the Silver Creek member.

CHAPTER V

MISSISSIPPIAN SYSTEM

This is the Mississippi Group, named by Alexander Winchell from the Mississippi Valley in 1869. It is the Lower Carboniferous or Sub-carboniferous of older geological literature.

General Characteristics.—Marine conditions prevailed in North America during the deposit of this formation. In the east clastic sediments (sands and clays) were laid down in the early part of the period. The deposits were more calcareous in the latter part. In the west conditions were favorable for the formation of limestones during the greater part of the whole period. The sea bottom where Kentucky now is, was transitional between the two sedimentary provinces during the early part of the period. The clastic sediments of the northeastern Lower Mississippian in Kentucky grade into the calcareous, organic and chemical precipitates of the southwestern portion.

At the close of the period clastic sediments, intermingled with calcareous, were laid down over the whole area. These, however, toward the northeast were largely removed by erosion as the result of being raised into a land area for a long time before the deposition of the strata of the next succeeding period.

Classification of the Mississippian in Kentucky

Series	*Stage*	*Sub-stage*	*Thickness in Feet*
Chester (Kaskaskia)	Pennington (E. Kentucky) Mauch Chunk Pennsylvania	Clore	0—150
		Palestine	0— 75
		Menard	0—100
		Tar Springs	0— 50
		Glen Dean	0—180
		Hardinsburg	0— 40
		Golconda	0— 90
		Cypress	0— 80
		Gasper (Ridenhower)	0— 50
		Bethel	0—100
Mammoth Cave (Newman)	Ste. Genevieve	Ohara	0—100
		Rosiclare	0— 10
		Fredonia	0—180
	St. Louis	St. Louis	0—500
Waverly (Includes Osage)	Warsaw	Spergen	0— 20
		Harrodsburg	0— 80
	Logan	Vinton Holtsclaw Allensville Byer Rosewood	160—530
	Cuyahoga	Berne Blackhand Kenwood	
		Raccoon New Providence	100—200
	Kinderhook	Sunbury	5— 10
		Berea	0— 20
		Bedford	0— 95

45. LOCATION OF THE WAVERLY OUTCROP

WAVERLIAN SERIES

CORRELATIONS AND GENERAL CHARACTERISTICS.—The Waverly (Caleb Briggs, 1838) took its name from a village in Ohio where sandstone of this age was quarried. It is about the same as the Knobstone (D. D. Owen, 1857) of Kentucky, the Pocono (J. J. Stevenson, 1877) of Pennsylvania, and the Marshall group (Alexander Winchell, 1861) of Michigan, and the Kinderhook, Burlington, Keokuk and Warsaw of Illinois and Iowa.

The formation in Ohio consists of shale sandstone and conglomerate, and where it enters Kentucky in Lewis County it has the same character, except that none of it is conglomeritic. In passing southward and southwestward through the State it loses its basal portion by gradual thinning, and becomes more calcareous by the introduction of limestones at the top and bottom. This is the phase which has received the name Fort Payne Chert (C. W. Hays, 1890) in Alabama and Tennessee, and Tullahoma (H. F. Bain, 1905) in Southern Illinois. The average total thickness is about 400 feet, the maximum being about 640 feet.

The Knobs, which suggested to Owen the name "Knobstone," for the formation, are those conical elevations which surround the Bluegrass from Vanceburg, on the Ohio in Lewis County, by way of Junction City in Boyle County, to the Ohio again in Jefferson County at a point opposite New Albany, Indiana. They are outliers of a more continuous outcrop of the formation farther back, the margin of which, retreating down the dip, has formed an escarpment with its steep face toward the Bluegrass. This escarpment, in its stretch along the southern margin of the Bluegrass from the Ohio River to Rockcastle County, has received the name "Muldraugh's (variantly spelled Muldrow's) Hill."

The most characteristic fossil of the formation, where it maintains its sandstone or shaly sandstone phase, is the cock-tail fucoid *Taonurus* (*Spirophyton*) *cauda-galli*.

The areal outcrop of the formation is characterized by great poverty of the soil where the sandstones and shales predominate. The knobs, however, are well adapted to fruit culture.

SUBDIVISIONS.—The Waverly may be divided in ascending order into the following stages: Kinderhook, Cuyahoga, Logan and Warsaw.

KINDERHOOK STAGE

(A. H. Worthen, 1866. Named from a locality in Illinois)

The Kinderhook, consisting of shale and sandstone aggregating a maximum thickness of 125 feet, is represented only in the northeastern exposures.

Subdivisions.—The formation may be divided into three members; named in ascending order: the Bedford, Berea and Sunbury.

The *Bedford* (J. S. Newberry, 1879), named from an Ohio locality, is largely a shale. It has a maximum thickness in Lewis County of ninety-five feet. It thins southward until, when Estill County is reached, its horizon is hardly identifiable.

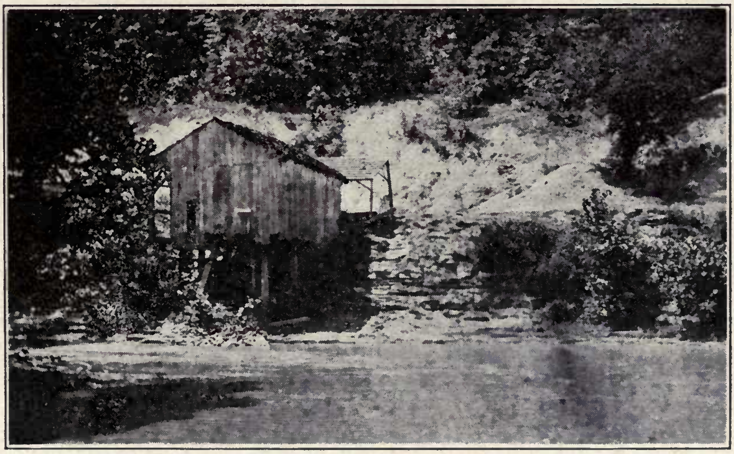
The *Berea* (J. S. Newberry, 1870) named from Berea, Ohio, is a sandstone. At Berea, Ohio, the stone is extensively quarried for grindstones. Under cover in Ohio, Pennsylvania, West Virginia and Northeastern Kentucky it is an important oil and gas horizon—the Berea grit oil sand. Near Vanceburg, where the formation crosses from Ohio, it furnishes a valuable building stone. The layers here are beautifully ripple-marked. It thins southward with the Bedford from a thickness of twenty-two feet at Vanceburg and disappears with it about the latitude of Estill County.

The *Sunbury* (L. E. Hicks, 1878), named from a village in Ohio, is a black bituminous shale. It is the "Waverly black slate" of E. B. Andrews, 1869. For a period before oil was obtained from drilled wells very extensively, this shale was quarried and oil distilled from it at Vanceburg. It ran as high as twenty-one per cent. bituminous matter. In the quarrying operations attendant upon this industry interesting fish remains were found in this shale. They belonged to the genus *Ctenacanthus* —a shark which swam the Waverlian sea of this epoch. Traces of the remains of this shark at the top of the "Black Shale" of Central Kentucky have made it possible to follow the horizon of the Sunbury this far south, even after the wedging out of the Bedford-Berea interval has brought the two black shales (the Ohio and the Sunbury) together. Professors August Foerste and W. C. Morse were the first to trace this thinning of the Bedford-Berea interval southward from the Ohio River and to prove that, in consequence of its final disappearance, the "Black shale" of Central Kentucky and southward was a Devonian-Mississippian composite.

CUYAHOGA STAGE

(J. S. Newberry, 1870. Named from the Cuyahoga River in Cuyahoga County, Ohio)

General Characteristics and Correlation.—In Ohio the Cuyahoga formation is a shale with intercalated sandstones. It is there from 275 to 300 feet thick. It thins southward in Ohio and across Kentucky, reaching in Jefferson County a thickness of 150 feet only. It also begins to change in stratigraphic character south of Central Kentucky, becoming there more calcareous. In Southern Kentucky it becomes largely a limestone, carrying an abundant crinoid fauna. This crinoid fauna shows the formation to be Burlington (Hall, 1856). Where there are sandstones in the formation these carry the impres-



46. LIGHT-COLORED, FRIABLE CUYAHOGA SHALE IN CONTACT WITH BLACK, BITUMINOUS SUNBURY-OHIO SHALE

The entrance to the mountain grist mill is at the plane of contact. Station Camp Creek, Estill County. Photograph by A. M. Miller.

sions of the spiral cock-tailed fucoid—*Taonurus* (*Spirophyton*) *cauda-galli*. This is the most easily recognized index fossil of the formation.

Subdivisions.—In Ohio the formation has been divided into three members—in ascending order: Raccoon, Blackhand and Berne.

The *Raccoon* (L. E. Hicks, 1878) is a greenish shale with sandstones intercalated. This is about the equivalent of the Linietta shale of Foerste, named from Linietta Springs, near Junction City, Boyle County, and of the

New Providence shale of W. W. Bordon, 1874, named from a locality in Indiana.

In its more southern outcrops, where it is in contact with the Sunbury now united with the Ohio, the basal layer about one foot thick is crowded with phosphate of lime concretions. Some of them are round as marbles and some are dumb-bell shaped. William Linney was of the opinion that they were fish coprolites. Higher up in the formation many carbonate of iron concretions occur. The sandstones of this bed furnish valuable building stone. The Buena Vista stone of the Ohio River, with its three and one-half-foot "city ledge" at the base, famous as building stone, and the Rowan County stone belong here.

As characteristic fossils may be mentioned the horn coral *Cyathaxonia cynodon* and *Cyathaxonia arcuata* and the crinid *Platycrinus sculptus*. The latter furnishes the stem-plates, known popularly as "fossil buttons," and "Indian beads," so common in certain localities where this formation is exposed; also the brachiopods *Rhipidomella oweni* and *Chonetes planumbona* are characteristic.

The *Blackhand* (L. E. Hicks, 1878) in Central Ohio is a quartz conglomerate fifty to 100 feet thick. The conglomerate phase of this portion of the Waverly does not occur in Kentucky, and just what portion of the Waverly should be included in this member in this State is uncertain. It is probable that the Kenwood sandstone (Charles Butts, 1915) of Jefferson County, is, in part at least, the equivalent of it.

It is described by Mr. Butts as forty-nine feet thick and sparsely fossiliferous—the brachiopod *Productus wortheni* being the only form found in it.

The *Berne* (J. F. Hyde, 1915) is generally a coarse conglomerate. It may reach a maximum thickness of forty feet in Ohio. The horizon has thus far not been recognized in Kentucky.

LOGAN STAGE

(E. B. Andrews, 1879. Named from the County Seat of Hocking County, Ohio)

Characteristics and Correlation.—The Logan formation in Ohio is a sandstone and shale series 160 to 530 feet thick. It has not been differentiated in Kentucky. It is of probable Keokuk age.

SUBDIVISIONS.—Professor J. E. Hyde has divided it in ascending order into three members in Ohio—the Byer, Allensville and Vinton. These three certainly cross into Kentucky.

The *Byer* (J. E. Hyde, 1915) named from a town in Jackson County, Ohio, is a shale and sandstone twenty-three to 154 feet thick in Southern Ohio.

The *Allensville* (J. E. Hyde, 1915), named from a village in Vinton County, Ohio, is a sandstone and shale reaching a maximum thickness in Southern Ohio of thirty-nine feet. It contains *caudi-galli* impressions and the lamellibranch *Allorisma winchelli.*

The *Vinton* (J. E. Hyde, 1915), named from Vinton County, Ohio, consists in Southern Ohio of fine-grained yellowish sandstone and shale. It does not there usually exceed fifty to seventy-five feet in thickness but may in exceptional cases reach 200 to 240 feet.

In Jefferson County, Kentucky, Charles Butts has established two divisions in the Upper Waverly—the Rosewood and Holtsclaw—which probably belong to the Logan Formation.

The *Rosewood* (Charles Butts, 1915) is a shale 190 feet thick along the Ohio south of Louisville. It takes its name from a village in Indiana. Characteristic fossils are the brachiopods *Cliothyridina parvirostris, Reticularia pseudolineata* and *Spirifer rostellatus.* These belong to the Keokuk and tend therefore to establish the Keokuk age of this shale.

The *Holtsclaw* (Charles Butts, 1915), named from a hill south of Louisville, is a sandstone about twenty feet thick. It also carries a Keokuk fauna. Characteristic species are the brachiopods *Orthotetes keokuk, Productus wortheni, Reticularia pseudolineata, Spirifer rostellatus, Spirifer keokuk, Rhynchoporo beecheri* and *Syringothyris testus.*

In Rockcastle County there is in places at the top of the Waverly (whether at this horizon or higher in the Warsaw has not been determined) a fine-grained sandstone which under the name "Rockcastle freestone" is extensively quarried for building purposes. Typical exposures of this stone may be seen near Orlando. Mr. J. B. Hoeing, former State Geologist, has identified this as the "Big Injun" of the oil well driller.

WARSAW STAGE

(James Hall, 1856. Named from Warsaw, Ill.)

General Characteristics and Fossils.—The Warsaw was applied by James Hall at the typical locality to eighteen feet of limestone which had formerly been called the "Second Archimedes limestone." In Kentucky the lower portion is cherty and geodiferous. The upper portion is rather pure, coarse grained and crinoidal. Characteristic fossils are as follows: the protozoan *Endothyra baileyi;* the corals *Zaphrentis elliptica, Cladochonus beecheri,* and *Palaecis carinata;* the bryozoa *Worthenopora spinosa* and *Dichotrypa sp.?;* the blastid *Pentremites conoideus;* and the brachiopods *Spirifer lateralis, Rhipodomella dubia* and *Productus magnus.*

Areal Outcrop and Topography.—The Warsaw is best developed as a surface exposure in the State along the brow of Muldraugh's Hill through Hardin and Larue to Taylor, Casey and Lincoln Counties, and thence southward through Green, Adair, Russell, Pulaski, Barren, Metcalf, Cumberland, Allen and Monroe. Eastward and northeastward from Lincoln County it cannot certainly be identified, unless here belongs an impure yellowish limestone found just below the St. Louis and always separated from it by a marked undulatory disconformity.

This formation usually gives rise to rather level land, and on account of the prevalence of limestone it is fairly well adapted to agriculture. However, these limestone soils of the Mississippian, on account of their deficiency in phosphorus, are far inferior to Ordovician limestone soil. The limestone of this formation gives rise to some caves and sinks—as for instance in Adair County.

Subdivisions.—The Warsaw may be divided in ascending order into two members—Harrodsburg and Spergen.

The *Harrodsburg* (T. C. Hopkins and C. E. Siebenthal, 1897), named from a town in Indiana, is prevailingly a siliceous limestone, containing much chert and many quartz geodes. The presence of these in the soil in the outskirts of the Bluegrass Region shows that the margin of this formation has retreated at least this far outward over the Bluegrass uplands of North-Central Kentucky, and is an additional evidence of the amount of reduction in surface area that some of the later Paleozoics in Kentucky have suffered.

The *Spergen* (S. S. Lyon, 1860), named from Spergen Hill, Indiana, is the member of the Warsaw which has sometimes been called the "Salem" (Gorby, 1886). It is also known in that State by the trade name "Bedford oolitic building stone," or simply the "Bedford stone." Where typically developed at Spergen Hill, and elsewhere in Indiana, it is an oolitic limestone of great purity and highly prized as a building stone. In Kentucky it does not exhibit these qualities, but is a rather coarse-textured limestone composed largely of fragments of crinoid plates. It is about twenty feet thick in this State. The best agricultural lands of Adair County—those with a strong growth of beech on them—are bedded on this formation.

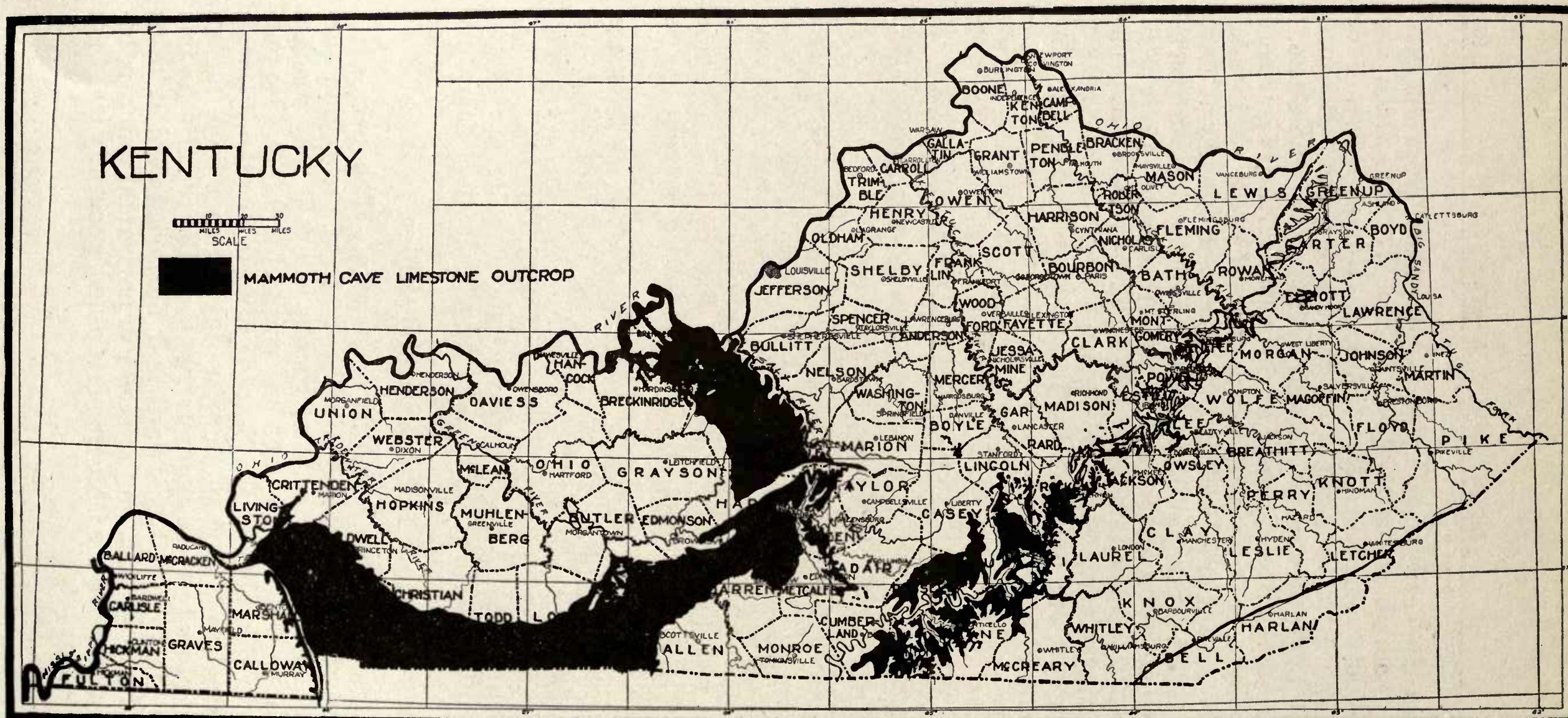
MAMMOTH CAVE LIMESTONE SERIES

(A. M. Miller, 1917. Named from the Celebrated Cave in Edmonson County, Ky.)

This name is proposed for the almost uninterrupted deposit of relatively pure limestone which has as a highly conspicuous feature the presence in it of caverns of considerable extent. Its outcrop in broad extent gives rise to a "karst" country; that is, it is a region pitted with sinks, and the drainage in it is largely underground.

As close equivalents in adjacent States we have the Maxville limestone (E. B. Andrews, 1871) of Ohio, the Greenbrier limestone (I. C. White, 1892) of West Virginia, and the Newman limestone (M. R. Campbell, 1893) of Tennessee. Also in many instances the term "Mountain limestone" of older American geological literature was a near equivalent. It is what is generally included in the "Big Lime" of the oil well driller.

Thickness and Areal Distribution.—This series has its greatest development in the State in the region surrounding the Western Coal Fields, where it may reach a maximum thickness at any one point of 600 feet. Its outcrop in this part of the State is almost coextensive with the treeless region of pioneer days known then, on account of its treeless character, as the "Barrens." As this series is followed eastward and northeastward it thins in vertical section, and narrows in horizontal outcrop, becoming, before the Ohio line is crossed, generally less than



47. LOCATION OF MAMMOTH CAVE LIMESTONE OUTCROP

100 feet in thickness, and forming exposures for the most part in nearly vertical cliffs.

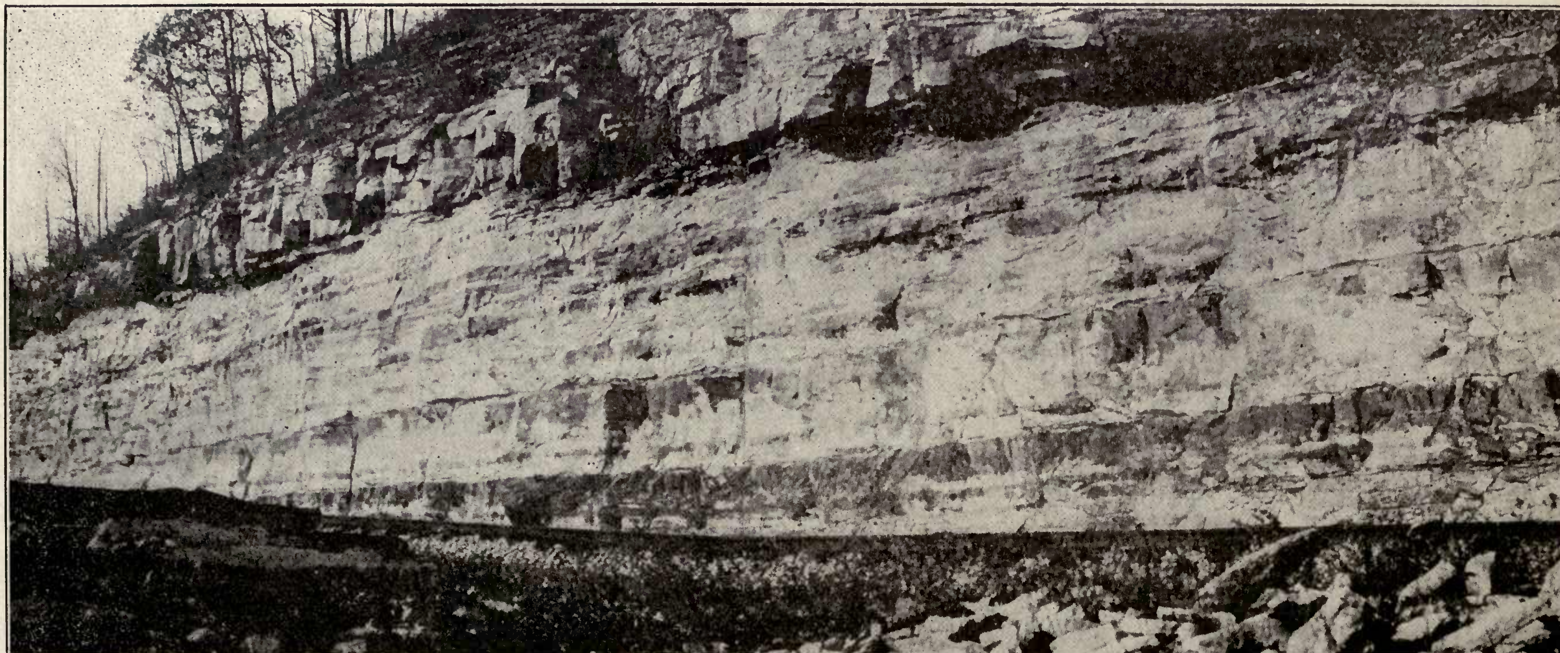
On that portion of Muldraugh's Hill from the Ohio River in Bullitt County to the border of the Eastern Kentucky Mountains in Rockcastle County, the formation seldom reaches to the brow of the escarpment, but thence northeastward it forms either the summit of it or a steep lower face, just beneath the basal sandstone or conglomerate of the Coal Measures. The formation has also been brought up by the Pine Mountains thrust fault and forms a long cliff in the face of the escarpment fronting northwestwards.

The total areal outcrop in Kentucky, including that of the Chester above, which on the State geological map has not been differentiated from it, is about 8,000 square miles.

Economic Features of the Mammoth Cave Outcrop Region.—The Mammoth Cave limestone gives rise by decay to a deep red soil fairly productive, though deficient in phosphorus. In the production of agricultural lands this formation is seen at its best in Warren, Franklin, Logan, Todd and Christian Counties.

In Crittenden and Livingston Counties, where this formation, along with the Chester and remnants of the lower Coal Measures, has been much faulted, it is traversed by mineral veins and dikes. The mineral veins carry fluorspar with some lead and zinc ore. For an account of these, see "Fluorspar" and "Lead and Zinc Ores" under Economic Geology, pages 320, 327. Certain beds of it furnish building and others lithographic stone.

Subdivisions.—The series has been divided in ascending order into the St. Louis and Ste. Genevieve stages.



48. UNCONFORMABLE CONTACT BETWEEN WARSAW AND ST. LOUIS LIMESTONE

St. Louis lies above Warsaw. Spergen limestone is absent. Louisville and Nashville Railroad cut, about one mile south of Colesburg, Hardin County. Photograph by Charles Butts

ST. LOUIS STAGE

(George Engelmann, 1847. Named from St. Louis, Missouri)

Lithological Characteristics and Fossils.—The St. Louis is a limestone, generally fine-grained in texture and gray in color. Excepting for bands of nodular chert in it and occasional argillaceous layers, it is of great chemical purity.

The chert tends to be spherical in shape and compact in texture. These features differentiate it from that of the Warsaw below, and the Ste. Genevieve above; the siliceous residues of which left in the soil by the decay of those formations, is block-like in form and porous in texture. Mr. Charles Butts assigns a probable maximum thickness of 500 feet to the formation in Western Kentucky. The average thickness there runs at about 300 feet.

The most characteristic fossil of the formation is the "Hornet's nest" like coral *Lithostrotion basaltiforme* (*canadense*). *Lithostrotion proliferum* also occurs here, but extends up into the Ste. Genevieve. Other fossils are the echinoid (sea urchin) *Melonites multiporus* and the brachiopod *Productus scitulus.*

Areal Distribution.—In Western Kentucky the St. Louis, according to Mr. Butts, "outcrops in a wide semicircular belt from Meade County to the Kentucky-Tennessee line, thence westward and northwestward through Trigg, Lyon and Livingston Counties to the Ohio River." * * * "According to locality the inner edge of the belt is ten to twenty miles distant from the margin of the coal field." Its general dip at all points is toward the coal field, which it underlies at considerable depths.

Along the western margin of the Eastern Coal Field, the St. Louis is everywhere present at the base of the Mammoth Cave, but it is much thinner than in the western area—especially northeastward.

STE. GENEVIEVE STAGE

(B. F. Shumard, 1857. Named from the old French Settlement of that Name in Missouri)

Lithological Characteristics and Fossils.—With the exception of a thin sandstone in the extreme western part of the area the Ste. Genevieve is a pure limestone. This is usually oolitic and thick-bedded, and tends to weather white where exposed in the fields. It is separated from the St. Louis by a disconformity which is difficult to discern, as there is "no physical evidence of a break between the two formations" (Butts). The exclusive presence of the coral *Lithostrotion basaltiforme* in the St. Louis and of the crinid *Platycrinus huntsvillae* in the Ste. Genevieve has furnished the surest means of discriminating between these two limestones. Also no oolitic layers have as yet been found in the St. Louis. This formation may reach a maximum thickness of nearly 300 feet.

Areal Distribution.—In the western area as outlined by Mr. Butts, "The Ste. Genevieve limestone outcrops in a broad belt lying between the outcrop of the St. Louis and the Western Coal Field. Irvington, Stephensport, Munfordville, Bowling Green, Russellville, Elkton, Hopkinsville, and Princeton are located on the Ste. Genevieve and roughly mark its outcrop."

Along the western margin of the Eastern Coal Field the Ste. Genevieve may be recognized by oolitic limestone superimposed on non-oolitic layers containing *Lithostrotion basaltiforme.*

Subdivisions.—The Ste. Genevieve in Kentucky has been divided in ascending order into three members: the Fredonia, Rosiclare, and Ohara.

The *Fredonia* (E. O. Ulrich, 1905), named from a village in Caldwell County, is prevailingly a coarse oolitic and thick-bedded limestone. It yields on weathering to soil secondary block chert, which covers the fields in the region of outcrop, or has been removed and built into rock fences surrounding them. This member reaches a thickness of 180 feet. Characteristic fossils of this bed are the coral *Lithostrotion harmodites* and the crinid *Platycrinus huntsvillae.* The Fredonia also possesses a group of certain small fossils which constitute a recurrent fauna from the Spergen.

The *Rosiclare* (E. O. Ulrich, 1905) is a calcareous sandstone one to ten feet in thickness. It takes its name from Rosiclaire on the Ohio River in Hardin County, Illinois. It has not been noted in Kentucky east of Caldwell and Trigg Counties.

The *Ohara* (E. O. Ulrich, 1905), named from a post office and quarries near Princeton in Caldwell County, is

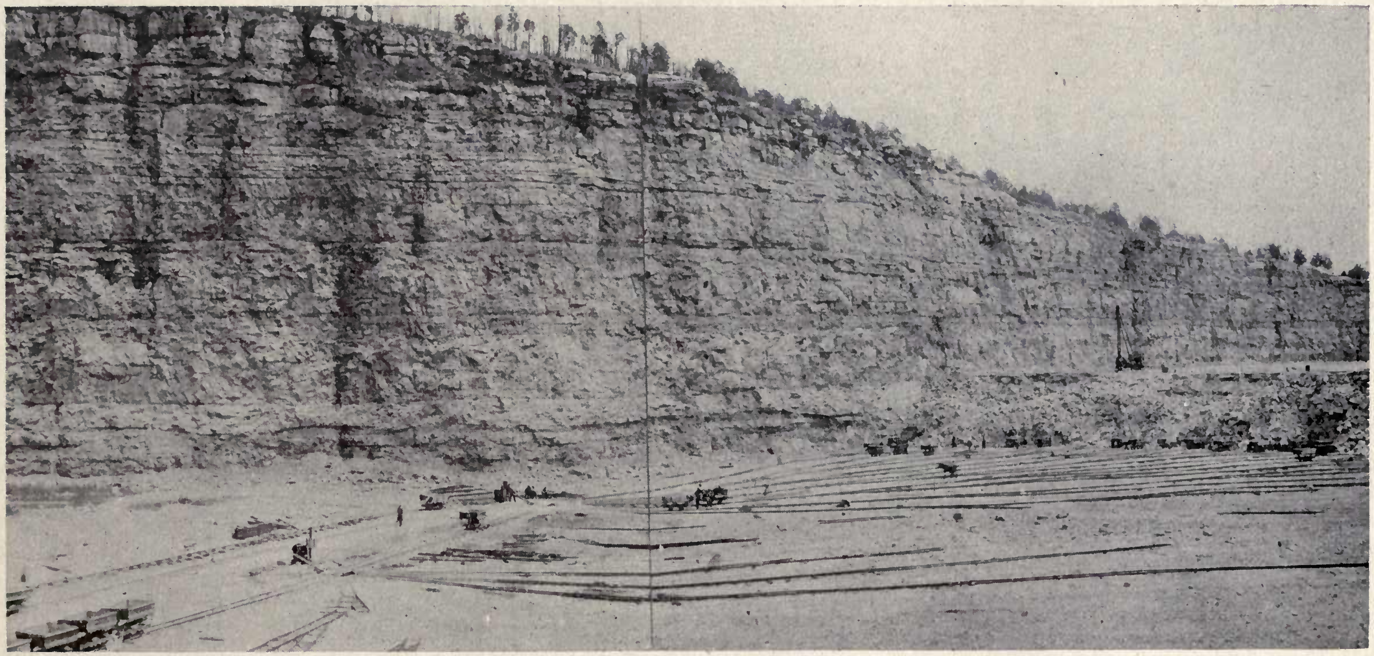
Bethel S. S. 4

Upper Ohara 3

Conglomerate 2

Lower Ohara Rosiclare 1

Fredonia oolite



49. FREDONIA AND OHARA MEMBERS OF THE STE. GENEVIEVE LIMESTONE

Quarry at Cedar Hill (Ohara), three miles southeast of Princeton, Caldwell County, looking northeast. Numbers to left of Ohara section refer to Ulrich's division. Photograph by Charles Butts.

mainly an oolitic limestone. It may reach a thickness of 100 feet.

But for the separation by the Rosiclare sandstone the Ohara would never have been constituted into a member separate from the Fredonia.

50. A LARGE MASS OF CORAL LITHOSTHOTION HARMODITES

Railroad cut just east of New Mystic, Breckinridge County. Photograph by Charles Butts

CHESTER SERIES

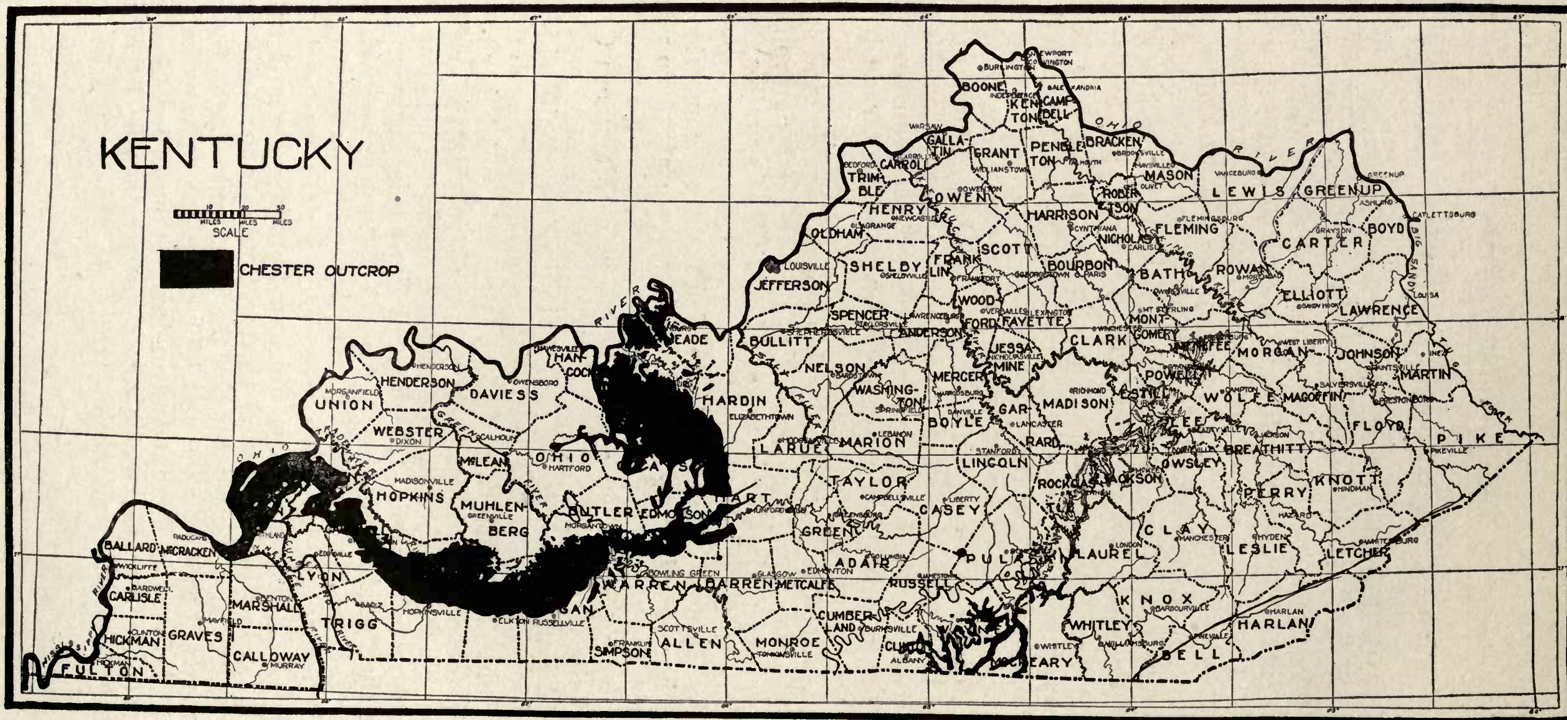
(G. C. Swallow, 1857. Named from Chester, Ill.)
(The Kaskaskia of Hall, 1856)

The Chester consists of a series of sandstones, shales and limestones aggregating in Western Kentucky probably a thickness of 600 to 800 feet. It is represented in Pennsylvania, at least in part, by the Mauch Chunk red shale (C. A. Ashburner, 1877) and in the Southern Alleghenies (including Southeastern Kentucky) by the Pennington shale (M. R. Campbell, 1893).

Areal Distribution.—The Chester in Western Kentucky surrounds the coal field in a belt five to ten miles wide, intervening between it and the Mammoth Cave limestone belt. As in the case of the Mammoth Cave, the general dip is at all points inward toward the center of the coal field under which it lies and on which the Coal Measures are bedded. On account of the predominance of sandstones and shales in it, its outcrop is marked by a strip of poor agricultural land.

This contrast between arable and non-arable land seen in passing from Mammoth Cave to Chester outcrop, is especially noticeable in the southern tier of counties from Logan to Caldwell Counties. A line connecting Russellville, Elkton, Hopkinsville and Princeton separates a southern good agricultural portion from a northern poor agricultural portion in each county. This is also roughly the boundary in that section between the Mammoth Cave and the Chester.

Along the western border of the Eastern Coal Field the Chester is in evidence in the southern part but much thinner than in Western Kentucky, probably not being over 100 feet in thickness. It was here correlated by Mr. Campbell with the Pennington of Virginia, which is upper Chester in the main. Northward along this western margin the Pennington thins, and north of the Kentucky River it is seldom descernible. The furthest north an outcrop of this formation has been recognized by the writer is at Blair's Mill in northern Morgan County. Here it contains a bed of undoubted Carter County nonplastic fire clay, and thereby establishes the Pennington age of this important economic deposit. There is also some evidence that below the Pennington in this region other Chester strata are present which are indistinguishable lithologically from the Mammoth Cave.



51. LOCATION OF CHESTER OUTCROP

Eastward under cover the Chester, or at least the upper portion of it, as revealed by oil well records, thickens, and where brought up by the Pine Mountain fault, shows the characteristic reddish color of the Eastern United States Mauch Chunk phase.

Economic Products.—In the Western Kentucky Chester occurs bituminous sandstone, which under the name "Kentucky asphalt rock" has been used for street and road surfacing. There is also a deposit of it at about the same horizon in Northeastern Kentucky. These are old oil sands, which on being elevated and dissected until they lie above drainage, have lost their more volatile constituents by oxidation. It is only thick tarry residues which now saturate the rock. For a fuller account of this "Asphalt Rock" see *Bituminous Sandstone* in treatment of Economic Geology.

Another economic product of the Chester is the fire clay already referred to as occurring in Northeastern Kentucky. See also *Fire Clay,* Chapter XVI.

Subdivisions.—These are, as established for Western Kentucky in ascending order: Bethel, Gasper, Cypress, Golconda, Hardinsburg, Glendean, Tar Springs, Menard, Palestine and Chlore.

The *Bethel* (Charles Butts, 1917), named from a school in Hardin County, Illinois, is a sandstone about 100 feet thick where it enters Kentucky from Illinois. It thins eastward at least till near the line between Christian and Todd Counties, where it is only ten feet thick. East of this it has not been observed.

The *Gasper* (Charles Butts, 1917), named from Gasper River in western Warren County, is mainly an oolitic limestone fifty feet thick. In Breckinridge, Hardin, Meade and Grayson Counties it includes a sandstone member—*Sample sandstone* (Charles Butts, 1917), named from a station in Breckinridge County on the Louisville, Henderson and St. Louis Railroad, and in Crittenden County appears to be represented entirely by a shale—*Ridenhower shale* (Charles Butts at suggestion of Stuart Weller, 1917), named from a locality in Johnson County, Illinois.

The Gasper is the valuable building stone so extensively quarried in Warren County and sold under the trade name, "Bowling Green stone." Very characteristic of the Gasper are certain crinoids; among blastids *Pen-*

tremites pyriformis and *Pentremites godoni;* among crinids *Talarocrinus patei* and *Agassizocrinus conicus* (the latter also extending into the overlying beds). At the top of the bed occurs a species of the screw bryozoan *Archimedes confertus.*

The *Cypress* (Henry Engelmann, 1868) is the main sandstone of the Chester. It is the Big Clifty of C. J. Norwood, 1879. It reaches a thickness of eighty feet and forms a conspicuous terrace surrounding the Western Coal Field. At the base the screw bryozoan *Archimedes confertus* occurs and through it are apt to be found casts of the scale tree *Lepidodendron.*

The so-called asphalt rock at Garfield in Breckinridge, and also one of the deposits in Grayson County is in the Cypress.

The Cypress is the sandstone found capping the ridge over Mammoth Cave, and also forms the tops of the highest knobs to the eastward—even across to the Eastern Coal Fields. Such knobs are Prewett's in Barren, Maxey

52. CLIFF EXPOSURE OF CYPRESS ("BIG CLIFTY") SANDSTONE
On Big Clifty Creek, one-fourth mile below the Illinois Central Railroad trestle, looking east. Photograph by Charles Butts

in Hart, and Green River Knob in Pulaski County. The presence of these scattered outliers over South Central Kentucky proves the former continuity of this portion of the Chester across the crest of the Cincinnati Arch, and makes it probable that the remainder of the Chester and even the Coal Measures once extended across.

The *Golconda* (E. O. Ulrich, 1915) takes its name from a town on the Ohio in Pope County, Illinois. It consists of limestone and shale and reaches a thickness of ninety feet. Its most characteristic fossils are the crinid *Pterotocrinus capitalis* and the blastid *Pentremites obesus.* The former, easily recognized from its curious condyle-like interbrachials, which are generally found detached, is not known to occur east of Crittenden County. The screw bryozoan *Archimedes lativolvis* is nearly confined to this bed.

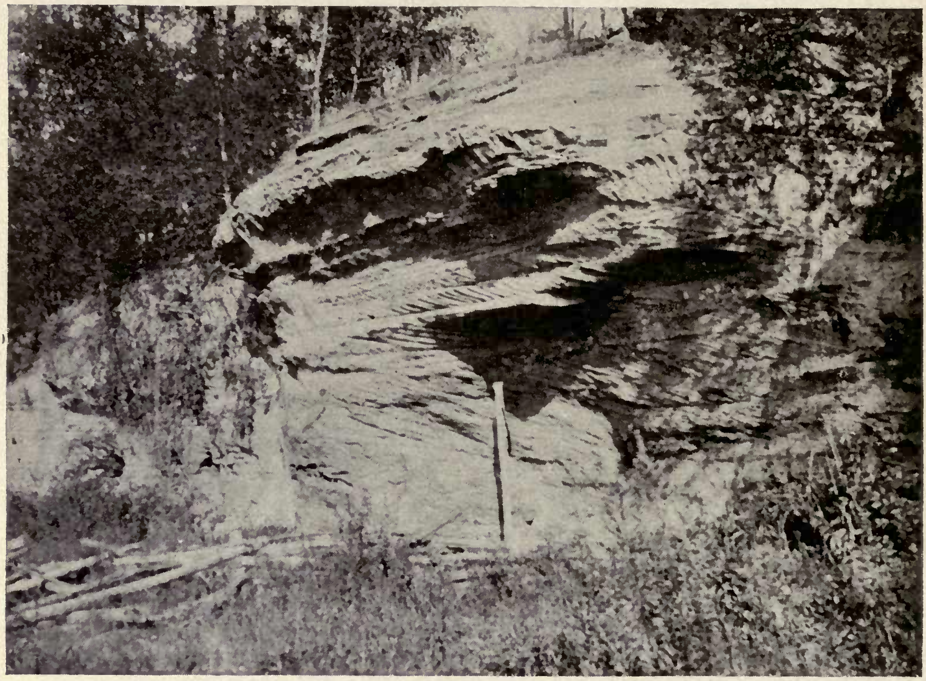
The *Hardinsburg* (Charles Butts, 1917) takes its name from the county seat of Breckinridge County. It is a sandstone about forty feet. It shows a tendency to be flaggy in its bedding and has been called the "Hardinsburg flagstone."

The *Glen Dean* (Charles Butts, 1917) is named from a village in the southern part of Breckinridge County. It is composed chiefly of shale and limestone. It reaches its greatest development in Kentucky near the Ohio River in Breckinridge County, where it shows a thickness of 180 feet. In Warren County it is fifty feet thick. It can be recognized by its characteristic fossils on the east side of the Cincinnati Arch, as at Sloans Valley in Pulaski County, where it forms a part of the Pennington of Marius Campbell.

The Glen Dean is the most fossiliferous member of the Chester. The number of species described from it exceeds that from any other. Especially characteristic are its bryozoa, crinids and blastids. Those species which, according to Mr. Ulrich are confined to it, are, among the bryozoa *Chilotrypa hispida, Meekopora clausa, Anisotrypa symmetrica, Eridopora macrostoma, Stenopora ramosa;* among blastids *Pentremites elegans, P. robustus, P. canalis, P. fohsi, P. spicatus, P. subplanus, P. brevis, P. lyoni;* and among crinids *Pterotocrinus acutus* and *P. bifurcatus.* The peculiarly shaped detached interbrachials of the last two species are especially abundant and characteristic. While not absolutely confined to this member the triangular prism-shaped bryozoan

Prismopora serrulata and the screw-shaped bryozoan *Archimedes laxus,* when their great abundance is considered, are diagnostic. The brachiopod *Eumetria costata* is also abundant.

The *Tar Springs* (David Owen, 1851) takes its name from a locality three miles south of Cloverport, Breckinridge County, where springs carrying a residual petro-



53. EXPOSURE OF TAR SPRINGS SANDSTONE
Five miles southwest of Cloverport, looking north. Photograph by Charles Butts

leum issue from it. It varies from a massive to a thin bedded shaly limestone. Where massive at the type locality it has a thickness of fifty feet. In Warren County it is thirty feet thick. From here westward on the south side of the Western Coal Field it thickens, and where it passes into Hardin County, Illinois, it may attain a thickness of 150 feet.

It carries fossil plant remains—precursors of the Carboniferous flora. Among these are the pinnules of the fern *Cardopteris polymorpha,* and the sandstone casts of *Stigmaria,* and *Lepidodendron.* According to David

White one of these is similar if not identical with *Stigmaria verrucosa* of the Carboniferous limestone of Europe, and another with *Lepidodendron velthemianum* of the Stanley shale of Oklahoma. The Cloverport deposit of bituminous sandstone is in this member.

The *Menard* (Stuart Weller, 1914) is named from a locality in Randolph, Illinois. It is commonly a thick-bedded limestone, but may contain shale. It may reach a thickness of 100 feet in Crittenden County. From here it thins eastward and disappears before reaching Warren County. On the north side of the Western Coal Field it appears to be present on top of the Tar Springs near Cloverport with a thickness of from one to fifteen feet.

The Menard is quite fossiliferous. While not confined to it exclusively, the lamellibranch *Sulcatopinna missouriensis* is, from its abundance, characteristic.

The *Palestine* (Stuart Weller, 1914) takes its name from a locality in Randolph County, Illinois. It is a "medium-grained flaggy, somewhat ferruginous sandstone and therefore weathers to a buff color" (Charles Butts). It is present with certainty in Kentucky only in Crittenden County, where it has a thickness of seventy-five feet. It contains occasional casts of *Stigmaria* and *Lepidodendron*—the latter probably *L. modulatum*.

The *Clore* (Stuart Weller, 1914) is named from a school in Randolph County, Illinois. It consists of shale, limestone and sandstone, the shale being in greatest proportion. It reaches its greatest development in Crittenden County where it may attain a thickness of 150 feet. East and northeast, in the Chester belt surrounding the Western Coal Field, it has not with certainty been identified, as have not the other members above the Tar Springs standstone. It has been proposed, therefore, by Charles Butts to class all the Chester above this sandstone in this section together, under the name *"Buffalo Wallow,"* from a locality in Breckinridge County.

The Clore, or perhaps better, the Buffalo Wallow, seems recognizable as the main most persistent portion of the Pennington shale along the western border of the Eastern Coal Field.

The Buffalo Wallow, including the Clore, carries an abundant fauna. Most of the species, however, are also found at a lower horizon. Fairly characteristic of the Buffalo Wallow, though not confined to it, is the brachiopod *Eumetria vera*.

THE MISSISSIPPIAN-PENNSYLVANIAN DISCONFORMITY

A progressive thinning of the upper Mississippian as it is followed northeastward up the Ohio Valley, with a tendency of its upper members to disappear, has been interpreted as due to a progressive uplift of the land which began in the upper Ohio Valley and proceeded in the opposite direction—that is, toward the southwest. As a result of this uplift finally the whole Mississippi basin—or at least all but the southern portion of it—was raised above the sea and underwent extensive erosion. Much of the top of the Mississippian was carried away and the land was at last reduced to base level. This base leveling process appears to have been aided by a subsidence movement which began in the southwest and proceeded northeastward. Upon this base-leveled land surface the next succeeding formation—the Pennsylvanian—was laid down disconformably.

It follows that if the movement in uplift began in the northeast and proceeded southwestward, and if the movement in depression began in the southwest and proceeded northeastward, the land in the northeast came up out of the sea first and went down close to it, perhaps at first slightly under it, last. The land surface in the northeast must, therefore, have been eroded the most, and here the hiatus between the Mississippian and the overlying Pennsylvanian would be the greatest. The soils formed during this erosion period seem to have been pretty completely removed. Certain beds of iron ore found on top of the Mammoth Cave limestone may date from this erosion interval. For an account of this ore see "Iron Ore," Chapter XIV, page 312.

REFERENCES

Those listed in Chapters III and IV which treat of the Mississippian in addition to the Silurian and Devonian, as follows: The one by Mr. Butts on Jefferson County, the one by Mr. Campbell on the Richmond Quadrangle and Vol. 1 by Owen.

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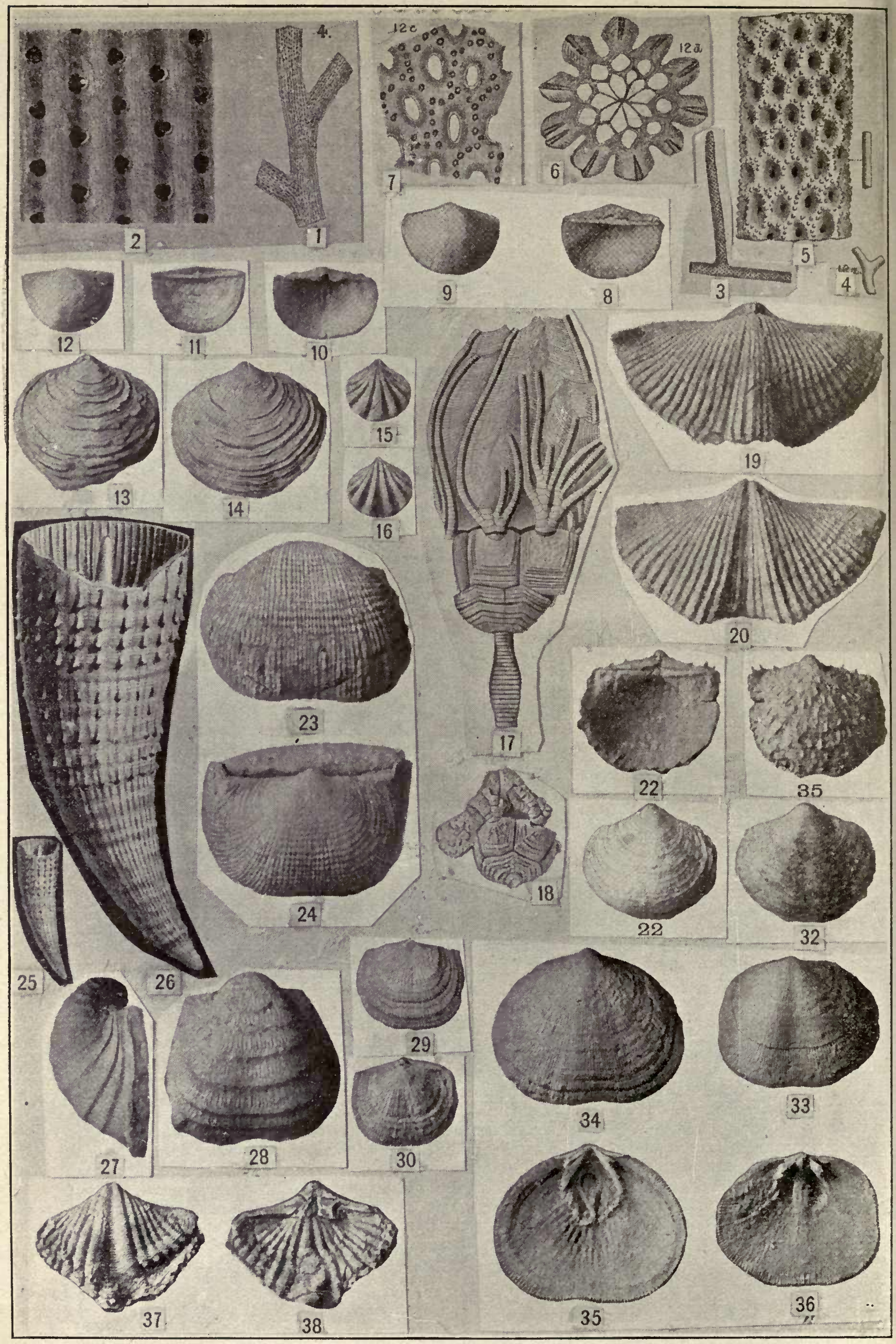

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PLATE 54

54. FOSSILS FROM THE CUYAHOGA (NEW PROVIDENCE) SHALE

A reproduction of Plate 49 in "Geology of Jefferson County," by Charles Butts; also appearing as Plate 4 in "Mississippian Formations of Western Kentucky," both books by the same author

1-2. *Cystodictya lineata* Ulrich; 1, a zoarium, natural size; 2, a portion of surface of same enlarged showing mouths of zoecia: a bryozoan ranging from the Cuyahoga to the Spergen.

3-7. *Rhombopora incrassata* Ulrich, after Ulrich; 3 and 4, fragments of zoaria, natural size; 5, portion of surface, X12; 6, transverse section enlarged; 7, tangential section enlarged: a bryozoan.

8-9. *Chonetes planumbona* Meek and Worthen; after Weller; 8, brachial valve; 9, pedicle valve: a common brachiopod.

10-12. *Chonetes shumardanus* De Koninck, after Weller; 10, interior of pedicle valve; brachial valve; 11, brachial valve; 12, pedicle valve: a common brachiopod.

13-18. *Platycrinus sculptus* Hall, after Wachsmuth and Springer: a crinid, the stem plates of which, known as "buttons" and "Indian beads," are so common in this formation.

19-20. *Spirifer vernonensis* Swallow, after Weller; 19, brachial valve; 20, pedicle valve: a brachiopod.

21-22. *Strophalosia cymbula* Hall and Clarke, after Weller: 21, pedicle valve; 22, brachial valve: a brachiopod.

23-24. *Productus fernglenensis* Weller, after Weller; 23, pedicle valve; 24, brachial valve and hinge: a brachiopod frequently listed from this formation as *P. semireticulatus.*

25-26. *Cyathaxonia cynodon* Rafinesque and Clifford, after Edwards and Haime: a horn coral common in this formation.

27-28. *Echinoconchus (Pustula) alternatus* (Norwood and Pratten), after Weller; 27, profile; 28, pedicle valve: a brachiopod or a similar one listed from this formation as Pustula punctata.

29-30. *Schuchertella lens* (White), after Weller; 29, pedicle valve; 30, brachial valve: a brachiopod.

31-32. *Cliothyridina glenparkensis* Weller, after Weller; 31 brachial valve; 32, pedicle valve: a brachiopod.

33-36. *Rhipidomella oweni* Hall and Clarke, after Weller; 33, brachial valve; 34, pedicle valve; 35, interior of pedicle valve; 36, interior of brachial valve: a brachiopod confined to the Cuyahoga.

37-38. *Spiriferina subelliptica* McChesney, after Weller; 37, pedicle valve; 38, brachial valve: a brachiopod.

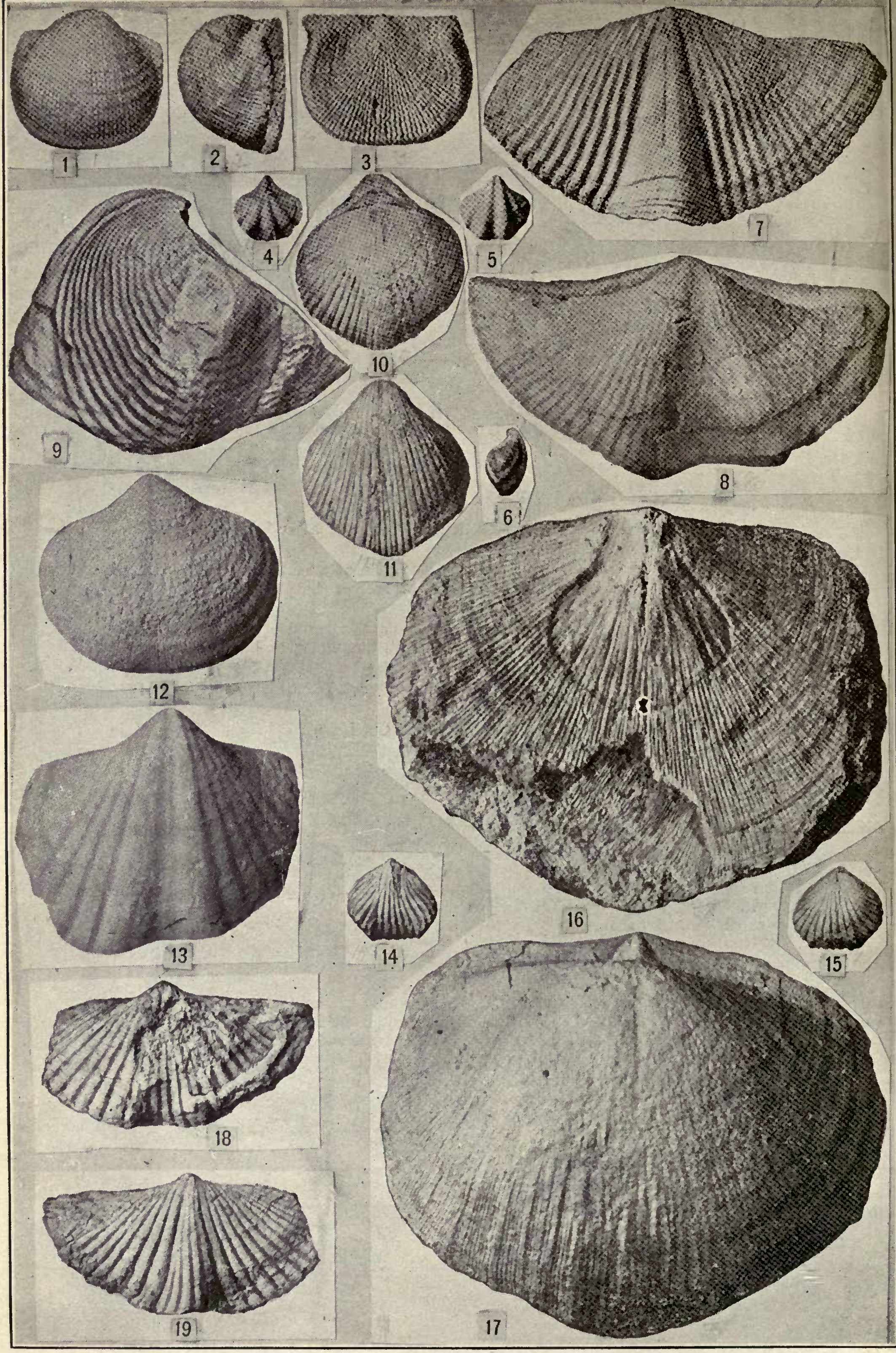

PLATE 55

55. FOSSIL BRACHIOPODS FROM THE ROSEWOOD SHALE AND HOLTSCLAW SANDSTONE

A reproduction of Plate 52 in "Geology of Jefferson County," by Charles Butts; also appearing as Plate 5 in "Mississippian Formations of Western Kentucky," by the same author. All specimens figured are after Weller

1-3. *Productus wortheni* Hall; 1, pedicle valve; 2, profile; 3, brachial valve: Kenwood and Holtsclaw sandstone. Common.

4-6. *Cyrtina burlingtonensis* Rowley; 4, brachial valve; 5, pedicle valve; 6, profile: Rosewood shale.

7-9. *Syringothyris textus* (Hall); 7, brachial valve; 8, pedicle valve; 9, profile: Holtsclaw sandstone only.

10-11. *Spirifer rostellatus* Hall; 10, brachial valve; 11, pedicle valve: Rosewood shale and Holtsclaw sandstone.

12. *Reticularia pseudolineata* (Hall); pedicle valve; Rosewood shale and Holtsclaw sandstone.

13. *Brachythyris* (*Spirifer*) *suborbicularis* (Hall); pedicle valve: Cuyahoga shale to Holtsclaw sandstone.

14-15. *Rhynchopora beecheri* Greger; 14, pedicle valve; 15, brachial valve: Holtsclaw sandstone.

16-17. *Orthotetes* (*Derbya*) *keokuk* (Hall); 16, pedicle valve; 17, brachial valve: Holtsclaw sandstone only.

18-19. *Spirifer crawfordsvillensis* Weller; 18, pedicle valve; 19, brachial valve: both Rosewood shale and Holtsclaw sandstone.

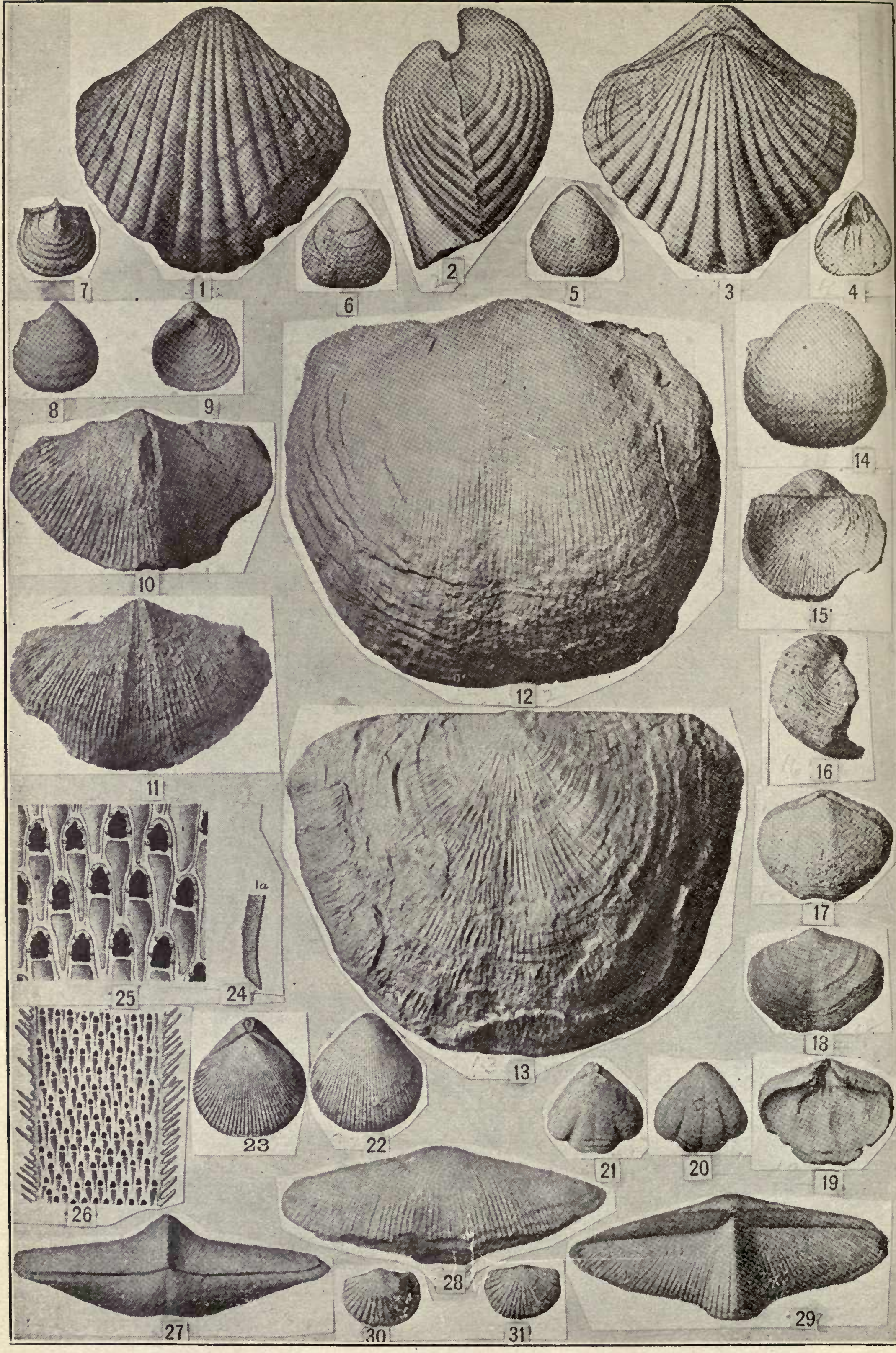
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PLATE 56

56. FOSSILS FROM THE WARSAW FORMATION

A reproduction of Plate 56 in "Geology of Jefferson County," by Charles Butts; also appearing as Plate 8 in "Mississippian Formations of Western Kentucky," by the same author. All specimens figured are after Weller except 24-26, and all but these are brachiopods

1-3. *Brachythyris subcardiformis* (Hall); 1, pedicle valve; 2, profile; 3, brachial valve.

4-6. *Rhipidomella dubia* (Hall); 4, interior of pedicle valve; 5, brachial valve: 6, pedicle valve. Common.

7-9. *Echinoconchus* (*Pustula*) *biseriatus* (Hall); 7, interior of a brachial valve; 8, pedicle valve; 9, brachial valve.

10-11. *Spirifer tenuicostatus* Hall; 10, pedicle valve; 11, brachial valve: Rosewood shale to Harrodsburg.

12-13. *Productus magnus* Meek and Worthen; 12, pedicle valve; 13, brachial valve: characteristic of the Harrodsburg.

14-16. *Productus altonensis* Norwood and Pratten; 14 pedicle valve; 15, brachial valve; 16, profile: Spergen limestone.

17-19. *Athyris densa* Hall; 17, brachial valve; 18, pedicle valve; 19, interior of pedicle valve: Harrodsburg.

20-21. *Composite trinuclea* (Hall); 20, brachial valve; 21, pedicle valve: Spergen limestone.

22-23. *Eumetria vernuiliana* (Hall); 22, brachial; 23, pedicle valve: Holtsclaw to Spergen.

24-26. *Worthenopora spinosa* Ulrich; 24, a zoarium, natural size; 25 and 26, surfaces of same enlarged; 26 shows the characteristic spines: a bryozoan.

27-29. *Spirifer lateralis* Hall; 27, hinge side; 28, pedicle valve; 29, brachial valve and hinge area.

30-31. *Streptorhynchus* (*Orthotetes*) *minutuings;* 30, brachial valve; 31, pedicle valve: Spergen limestone.

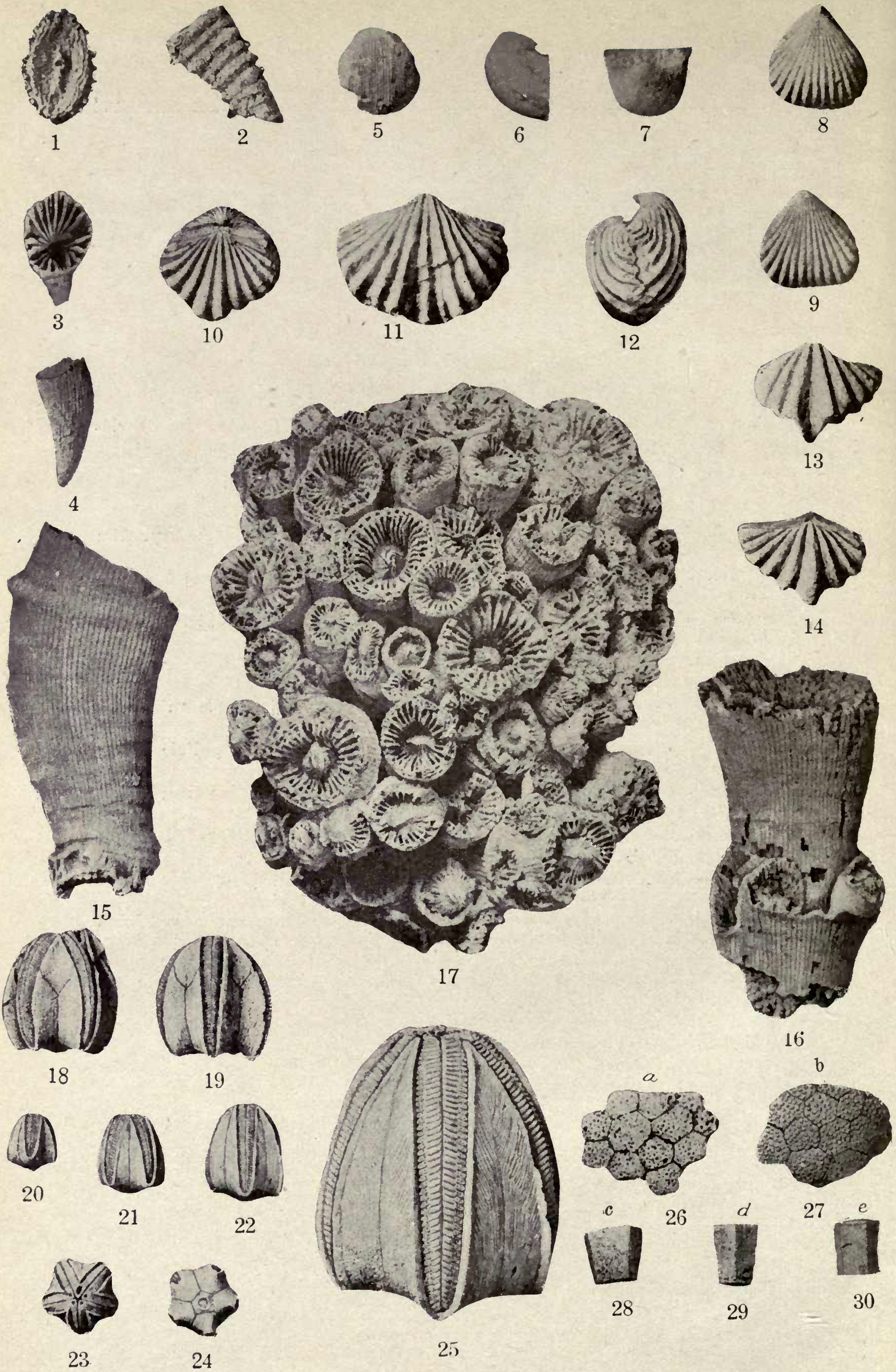
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PLATE 57

57. FOSSILS FROM WARSAW AND MAMMOTH CAVE FORMATIONS

A reproduction of Plate 10 in "Mississippian Formations of Western Kentucky," by Charles Butts

1-2. *Platycrinus sp.* 1, a stem plate; 2, fragment of stem: a crinid, Warsaw.

3-4. *Triplophyllum sp.* 3, a small specimen, X2, top view; 4, side view of specimen, natural size: a horn coral, Warsaw.

5-7. *Productus scitulus* Meek and Worthen; 5, pedicle valve; 6, side (profile); 7, brachial valve: a brachiopod, St. Louis limestone.

8-9. *Tetracamera arctirostrata* (Swallow), after Weller; 8, brachial valve; 9, ventral valve: a brachiopod, St. Louis limestone.

10-12. *Spirifer bifurcatus* Hall; 10, brachial valve and hinge area; 11, pedicle valve; 12, profile: a brachiopod, Warsaw to St. Louis.

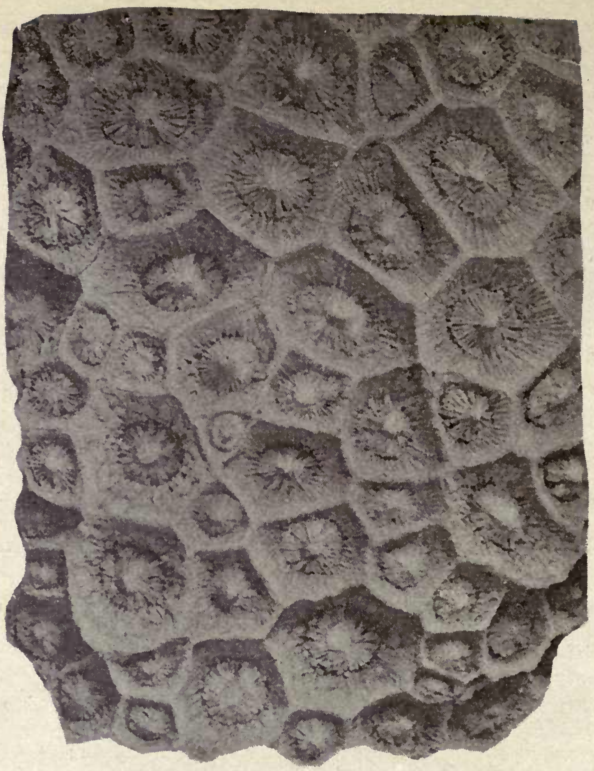
13-17. *Spiriferina salemensis* Weller; 13, pedicle valve; 14, brachial valve: a brachiopod, Spergen and St. Louis limestones.

15-17. *Lithostrotion proliferum* Hall, after Ulrich; 15-16, side views of coralites; 17, a colony seen from above: a compound horn coral characteristic of the St. Louis and lower part of the Ste. Genevieve.

18-19. *Pentremites cavus* Ulrich, after Ulrich; side views: a blastid Mammoth Cave limestone.

20-25. *Pentremites conoidens* Hall; various sizes and views; 25, same as 22, X3: a blastid, Warsaw to Ste. Genevieve.

26-30. *Melonites multiporus* Owen and Norwood, after Ulrich; plates of a sea urchin characteristic of the St. Louis limestone.



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58. FOSSILS FROM THE ST. LOUIS LIMESTONE

58. FOSSILS FROM THE ST. LOUIS LIMESTONE

A reproduction of Plate 11 in "Mississippian Formations of Western Kentucky," by Charles Butts

1-2. *Lithostrotion basaltiforme* Owen, after Ulrich; same as *L. canadense* (Castelnau); 1, top view; 2, side view: a compound horn coral diagnostic of the St. Louis.

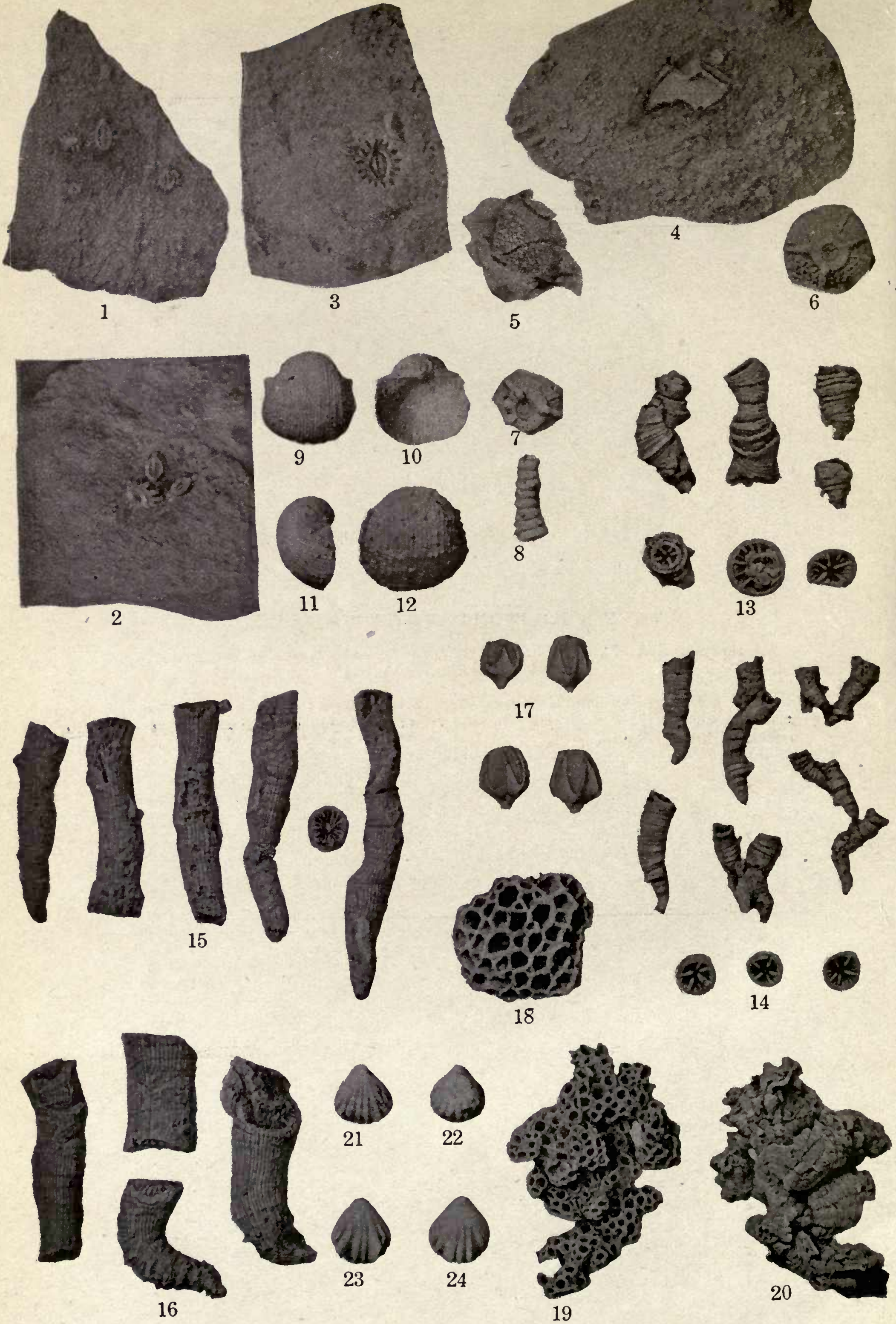

PLATE 59

59. FOSSILS MAINLY FROM THE STE. GENEVIEVE LIMESTONE

A reproduction of Plate 14 in "Mississippian Formations of Western Kentucky," by Charles Butts

1-8. *Platycrinus huntsvillae* Wachsmuth and Springer; 1-2, stem plates in limestone; 3, stem plate mold in limestone; 4-5, bases of calyx in limestone; 6-7, bases of calyx; 8, fragment of stem: a crinid common in and highly characteristic of the Fredonia oolite.

9-12. *Productus parvus* Meek and Worthen, after Weller; 9 and 12, pedicle valves; 10, brachial valve and hinge; 11, side (profile): a brachiopod from the Fredonia oolite.

13. *Cystelasma rugosum* Ulrich, after Ulrich; a group of specimens showing different aspects: a coral from the Fredonia oolite.

14. *Cystelasma quinqueseptatum* Ulrich, after Ulrich; a group of specimens showing different aspects of the coralites: a coral from the Fredonia oolite.

15. *Lithostrotion harmodites* Edwards and Haime, after Ulrich; a group of specimens showing different aspects of the coralites: a compound horn coral from the Fredonia oolite, of which it is characteristic.

16. *Amplexus geniculatus* Worthen; a group of specimens showing different aspects of the coralites: a horn coral characteristic of the Ohara member.

17. *Pentremites princetonensis* Ulrich, after Ulrich; a side view of four different specimens: a blastid from the Fredonia oolite.

18. *Michelinia princetonensis* Ulrich, after Ulrich; a honeycomb coral from the Fredonia oolite.

19-20. *Michelinia subramosa* Ulrich, after Ulrich: a honeycomb coral from the Fredonia oolite.

21-24. *Pugnoides ottumwa* (White), after Weller; a brachiopod from the Fredonia oolite; not common.

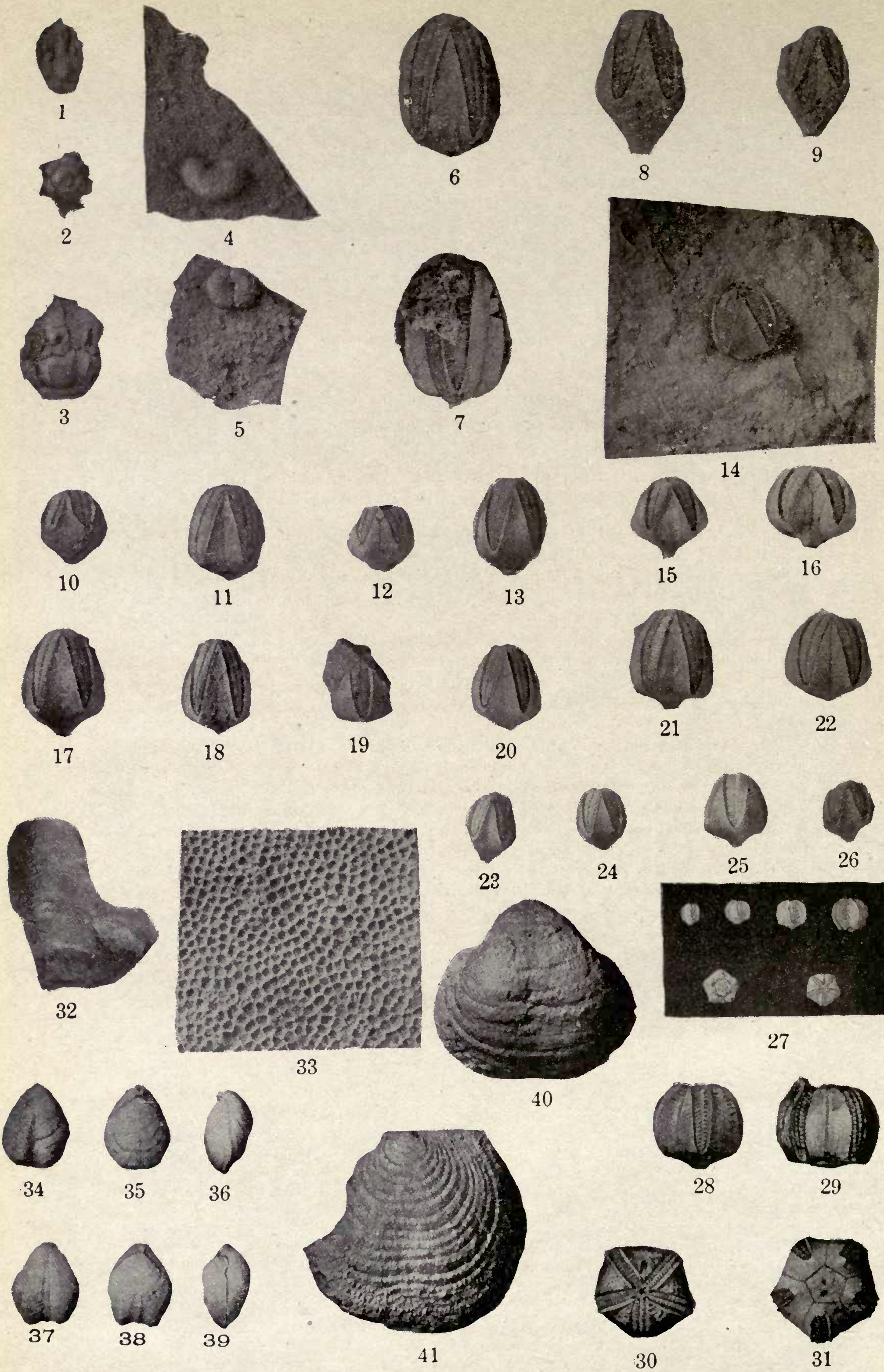
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PLATE 60

60. FOSSILS FROM THE STE. GENEVIEVE AND LOWER CHESTER FORMATIONS

A reproduction of Plate 15 in "Mississippian Formations of Western Kentucky," by Charles Butts

1-2. *Talarocrinus sp.;* 1, side view; 2, basal view: a crinid from the Ohara bed.

3-5. *Talaroerinus trijugis Miller;* 3, side; 4 and 5, basal plates in limestone: a crinid from the Ohara bed.

6-7. *Pentremites ovoides* Ulrich; side views: a blastid from the Ohara bed.

8-9. *Pentremites buttsi* Ulrich; side views: a pentremite from the Ohara bed.

10-26. *Pentremites princetonensis* Ulrich; side views of various varieties: a blastid from the Ohara bed.

27-31. *Mesoblastus glaber* Meek and Worthen, after Ulrich; various aspects of the heads shown: a blastid from the Ohara bed.

32-33. *Stenopora tuberculata* Ulrich; 32, natural size; 33, X6: a bryozoan ranging through the St. Louis and Chester groups.

34-36. *Girtyella indianensis* (Girty), after Weller; 34, pedicle valve; 35, brachial valve and hinge; 36, side (profile): a brachiopod from the Ohara and Gasper beds.

37-39. *Girtyella brevilobata* (Swallow), after Weller; 37, pedicle valve; 38, brachial valve; 39, side (profile): a brachiopod from the Ohara and Ohara beds.

40-41. *Echinoconchus* (*Pustula*) *genevievensis* Weller, after Weller; 40, pedicle valve; 41, brachial valve: a brachiopod from the Fredonia and Gasper beds.

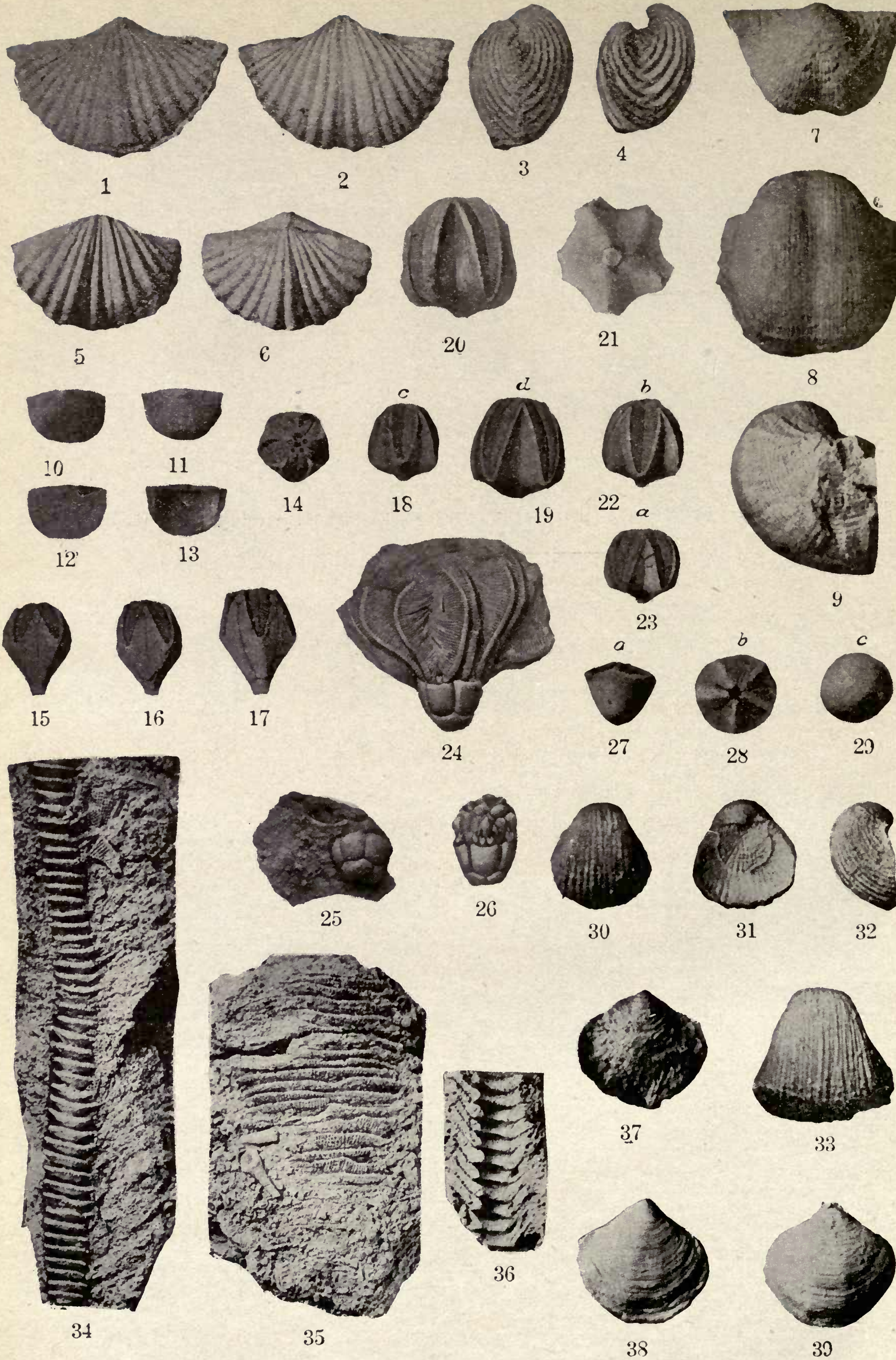
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PLATE 61

61. FOSSILS FROM THE STE. GENEVIEVE AND CHESTER FORMATIONS

A reproduction of Plate 21 in "Mississippian Formations of Western Kentucky," by Charles Butts

1-3. *Spirifer pellaensis* Weller, after Weller; 1, brachial valve; 2, pedicle valve; 3, side (profile) : a brachiopod ranging from Fredonia to Gasper oolite.

4-6. *Spirifer leidyi* Norwood and Pratten, after Weller; 4, side (profile) ; 5, pedicle valve; 6, brachial valve: a brachiopod ranging from Fredonia to Gasper oolite.

7-9. *Productus inflatus* McChesney, after Weller; 7, brachial valve; 8, pedicle valve; 9, side (profile) : a brachiopod ranging from Fredonia to Gasper oolite.

10-13. *Chonetes chesterensis* Weller, after Weller; a brachiopod from the Gasper oolite.

14-17. *Pentremites pyriformis* Say; various views of calyx: a blastid from the Gasper oolite.

18-19. *Pentremites godoni biconvexa* Ulrich, after Ulrich; a blastid.

20-23. *Pentremites godoni* Defrance, after Ulrich; a blastid confined to the Gasper oolite. The commonest pentremite in the Mississippian. From its abundance in southern Kentucky is has been called the "Kentucky fossil."

24-26. *Talarocrinus patei* Wachsmuth and Springer, after Wachsmuth and Springer; 24, a complete specimen from the side; 25 and 26, views of the calyx from the side: a crinid from the Gasper oolite.

27-29. *Agassizocrinus conicus* Owen and Shumard, after Ulrich; 27, calyx from the side; 28, calyx from the top; 29, calyx from the bottom: a free-floating stemless crinid, ranging now in the rocks from the Gaspel to the Glen Dean.

30-33. *Diaphragmus* (*Productus*) *elegans* (Norwood and Pratten), after Weller; 30, pedicle valve; 31, brachial valve; 32, side (profile) ; 33, pedicle valve of a larger specimen: a brachiopod ranging from the Fredonia oolite to the top of the Chester.

34-36. *Archimedes confertus* Ulrich, after Ulrich; a screw bryozoan from the Gasper oolite.

37-39. *Cliothyridina sublamellosa* (Hall), after Weller; 38, pedicle valve; 39, brachial valve: a brachiopod common in the Chester.

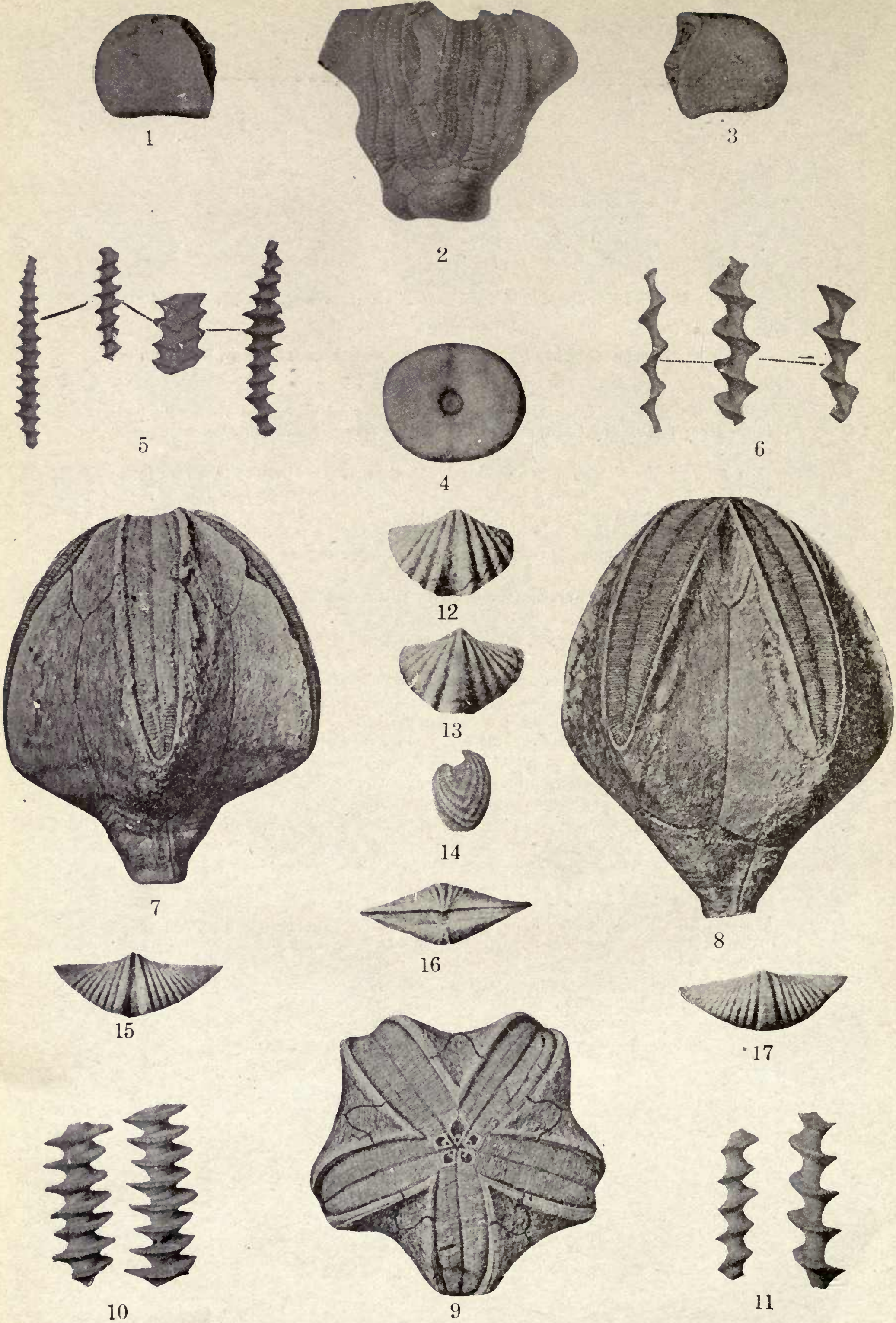


PLATE 62

62. FOSSILS FROM THE CHESTER FORMATION

A reproduction of Plate 23 in "Mississippian Formations of Western Kentucky," by Charles Butts

1-4. *Pterotocrinus capitalis* Lyon; 1 and 3, interbrachials, after Ulrich; 4, the two basal plates, after Ulrich; 2, a complete head looked at from the side, after Wachsmuth and Springer: a crinid restricted to the Golconda bed.

5. *Archimedes compactus* Ulrich, after Ulrich; several specimens of the spiral axes of the colonies: a common bryozoan in the Golconda bed.

6. *Archimedes terebriformis* Ulrich, after Ulrich; three specimens of the spiral axes of the colonies: a bryozoan common in the Golconda and Glen Dean beds.

7-9. *Pentremites obesus Lyon,* after Ulrich; 7 and 8, side views of the calyx; 9, the calyx from the top: a blastid from the Golconda bed.

10. *Archimedes lativolvis* Ulrich, after Ulrich; two specimens of the spiral axes of the colonies: a bryozoan from the Golconda bed.

11. *Archimedes swallowensis* Hall, after Ulrich; two specimens of the spiral axes of the colonies: a bryozoan from the Golconda bed.

12-14. *Spiriferina spinosa* (Norwood and Pratten), after Weller; 12, pedicle valve; 13, brachial valve; 14, side (profile): a brachiopod common throughout the Chester.

15-17. *Spiriferina transversa* (McChesney), after Weller; like *Sp. spinosa* but with finer markings; 15, pedicle valve; 16, posterior (hinge) side; 17, brachial valve: a brachiopod very common in the Chester.

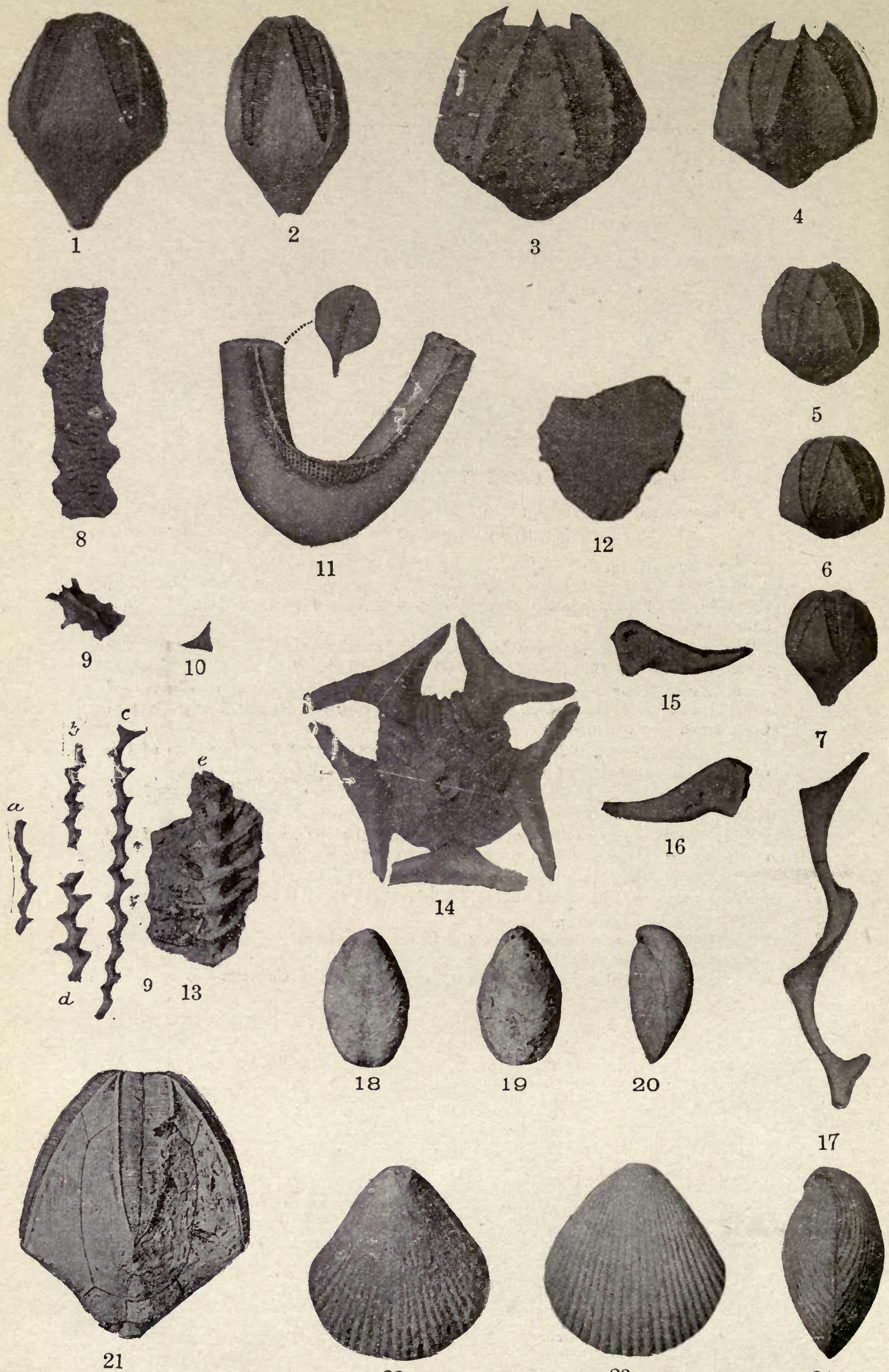


PLATE 63

63. FOSSILS FROM THE CHESTER FORMATION

A repreduction of Plate 24, "Mississippian Formations of Western Kentucky," by Charles Butts

1-2. *Pentremites pyramidatus* Ulrich; side views: a blastid probably restricted to the Glen Dean bed.

3-4. *Pentremites spicatus* Ulrich; side views: a blastid common in the Glen Dean bed, doubtfully identified in the Golconda.

5. *Pentremites tulipaeformis* Hambach: a blastid from the Glen Dean bed.

6. *Pentremites brevis* Ulrich: a blastid confined to the Glen Dean bed.

7. *Pentremites canalis* Ulrich: a blastid confined to the Glen Dean bed.

8-10. *Prismopora serrulata* Ulrich; 8, one face, X2; 9, perspective view, natural size; 10, end, natural size: a bryozoan almost invariably present in the Glen Dean bed.

11. *Lyropora ranosculum* Ulrich; U-shaped base between the limbs of which stretched a fenestelid-like zoecial colony: a bryozoan apparently restricted to the Glen Dean bed.

12. *Pterotocrinus depressus* Lyon and Casseday; a wing-like interbrachial: a crinid from the Glen Dean and higher beds of the Chester.

13. *Archimedes meekanus* Hall; specimens of the spiral zoarial axes of various sizes: a bryozoan ranging from the Fredonia to the Clore beds.

14. *Pterotocrinus bifurcatus* Wetherby after Wachsmuth and Springer; the forked-wing plates characteristic: a crinid confined to the Glen Dean bed.

15-16. *Pterotocrinus acutus* Wetherby; side views of two interbrachials: a crinid characteristic of the Glen Dean bed.

17. *Archimedes laxus* Hall; a spiral zoarial axis: a bryozoan highly characteristic of the Glen Dean bed.

18-20. *Dielasma illinoisensis* Weller, after Weller; 18, pedicle valve; 19, brachial valve; 20, side (profile): a brachiopod ranging from Ohara to Glen Dean.

21. *Pentremites fohsi* Ulrich, after Ulrich; resembles *P. obesus* but is smaller: a blastid characteristic of the Glen Dean bed.

22-24. *Eumetria costata* (Hall), after Weller; 22, brachial valve; 23, pedicle valve; 24, side (profile): brachiopod from the Glen Dean bed.

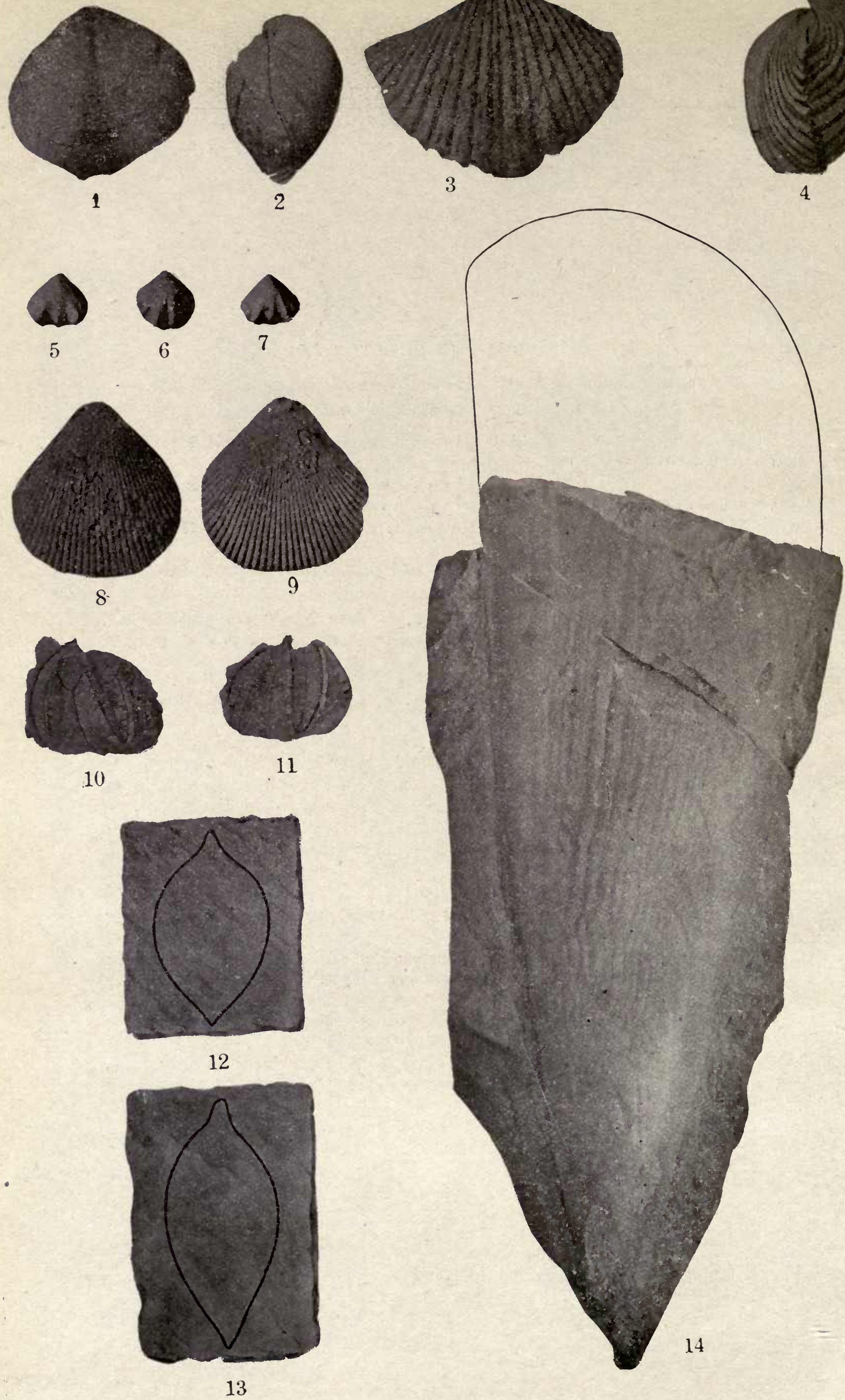


PLATE 64

64. FOSSILS FROM THE UPPER CHESTER FORMATION

A reproduction of Plate 28 in "Mississippian Formations of Western Kentucky," by Charles Butts

1-2. *Composita subquadrata* (Hall); 1, pedicle valve; 2, side (profile): a brachiopod in the Menard, Clore and Buffalo Wallow beds.

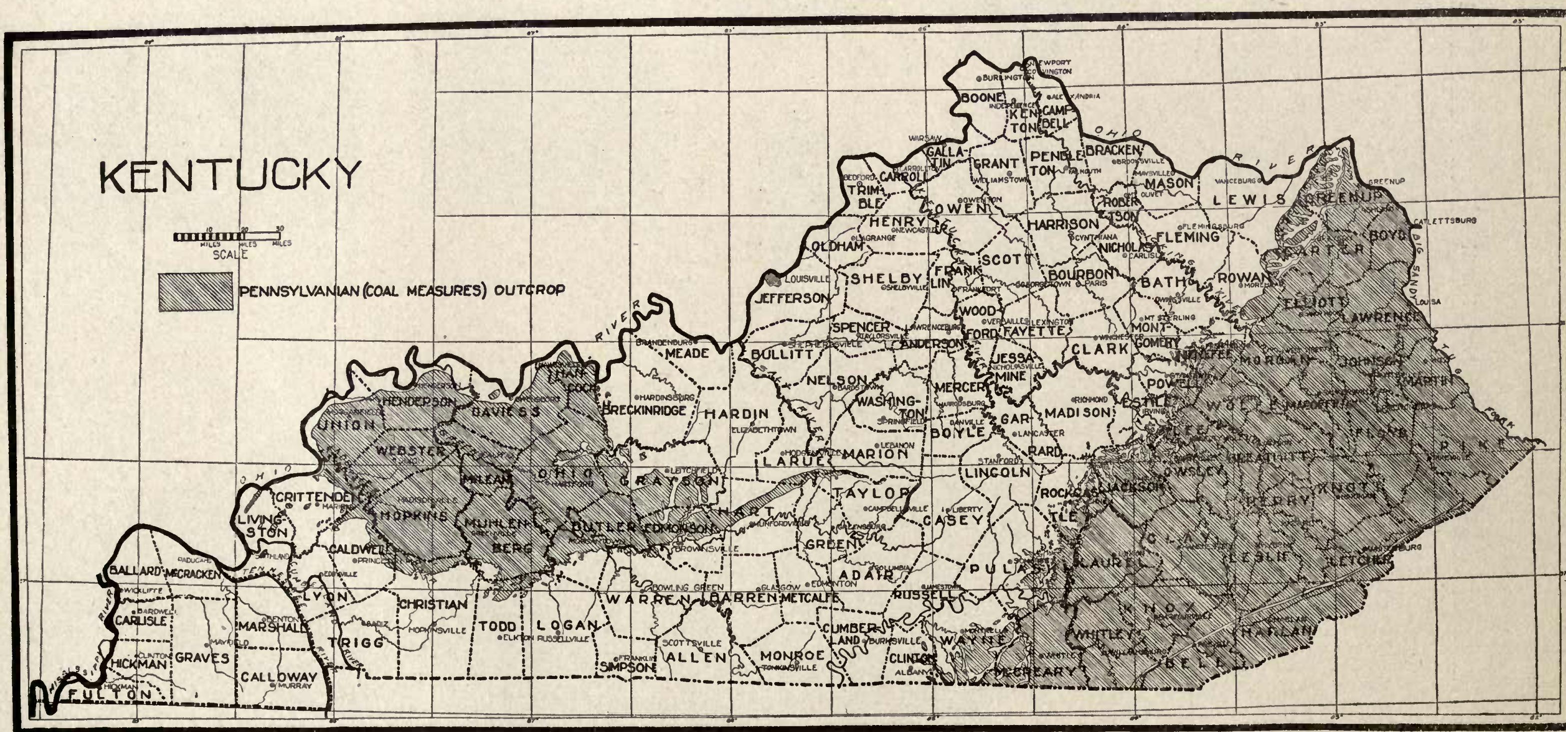
3-4. *Spirifer increbescens* Hall; 3, pedicle valve; 4, side (profile): a brachiopod with the same range as the foregoing.

5-7. *Camarophoria explanata* (McChesney; 5, pedicle valve; 6 and 7, brachial valves: a brachiopod of the Menard bed.

8-9. *Eumetria vera* (Hall); 8, pedicle valve; 9, brachial valve: a brachiopod common in the Clore and Buffalo Wallow beds.

10-11. *Pentremites serrata* Hambach; side views: a blastid from the Buffalo Wallow bed.

12-14. *Sulcatopinna missouriensis* (Swallow); 12-13, cross sections of both valves together; 14, a portion of one valve: a lamellibranch ranging from the Menard to the top of the Chester.



65. LOCATION OF PENNSYLVANIAN (COAL MEASURES) OUTCROP

CHAPTER VI

PENNSYLVANIAN SYSTEM

This formation was named from the State of Pennsylvania by H. S. Williams in 1891. It is synonymous with the Coal Measures of earlier geological literature.

General Stratigraphic Features of the Pennsylvanian and Their Bearing on the Origin of Coal.—The Pennsylvanian consists of sandstones, shales and occasional thin, impure limestones. Intercalated with these are coal seams. The sandstones are commonly cross-bedded and show therefore deposition in rapid currents of water.

Nearly everywhere at the base are lenses of quartz pebble conglomerate. Opinion is not in entire accord as to just what were the conditions under which this mass of strata which included coal seams was laid down. Coal is undoubtedly fossil vegetation; but did it grow where the coal is now found, or was it floated thither? If the former view is correct, did the vegetation grow on extensive river flood plains near sea level, or in vast marine swamps? If the vegetation from which coal was formed was a river flood plain growth, then the sandstones and shales with which it is intercalated must have been originally river deposits, and hence of fresh water origin.

If the vegetation grew in marine swamps these sandstones and shales are at least in part marine—a deposit in salt or brackish water.

To the writer the evidence in the main points to coal and the including strata being a fresh water river deposit.

The evidence afforded by the conglomerates is conflicting. Their pure quartz pebble composition points to a beach deposit, in which case they would be marine. On the other hand their very lenticular bedding, and especially their frequent occurrence as fillings of erosion channels, point to their deposition in rapid flowing streams.

Areal Distribution of the Pennsylvanian in Kentucky.—The "Coal Measures" in Kentucky have not been covered by any later deposits. They occupy in outcrop about 15,000 square miles and are divided into two fields—an Eastern of 10,400 square miles and a Western of 4,600 square miles. The Eastern Kentucky Coal Field is a part of the larger Appalachian Field, and the Western Kentucky Coal Field is a part of the Western Interior Field.

Subdivisions of the Pennsylvanian in the Eastern United States.—From 1856 to 1858 H. D. Rogers, State Geologist of Pennsylvania, elaborated a fivefold classification for the Coal Measures of Pennsylvania and Virginia. These in ascending order were Conglomerate, Lower Productive, Lower Barren, Upper Productive and Upper Barren. To these descriptive names were later attached geographic ones: in ascending order, Pottsville, Allegheny, Conemaugh, Monongahela and Dunkard. The Dunkard was afterwards set off as belonging properly to the Permian, leaving a fourfold classification for the Pennsylvanian of the Eastern United States.

Pioneer work on the classification of the "Coal Measures" of Kentucky was done by David Dale Owen, her first State Geologist. Most of his investigations were carried on in the Western Field. The Coal Measures there were divided by him in his first report, published in 1856, into two series: a lower and an upper, with a sandstone separating the two. To this sandstone he gave the name "Anvil Rock," from the resemblance to an anvil a detached block of this formation exhibits on Hines Creek, near Dekoven in Union County. He did not include the basal conglomerate sandstone or the underlying shale in this classification, even though they might contain some thin coal, holding that they were the "False Coal Measures," even after he learned that along the southwestern border of the Eastern Coal Field they contained three workable seams of coal.

Owen assigned as thicknesses to these divisions, 986 feet to the lower series, forty-three feet to the "Anvil Rock" and 2,400 feet to the upper series, making a total of 3,429 feet. If to this a thickness of about 100 feet be assigned to the Conglomerate and its underlying shale, we obtain for the whole Pennsylvanian in Western Kentucky a thickness of about 3,500 feet. Recently Wallace Lee, in his report on the Shawneetown quadrangle, 1916, estimated the total thickness of the Pennsylvanian in Union County at 2,650 feet.

Owen identified in his Coal Measures proper in Western Kentucky about eighteen coal seams, eight above the Anvil Rock and ten below. Not all of these, however, are workable. In his second, third and fourth reports—the latter published in 1861, the year of his death—he had so far revised his classification as to establish for the Western Field three divisions: a Lower, Middle and Upper, to each of which he assigned a thickness of about 500 feet.

In this revised classification he selected the Anvil Rock as the horizon for separating the Upper from the Middle Coal Measures and a newly recognized sandstone, the Curlew, as the horizon for separating the Middle from the Lower Measures.

The Curlew (David Owen, 1857) got its name from an elevation now called "Indian Hill," near Dekoven in Union County. Later Owen numbered his coals from one to eighteen, and, beginning on top of the "Conglomerate," assigned them to his three divisions as follows: numbers one to four inclusive to the Lower, five to twelve inclusive to the Middle, and thirteen to eighteen inclusive to the Upper. He refused to the last to admit the Conglomerate and Sub-conglomerate strata to his coal measure classification.

Mingled Correct and Incorrect Views of Owen and Lesquereaux.—Though Owen was accurate as an observer, and reliable in his correlations when he did not attempt to extend them over too wide a field (his classification of the Measures in the Western Field has thus far withstood the attacks of all his critics), his Wernerian ideas led him into error when he attempted long range correlations. Thus not only did he assume that a "coarse-grained pebble rock" low down in the coal series here in North America must be identical with one at the very base of the Coal Measures in England—the one the English miner there calls the "farewell rock"; but he also thought that, by reason of their numbered place in the series, or their intervals in feet, or certain physical characters possessed by them, he could correlate seam for seam the coals in Kentucky with those in Pennsylvania or even with those of the British Isles.

It remained for Leo Lesquereaux, the Swiss paleobotanist, secured by Owen to report on the fossil plants of the Kentucky Coal Measures, and to attempt correlations therefrom, to point out to Owen his error. Lesquereaux, writing for Volume IV, held that the coal forming period had already been ushered in, even before the conglomerate sandstones had been laid down, and called attention to the "fallacy" of those who supposed that "the appearance of coal below the Conglomerate was something abnormal and a local phenomenon without direct connection with the Carboniferous Epoch,'' and that ''it would be useless to search for coal beneath it.''

Lesquereux, however, was himself in error in including the Sub-carboniferous limestone within the Coal Measures, and, despite his paleontological knowledge, was disposed at times to attempt long range correlations of rock beds based entirely on lithological resemblances. He readily endorsed Owen's identification of the Curlew sandstone with the Mahoning of Pennsylvania, and unhesitatingly correlated almost seam for seam the coals of Western Kentucky with those of Pennsylvania. In this classification he correlated the No. 11 coal of the Western Field with the Pittsburg coal of the Eastern.

We now know that sandstones, and especially the coarser conglomeritic types, are entirely too lenticular to be traced certainly as individual beds over wide areas. Such expressions then as ''The Conglomerate Formation'' and the ''Sub-conglomerate Coal,'' where they are intended to refer in each case to an originally continuous formation extending over large scopes of country, are objectionable, since they are almost certain to involve error.

Classification of the Pennsylvanian in Kentucky

Series	*Stage*	*SUB-STAGE* Eastern Field	*SUB-STAGE* Western Field	*Thickness in Feet*
Monongahela		Wanting	Shale and sandstone, Geiger's Lake coal.	130
Conemaugh		Red and purple shales, sandstones, thin limestones. L. Cambridge and Ames Coals 9 to 12.	Shales and sandstones. Coals 13 to 18.	400—1000
		Mahoning	Anvil Rock?	50— 100
Allegheny		Mostly shales. Coals 5 to 9 red kidney, yellow kidney and ferriferous limestone ores.	Mostly shales. Coals 5 to 12.	100— 400
Pottsville	Breathitt. Wise in E. Field, Tradewater in W. Field.	Homewood sandstone. Harlan sandstone?	Curlew sandstone.	25— 100
		Mostly shales. Coals 1 to 4.	Mostly shales.	500
		Corbin conglomerate (Gladeville sandstone?)	Caseyville conglomerate.	0— 150
	Norton?	Mainly shales. Barren Fork coal. (Beattyville coal?)		300— 600
	Lee in E. Field.	Rockcastle conglomerate.		0— 150
		Beattyville shales. Beaver Creek and Hudson coals. Oil sands.		0— 150

POTTSVILLE SERIES

(Pottsville Conglomerate: C. A. Asburner, 1877. Named from Pottsville, Pa.)

Lithological Characteristics and Correlations.—The most striking feature of the Pottsville is the prevalence in it of coarse beds; hence the name by which it is most commonly known—"Pottsville conglomerate."

In Pennsylvanian there are three prominent and persistent beds of coarse sandstone which are frequently conglomeritic. These are, in ascending order, the Sharon, Conoquenessing and Homewood.

Only the upper of these—the *Homewood* (Platt, 1880) has been identified in Kentucky with certainty. The *Sharon* (I. C. White, 1891) may be represented by one or the other or both of the two lower Pottsville conglomerates differentiated in the State.

In Pennsylvania the Pottsville carries four workable seams of coal—in ascending order the Sharon, Quakertown, Lower Mercer and Upper Mercer.

It was only the probable equivalent of the lower or Sharon conglomerate, which is strikingly conglomeritic in Kentucky, and it was only this portion which was referred to by them under the term "Conglomerate."

As we have already learned there is no workable coal in this conglomeritic member of the southwestern part of the Western Kentucky Coal Field, and hence, in numbering the coals of that region, Owen began on top of the "Conglomerate." Owen lived long enough to know that the same thing was not true of the Eastern Field, but that there were several workable coals there in the Conglomerate Series.

However, neither he nor his successors in Kentucky geology, modified this system of numbering coals which had been inaugurated, so that these numbers have become pretty firmly established as designations for certain coal seams in certain localities. Especially is this true in the Western Field. The numbers used in this text, as applied to coal seams, are intended to be in accordance with this system introduced by Owen.

EASTERN COAL FIELD

History of Attempts to Unravel Its Stratigraphy. —Joseph Lesley, working for the Owen Survey in 1858-9, was the first to study the outcrop of the lowest measures along the western border of the Eastern Coal Field. He was evidently under the impression that he had to do at that time with the whole conglomerate formation as represented in Pennsylvania. He noted the general thickening of the series as it was followed toward the southwest, but being imbued with the fixed notion that the "Conglomerate" and "Sub-conglomerate" were each single continuous beds of unvarying lithological character, he failed to recognize the appearance and disappearance of separate beds of conglomerate and shale as they were followed in the direction pursued, and hence always reserved the name "Conglomerate" for the lowest pebbly sandstone, and the name "Sub-conglomerate" for any shale bed which might lie between this pebble rock and "Sub-carboniferous limestone."

A. R. Crandall in his report on Whitley and Part of Pulaski County, published in 1885, proposed to substitute "Rockcastle Conglomerate" for the former term. The name was taken from the Rockcastle River, along which there are such splendid exposures of conglomerate in picturesque cliffs. Owing, however, to his failure to recognize the presence of two conglomeritic sandstones in the very much thickened series in this region, the upper member of which was frequently not a pronounced conglomerate, he generally applied the term to the lower member only.

Marius Campbell in his report on the Estillville Quadrangle (1894), which covered part of Harlan County, Ky., classified the Pottsville in that region as follows:

	Feet Thick
Harlan sandstone, named from Harlan County, Ky. (hard, massive ledge at base)	40
Wise formation, named from Wise County, Va.	1270
Gladeville sandstone, named from Gladeville, Va.	100— 120
Norton formation, named from Norton, Va.	1250
Lee conglomerate, named from Lee County, Va.	1200—1530

In his report on the London and Richmond Quadrangles (1898), covering a portion of the southwestern border of the Eastern Coal Field, he divided the Pottsville there into the Lee and Breathitt without defining the upper limits of the Breathitt. It is also doubtful if his Lee here is the equivalent of the one of Lee County, Va. In the Lee he identified two massive conglomeritic sandstones and somewhat provisionally a third. He named the lower of the first two the "Rockcastle lentil," and the upper the "Corbin lentil," named respectively from the Rockcastle River and a town in Whitley County. The third conglomerate he found occupying narrow erosion channels in the drainage of Roundstone and Horselick Creeks, where they were sunken down into, and in some cases through, the underlying limestone, which he had named the Newman. He proposed no name for this latter conglomerate, not being certain that it was of different age from the Rockcastle conglomerate. He called attention to the smaller size of the pebbles in the Corbin and their pinkish color as distinguishing this lentil from the Rockcastle.

The writer in 1910, in his report for the Kentucky

Geological Survey on the Western Border of the Eastern Coal Field, confirmed in the main the work of Mr. Campbell, and extended the mapping of these subdivisions into outlying areas, the strip covered reaching from the Tennessee line to Menefee County. He was not able certainly to identify the Rockcastle as a separate lens much north of Jackson County, though as far north as Estill and Lee Counties there was found a lower massive cliff-forming sandstone about twenty to forty feet thick which might represent the Rockcastle of sections further south. He suggested the name "Livingston" for the conglomerate in the Roundstone and Horselick drainage.

Mr. W. C. Phalen in his report on the Kenova Quadrangle for the United States Geological Survey was the first to place a definite limit to the top of the Pottsville in Kentucky. He drew it on top of a sandstone which he identified with the Homewood of Pennsylvania. This, according to the Kentucky system of numbering coals, inaugurated by Owen, would place in the Pottsville of Kentucky numbers one to four inclusive.

Mr. J. B. Hoeing, State Geologist of Kentucky, in his annual report for 1913, commenting upon Professor I. C. White's division of the Pottsville of West Virginia in ascending order into the Pocahontas, New River and Kanawha groups, identified only the upper one of these as extending in any very great thickness into the upper Big Sandy drainage. In his report on the Pound Quadrangle, Mr. Charles Butts in Bulletin 541-F, United States Geological Survey, 1914, accepted the classification of the Pottsville for that region proposed by Mr. Campbell in 1894, and gave the thicknesses of the divisions as they are found exposed in Letcher and adjacent portion of Pike County.

These, as given, are, Lee formation 1,030 feet, Norton formation 1,191 feet, Gladeville sandstone 100 feet, Wise formation 2,070 feet and Harlan sandstone 400 feet.

Mr. J. B. Hoeing in his preface to Mr. Crider's report on Letcher County in 1916 accepted a threefold division of the Pottsville for that county, using for them the names proposed by Campbell. These with the thicknesses as given in this report are as follows:

Wise formation	1225 feet
Norton formation	1535 feet
Lee formation	985 feet
Total	3745 feet

THE THICKENING OF THE POTTSVILLE AS IT IS FOLLOWED FROM THE OHIO RIVER SOUTHWESTWARD AND SOUTHEASTWARD.—The "Conglomerate" at the Ohio River in Greenup County, probably the equivalent of the Sharon conglomerate series of Pennsylvania and of both the Lee and Norton formations of Virginia, is sixty feet thick.

Along the western border of the Eastern Coal Field this formation is seen to thicken steadily to the Tennessee line. It is 250 feet thick in Menefee County, 300 in Powell, 400 feet in Lee, 400 feet in Jackson, 400 feet in Rockcastle, 500 feet in Laurel, and 750 feet in McCreary County.

The thickening toward the southeast is even more pronounced. Well records give 603 feet for this formation in Lawrence County, and 995 feet in Johnson. Measured outcrop gives 2,500 feet for the same interval in Letcher County.

The remainder of the Pottsville above the Sharon conglomerate series in Kentucky also thickens toward the southeast from 500 feet near the Ohio River to 2,500 feet near the West Virginia line.

THE TOPOGRAPHY.—On account of the prevalence of hard conglomeritic ledges, interspersed with shales, the basal measures in Kentucky give rise in outcrop to a very rugged topography. Precipitous cliffs abound, some of them offering sheer faces of 200 to 300 feet. The master streams, which traverse this formation, have cut deep gorges in it. These are boulder filled and known as "devil's jumps." The Cumberland River itself, in traversing this formation, falls over a hard ledge of the Rockcastle conglomerate and thus forms the Cumberland Falls, sixty-five feet high. The very much ramified smaller tributaries in this border strip to the Eastern Coal Field have sunk themselves deeply into the formation and by their sources retreating headward, have reduced the divides to very narrow sinuous ridges.

VEGETATION.—The outcrop of the Conglomerate Measures is marked by a very characteristic vegetation. Here the true mountain flora begins; conspicuous elements being yellow and white pine and chestnut on the ridges, and spruce pine (or hemlock) in the gorges. Accompanying these are found as undergrowth or small trees, the rhododendron and laurel, the sourwood and the large-leaved mountain magnolia, the huckleberry and the trailing arbutus. The arbutus, which clings to the conglomerate or coarse sandstone ledges of this formation, is found nowhere else in the State.

Cultural Features.—The outcrop of the Conglomerate Measures forms a region poor agriculturally. A scattered population of poor cabin folk live in its narrow stream valleys. The ridges, which are covered by a scant sandy soil, are for the most part uninhabited. They are reserved for the main roads and trails. This strip of country, forming the western border of the Eastern Kentucky Mountains, has from the earliest settlement of the State presented a barrier something like a Chinese wall tending to shut out the population of Eastern Kentucky from intimate contact and association with that of the central Bluegrass counties.

Coals.—W. C. Phalen, in his report on the Kenova Quadrangle for the Federal Survey in 1912, was the first to carry satisfactorily the Pennsylvania-Ohio divisions of the Pottsville into Northeastern Kentucky and to support his correlations as regards the equivalency of the coals by appeals to paleobotanic evidence. The thickening of the Pottsville to the southeast and southwest is attended with the introduction of new seams which do not fit in with this system of classification, that was worked out for the formation where it is thin. Especially does it invalidate the old system of numbering coals begun in this State by Owen. There are two seams, however, which show great persistence and can each be traced across the State from the Ohio to the Tennessee line in perfect continuity. These are the No. 1 or the Barrett Creek (Sharon?) and the No. 4 or the Hunnewell (Upper Mercer). The latter is marked by a flint fire clay occurring as a parting, or in some cases as an underclay, of such unique character that it serves to identify this seam wherever it outcrops.

The correlations presented in the following table must be considered approximate only in a great many cases. They apply in some cases better to groups of coals than individual seams.

Table, Showing Correlation of Coals of the Pottsville of Eastern Kentucky with Those of the Same Formation in Pennsylvania, West Virginia, Virginia and Ohio

Kentucky	*Ohio*	*Virginia and West Virginia*	*Pennsylvania*
Homewood Sandstone	**Homewood Sandstone**	**Homewood Sandstone**	**Homewood Sandstone**
No. 4, Hunnewell of Greenup, "Big vein" and 5-foot vein of Lawrence, Hyden of U. North Fork of Kentucky R., Georges Creek of Breathitt, Dean of Cumberland R., Flatwoods of Pike, Fire Clay Seam.	32, Bruce, Bedford, Strawbridge, Newland.	Lower Thacker? Chilton.	Upper Mercer.
Amburgy of Letcher.			
No. 3, Turkey Lick of Greenup, Mc Henry, Peach Orchard and Torchlight of Lawrence, Elkhorn of Pike, and Letcher, Jackson of Breathitt, Jellico? of Whitley, Straight Creek of Bell.	No. 3, Flint Ridge Cannel, Blue Limestone Seam.	Taggart of Va., Alma of W. Va., No. 2 Gas. of W. Va.	Lower Mercer.
Ivel of U. Levisa Fk. of Big Sandy, Collier of Letcher.		Powelton of Va.	
No. 2, Danleytown and Clod of Greenup, Kibby, Jones and Lewis of Carter, Van Lear of Johnson, Paintsville of Johnson, U. Marrowbone of Pike, Penny of Letcher, Harlan of Harlan.	No. 2, Wellston, Jackson Hill.	Eagle, No. 1 Gas., Freeburn of W. Va.	Quakertown.
Shelby Gap? of Pike.			
Kelley.			
No. 1, Barrett's Creek of Carter, Zachariah of Wolfe, Manchester of Clay, Lily of Laurel, Williamsburg of Whitley, Pine Knot of McCreary, Jim Dotson?, Syke? and Fed? of Pike.	Jackson Shaft, Brier Hill, Massilon.	Imboden? of Va.	Sharon.
Corbin Conglomerate.		Gladeville? of Va.	Sharon? Conglomerate.
Barren Fork of McCreary, Pine Hill of Rockcastle.			
Rockcastle Conglomerate.			
Beaver Creek and Stearns No. 2 of McCreary, Beattyville of Lee.			
Hudson of Pulaski, Stearns No. 1.			

Iron Ore.—Iron ore occurs in erosion hollows of the Mammoth Cave Limestone underneath the Pottsville and in the shales associated with the coal seams from No. 1 to No. 4. The latter are termed "block" ores. All of them are limonites. See *Iron Ore* under Economic Geology, Part IV.

WESTERN COAL FIELD

History of Progress in Interpreting Its Stratigraphy.—The Conglomerate member in the Western Field did not receive much attention from Owen and the other earlier Kentucky geologists. This was because it did not contain any workable coal. Owen in 1857 gave to it in the Tradewater district the name "Caseyville sandstone," from Caseyville, in Union County. It is the Mansfield sandstone (Hopkins, 1896) of the Indiana Survey reports. In 1884 Mr. P. N. Moore (in Volume D for the Shaler Survey) recognized two conglomerates in the Nolin River district, a lower coarse-pebbled-quartz conglomerate, to which he gave no name, and an upper small-pebbled quartz conglomerate, to which he gave the name "Bee Spring sandstone." The pebbles of the lower conglomerate were described as being quite large—some of them as big as hen's eggs. Those of the Bee Spring sandstone were much smaller and often of more pinkish cast.

It is significant that similar differentiating features apply to the Rockcastle and Corbin conglomerates of the Eastern Coal Field. It is possible that these two conglomerates may be stratigraphic equivalents in the two separated fields. The lower conglomerate was found to reach its maximum thickness—180 feet—near the junction of the Nolin and Green Rivers. The Bee Spring conglomerate was found to be of wider areal extent. It ranged in thickness between fifty and sixty feet. Shales reaching a maximum of 100 feet in thickness intervened between the two conglomerates. The Main Nolin Coal—a workable seam—occurs on top of the lower conglomerate, and is hence an interconglomerate seam, though the designation Owen gave to it—Number 1-B—indicated that he considered it as coming next above the Conglomerate Measures.

Mr. Moore, in his report on Hancock County in this same Volume D, also recognized the presence of two conglomeritic sandstones in this portion of the margin of the Western Coal Field—that near the Ohio River—and he provisionally correlated them with the two conglomerates of the Nolin River district.

Professor L. C. Glenn, in a report prepared for the Norwood Survey in 1910, refers to the conglomerate in the Tradewater district as the "Pottsville," though it is not likely that it can represent any portion of that formation but the lowest, or Sharon member.

Mr. Wallace Lee, in his report on the Shawneetown Quadrangle for the Hoeing Survey in 1916, with the paleobotanic aid of Mr. David White was enabled to extend the term Pottsville for the Western Field so as to include in it not only the Caseyville conglomerate but also that portion of the Coal Measures above it to the base of the Davis Coal or the No. 5 of Owen. This would be the limit of the Tradewater formation (Glenn, 1910), and would give to the Pottsville in Union County a thickness of 1,100 feet. It appears to the writer that it is better to draw the line for the top of the Pottsville at the top of the Curlew sandstone, which may possibly correlate with the Homewood of the Eastern Field. It certainly is not the Mahoning sandstone as Owen thought. The coals placed by Mr. Lee in the Pottsville of Union County are in ascending order, using the Owen designation, No. 1, Battery Rock; No. 2, Bell; No. 3, Ice House; No. 4, Smith, and No. 5, Curlew.

Distribution and Topographic Features.—The Pottsville exhibits its conglomeritic or coarse sandstone phase as a continuous border to the Western Coal Field, except on its eastern side. Here there is a considerable stretch where no conglomerate occurs. The conglomerate outcrop gives rise to a rugged strip of country similar to that which it occasions in the Eastern Field. However, since it lies at a lower elevation from sea level, and is comparatively thin (Sidney Lyon estimated its average thickness as between seventy-five and 100 feet), it has not, as a rule, been carved into the mountainous topography that the same type of stratigraphy presents in the Eastern Field. There is an interesting outlier, or rather long tongue-like projection of the lower conglomerate of the Western Field, which stretches in virtual continuity from the extreme eastern end of it through Hart County, and along the boundary of Larue and Green and Taylor Counties as far as the top of Muldraugh's Hill, forming the boundary of Taylor and Marion Counties north of Spurlington.

This strip crosses the main Louisville & Nashville Railroad near Bonnieville. The conglomerate in this stretch is a very much disintegrated mass, eighty to 100 feet thick, of coarse pebbles and sand. The pebbles are the size of hens' eggs, and hence the formation links itself on to the lower Nolin River conglomerate as a continuation of the same. Like the latter it is also a channel-filling conglomerate, lying in the St. Louis limestone, the Chester and Ste. Genevieve having been cut out. This conglomerate can be further traced in patches lying on the highest points of the watershed separating Green from Salt River, and thence between Dix River, an affluent of the Kentucky, and Buck Creek, of the Cumberland, to the Eastern Coal Field in Rockcastle County. It may indeed at one time have linked up with the Livingston channel-filling conglomerate, as the deposit of a great river of Pottsville time trenching across what is now a saddle on the Cincinnati Anticline. It is difficult to surmise in which direction this river flowed, but the larger sized pebbles in the western portion of the strip would seem to indicate that this was toward the headwaters, and that the general direction of flow was from west to east.

Economic Deposits.—The coals of the Pottsville in Western Kentucky are only of local importance. Little mining on a commercial scale is done on them.

Some of the asphalt rock of Western Kentucky—that in Edmonson and Warren Counties—is in lower Pottsville conglomeritic sandstone. Iron ore is found, as in the Eastern Field, in hollows of the Mammoth Cave limestone underneath these coarse basal sandstones.

ALLEGHENY SERIES

(H. D. Rogers, 1849. Named from the Allegheny River)

EASTERN KENTUCKY

Limits and Stratigraphy in Pennsylvania and in Eastern Kentucky.—The Allegheny comprises in Pennsylvania those strata lying between the top of the Homewood and the base of the Mahoning sandstone. As contrasted with the Pottsville it is a great shale series with more persistent coal seams. This division was first definitely identified in Kentucky (in the northeastern portion) and assigned limits by Mr. W. C. Phalen in his report on the Kenova Quadrangle previously cited. The thickness of the Allegheny in this portion of the State ranges between 100 and 200 feet. The most common measurement is 180 feet. The same five coals which have been mined in the Allegheny of Pennsylvania have been traced in outcrop through Ohio and some 100 miles south in Kentucky. It is highly probable they are continuous with the length and breadth of the Allegheny in Eastern Kentucky.

Designations and Correlations of the Coals.—In Pennsylvania the five persistent coals of the Allegheny are known in ascending order as the Brookville, Lower Kittanning, Middle Kittanning, Lower Freeport and Upper Freeport. The work of A. R. Crandall, Edward Orton and W. C. Phalen has enabled us to establish the correlation of these coals in Pennsylvania, Ohio and Kentucky as set forth in the following table.

Table, Showing Correlation of Coals in the Allegheny of Eastern Kentucky with Those of the Same Formation in Pennsylvania West Virginia, Virginia and Ohio

Kentucky	*Ohio*	*Virginia and West Virginia*	*Pennsylvania*
Mahoning Sandstone.	Mahoning Sandstone.	Mahoning Sandstone.	Mahoning Sandstone
Interval 40′—70′.			
No. 9, Hindmann of Knott County, High Split.	N. 7 Waterloo.		U. Freeport.
Interval 30′ to 50′.			
Hatcher of N. E. Kentucky.	N. 6A.	Coalburg, W. Va.	L. Freeport.
Interval 45′ in which comes red kidney ore.			
No. 7, Coalton of Boyd County; Flag, Cornett of Letcher County.	Nelsonville, No. 6.		M. Kittanning.
Interval 35′—45′ in which comes yellow kidney iron ore.			
No. 6, Keys Creek of Boyd County; Hazard of Perry County.	No. 5, Newcastle.		L. Kittanning.
Interval 15′ to 20′.			
Vanport (Ferriferous) limestone 4′—5′.	Hanging Rock limestone.	Buffalo Creek limestone of W. Va.	Vanport limestone.
Interval 30′ to 40′.			
No. 5, Pennington and Cooksie Fk. of Lawrence; Haddix of Breathitt.	Conway, Upper limestone coal.	Pardee and Parsons of Va.; U. Thacker of W. Va.	Brookville.
Homewood Sandstone.	Homewood Sandstone.	Homewood Sandstone.	Homewood Sandstone.

The Economic Importance of the Coal and the Iron. —It will be seen from the foregoing that the Allegheny is a very important coalbearing formation well deserving the name "Lower Productive." It also contains three iron ore beds, which along with those from the underlying Pottsville, were as late as the eighties of the last century much worked and smelted in Northeastern Kentucky.

The fuel used was largely charcoal. The ruins of these old furnaces—Mt. Savage, Boone, Kenton, Hunnewell, Raccoon and ten others, still remain in that region as testimony to an industry that has vanished from the State. One of the most important of these Allegheny ores occurred primarily as the replacement in the form of carbonate of iron of a bed of limestone four to five feet thick—the "Ferriferous limestone" (J. S. Newberry, 1874) of Ohio, Kentucky and Pennsylvania; "Hanging Rock limestone" (Edward Orton, 1878) of Ohio; Vanport limestone (I. C. White, 1878) of Pennsylvania. It was this ore weathered to a limonite, which was the mainstay of the iron industry in the Hanging Rock Iron Region of Ohio and Kentucky. Above the Vanport limestone in the shales between the Lower and Middle Kittanning and again in those between the Middle Kittanning and Lower Freeport coals are the yellow and red kidney ores respectively. These are in the form of nodules more or less kidney shaped. Though originally a carbonate of iron, they are now, where exposed at or near the surface, hydrated oxide of iron—that is, *limonite*. This is the highest horizon at which workable iron ore has been found in the Coal Measures of Kentucky.

Areal Distribution of the Strata.—The position of the Allegheny in the Eastern Coal Field is mainly in the middle of the Eastern Kentucky Syncline. Along the axis of this trough it extends almost completely across Eastern Kentucky. It is also found in the Black Mountain Syncline on the southeast side of Pine Mountain.

WESTERN KENTUCKY

Stratigraphy and Coals.—The Allegheny, or Carbondale (David White, 1908), as it has been named in Illinois, is 330 to 390 feet thick. It includes, according to Mr. Lee, those shales, sandstones, impure limestones and coals between the base of No. 5 coal of Owen—his four-foot coal—or the Davis, and the base of the Anvil Rock sandstone. Mr. Lee, indeed, selects as the top of the formation coal No. 11, which comes next under this sandstone, but admits that he does this arbitrarily for mapping purposes. The Anvil Rock sandstone, according to this classification, would have the position of the Mahoning sandstone of the Eastern Field and may provisionally be placed as its correlate. It would also appear to the writer best to extend the limits fifty to 100 feet downward to the top of the Curlew sandstone of Owen as previously stated in defining the limits of the Pottsville in Western Kentucky. As in the Appalachian Field, this western Allegheny, or Carbondale, includes in it more valuable coal than any other equal thickness of Coal Measures. The No. 9, Springfield, or Mulford seam, is especially persistent and important. It is the mainstay of the coal mining industry in Western Kentucky, and also in the whole Eastern Interior Field, comprised in the States of Illinois, Indiana and Western Kentucky. It is here estimated to underlie 25,000 square miles—a larger area than that underlaid by the great Pittsburg seam of the Appalachian Field. Throughout the whole area the Springfield coal seldom falls below four feet in thickness and is usually five feet thick. The No. 11, or Herrin seam, has about the same thickness as the No. 9, and is only second to it in importance; being, although somewhat inferior in quality, almost as persistent. The next most important seam of the Carbondale is the Davis coal, Owen's No. 5. (No. 6 according to a common, though mistaken usage in the Western Field.) The stratigraphic relation of these coals is presented in the following table, in which the Owen numbering is retained.

Table, Showing the Stratigraphic Relation of the Coals in the Allegheny (Carbondale) of Western Kentucky

Anvil Rock sandstone—Mahoning (?) of the Appalachian Field.
  Interval 0 to 20 feet.
Coal Number 12—24 to 60 inches thick.
  Limestone 2 to 10 feet thick, containing the fossil *Girtyina ventricosa*.
Coal Number 11 (Herrin)—48 to 60 inches thick.
  Interval 40 feet.
Coal Number 10 (Briar Hill)—30 to 36 inches thick.
  Interval 55 to 75 feet.
Coal Number 9 (Mulford, Springfield of Illinois)—48 to 60 inches thick.
  Interval 75 to 100 feet.
Coal Number 8 (Well)—24 to 36 inches thick.
  Interval 45 feet.
Coal Number 7.
  Interval 45 to 50 feet.

Coal Number 6 (Number 7 according to some usage) (Dekoven)—36 inches thick.
Interval 28 to 50 feet.
Coal Number 5 (Number 6 according to some usage) (Davis)—48 inches thick.
Interval 50 to 100 feet.
Curlew sandstone—Homewood (?) of the Appalachian Field.

While long distance correlations are hazardous, both the position and persistent character of the Middle Kittanning of the Appalachian Field and the Springfield of the Eastern Interior Field would suggest that they might be the same seam.

Norwood's Proposed Designations for Western Kentucky Coals.—Professor C. J. Norwood in 1880 proposed letters as designations for the Western Kentucky coals, beginning with "A" for Owen's No. 12 and proceeding downward to "G" for the coals in the Allegheny Series, which appears to be at about the horizon of Owen's No. 6. He gave no designations for the coals below No. 6 except that to one occurring at about the horizon of Owen's No. 3 he gave the name "Elm Lick." Later, in 1895, he revised these letters, introduced Ea., Fa., Fb., etc., and extended the designation down to "L," identifying it with Owens' 1-B.

Iron Ore.—No deposits of iron ore have been successfully worked in the Allegheny of the Western Field. For a time an attempt was made to work a black band ore occurring on top of the No. 12 coal near Paradise on the Green River in Muhlenburg County, but the project was abandoned after a considerable fruitless expenditure of money.

CONEMAUGH SERIES

(C. C. O'Harra, 1900. Named from the Conemaugh River)

LOWER BARREN MEASURES

(H. D. Rogers, 1858)

This formation in Pennsylvania consists of those sandstones, shales, limestones and thin coals which intervene above the Allegheny between the Upper Freeport and the Pittsburg seams.

The shales of the formation tend toward purple in color. The most persistent stratigraphic feature near the base is the Mahoning sandstone (Joseph Lesley, 1856). The term "Barren Measures" is appropriate for the formation, because it is almost devoid of workable coal.

EASTERN COAL FIELD

STRATIGRAPHY AND AREAL DISTRIBUTION.—The recognition in Eastern Kentucky of the Lower Barren Measures with the Mahoning sandstone at the base is due to Professor A. R. Crandall in 1884. To Mr. W. C. Phalen (Kenova Quadrangle, 1912) belongs the credit for a full description of the formation in Northeastern Kentucky and a mapping of its areal distribution. It forms the surface in that portion of Lawrence and Boyd Counties lying mainly in the Big Sandy drainage between Louisa and Catlettsburg. Nearly the complete thickness of the Conemaugh (500 to 600 feet) is exposed here. Further south, as in Knott and Harlan Counties, the highest portions of the country carry Conemaugh. In the latter county, the Black Mountains have 500 to 600 feet of strata above the Upper Freeport coal.

The prevalence of red and purple shales and the absence of commercial coals are as much features of the formation here as in Pennsylvania, Ohio and West Virginia. These stratigraphic characteristics are interpreted as indicating a climate more arid during Conemaugh time than during that of the Allegheny preceding, or of the Monongahela following it.

Table, Giving a Generalized Section of the Conemaugh in Northeastern Kentucky

Strata *Shales to Top*	*Thickness*
Morgantown (?) Saltsburg (?) sandstone....	35 to 40 feet
Shale	100 feet
Ames (?) Upper Cambridge (?) limestone...	8 to 10 feet
Shale	30 feet
Buffalo sandstone	25 to 40 feet
Shale	10 feet
Bolt coal (No. 11 of the E. Ky. Survey)......	42 inches
Shale	30 feet
Lower Cambridge limestone, Brush Creek Coal (No. 10 of the E. Ky. Survey)...........	30 inches
Mahoning sandstone	70 to 100 feet

WESTERN COAL FIELD

According to David White it is the McLeansboro (White), named from a town in Illinois, which in the Eastern Interior Coal Field correlates with the Conemaugh of the Appalachian Field. As defined by Mr. Lee in 1916 this formation in Western Kentucky includes some 970 to 1,000 feet of shales, sandstones, limestones and thin coals which intervene between the top of the No. 11 (Herrin) coal and the base of a prominent sandstone

—the Henshaw (Lee, 1916). It is evident, however, that the lower limit thus fixed is arbitrary, and that it would be better to begin the formation with the disconformity which exists at the base of the Anvil Rock standstone (David Owen, 1856).

A marked absence of commercial coals and an increase in the number of thin limestones characterize the western Conemaugh as it does the eastern, and it would appear not altogether improbable that the basal sandstones in both cases (Anvil Rock in the west and Mahoning sandstone in the east) may also correlate.

The Conemaugh in the Western Field has its best development near the Ohio River, where, on account of much of it being covered with ancient river alluvium, good exposures of any considerable extent are rare. The best sections are given by coal prospecting drill holes. Owen, being limited to natural outcrops, was able to assign to the Coal Measures above the Anvil Rock in Western Kentucky a thickness of only 518 feet. He identified in this interval six coals and assigned to them in ascending order Numbers 13 to 18 inclusive.

MONONGAHELA SERIES

(H. D. Rogers, 1840. Named from the River of that Name in Pennsylvania)

THE UPPER PRODUCTIVE MEASURES

(H. D. Rogers, 1856)

This formation is not known to exist in Eastern Kentucky, although a small outlier of it near Lett in West Virginia lies so close to the Kentucky line that we are justified in assuming that it once extended into this portion of the State and has been removed from it by erosion. The Pittsburg coal at the base of the formation is here just caught by the top of the highest knob in that portion of West Virginia.

WESTERN COAL FIELD

Professor L. C. Glenn, in his report on the Coals of the Tradewater Region (1912), discovered some 600 feet of strata in the Western Field which were higher than any yet previously discovered by any geologist. The upper 130 feet of this section is now, as the result of the work of Lee (Shawneetown Quadrangle, 1916) placed in the Monongahela. The coal found at the base—the Geiger's Lake coal—would therefore correlate pretty closely with the Pittsburg seam at the base of the series in Pennsylvania. It is in this Western Kentucky section forty-two inches thick.

THE INTERVAL FROM THE END OF THE PENNSYLVANIAN PERIOD TO THE BEGINNING OF THE UPPER CRETACEOUS

Physiographic Processes of This Period and Their Results.—With the close of the Monongahela period the Pennsylvanian in the Eastern United States, with its low-lying lands and moist climate, gave way to the Permian, with its higher relief and increasing aridity.

At first—during the Dunkard stage—aggradational processes still prevailed and continental deposits of sands and clays with their characteristic red color were laid down. Later, increasing elevation, culminating in the development of folded structure in a belt from Vermont to Georgia (Allegheny Mountains), so rejuvenated the streams that a period of land degradation ensued. This period lasted from Middle Permian to Upper Cretaceous time, and extensive denudation of land surface was accomplished. Hence in that portion of the United States, where Kentucky now lies, no deposits of late Permian, or of Triassic, or of Jurassic age were made, and much of those made in previous time, especially in the Pennsylvanian and early Permian ages, were worn away. The disappearance by erosion of the Permian and Pennsylvanian strata took place first along the axes of the geanticlines and proceeded from these toward the axes of the geosynclines. Hence the Coal Measures of the Eastern United States today lie in separated geosynclinal basins, with Permian (early Permian) in one instance—that of the Appalachian Field—lying as topmost strata over the central portion of the basin. Whether or not any portion of the Permian area ever extended into Kentucky cannot be told. All we can say is that at present no Permian rocks exist in the State, nor in that portion east of the Tennessee River are there any other more recent formations until the late Tertiary or early Pleistocene period is reached.

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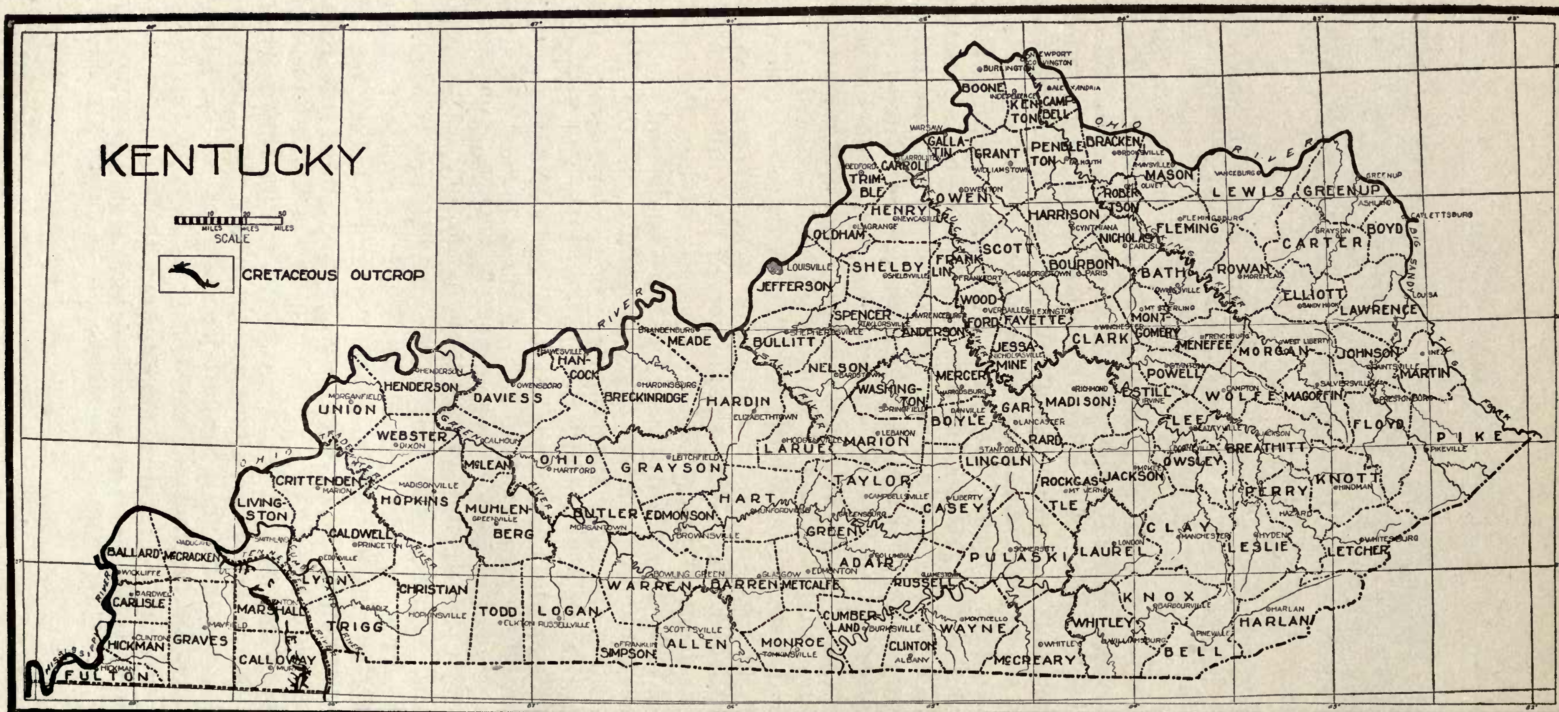
See the various reports on coal and coal fields in the bibliography constituting Part VI. Many of these are also listed in Chapter XII, Part IV.



66. LOCATION OF CRETACEOUS OUTCROP

CHAPTER VII

CRETACEOUS, TERTIARY AND QUATERNARY SYSTEMS

CRETACEOUS SYSTEM

(D'Halloy, 1822. Named from the presence of chalk in the formation. Only the Upper Cretaceous, represented by Ripley, is found in Kentucky)

RIPLEY

(E. W. Hilgard, 1860. Named from a town in Tennessee)

STRATIGRAPHY, AREAL OUTCROP AND ECONOMIC PRODUCTS IN KENTUCKY.—The Ripley or "Coffee sands" of J. M. Safford, 1884, consist in Kentucky of variegated sand and clays—the former often cemented by iron oxide into tubular "pipes," and the latter frequently lignitic—the whole ranging from 200 to 400 feet in thickness.

The formation outcrops in a belt four to six miles wide along the eastern margin of the Jackson Purchase Region, separated by a narrow strip of Mississippian from the Tennessee River. It is exposed mainly in ravines, being covered on the level land by later formations.

No fossil other than the imprint of leaves are known to occur in it. Both these fossil leaves and the lignitic wood indicate that it was a fresh or brackish water deposit laid down in the old Mississippi embayment when it extended to and a little beyond the Ohio River at its present mouth.

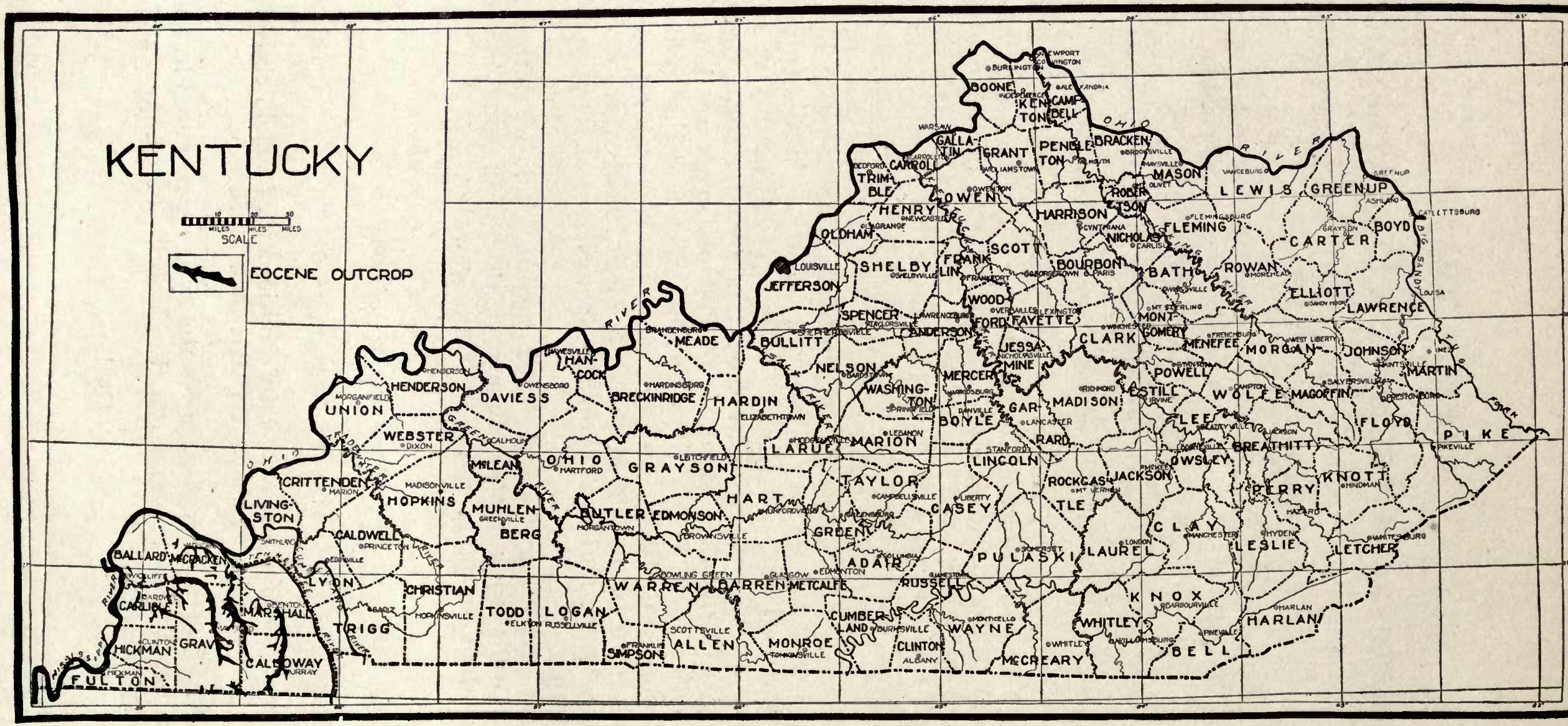
It yields clays suitable for certain kinds of pottery, and wells sunk rather deeply in it find in some cases abundant supplies of good drinking water.

TERTIARY SYSTEM

(Cuvier and Brougnairt, 1810)

(Named from its being the third division of a fourfold classification of geological time then in vogue)

The Tertiary system in Kentucky is represented by its earliest and latest division, the middle one apparently being absent.



67. LOCATION OF EOCENE OUTCROP

Classification of the Tertiary in Kentucky

Series	*Stage*	*Sub-stage*	*Thickness in Feet*
Cenozoic	Pliocene	Lafayette (Irvine?)	0— 45
	Eocene	LaGrange	430
		Porters Creek	100—160

EOCENE STAGE

(Sir Charles Lyell, 1833. Named from two Greek words: *eo,* dawn; and *kainos,* new—meaning dawn of the recent)

The Eocene in Kentucky is divided in ascending order into two members, the Porters Creek and LaGrange.

The *Porters Creek* (J. M. Safford, 1864) is mainly a clay 100 to 160 feet thick. It is dark when wet and leaden color when dry. It is called locally "soapstone." Loughridge in his report on the Jackson Purchase for the Kentucky Geological Survey described it as "joint clay." Interbedded with the clay are layers of fine sand and in the lower part green sand or glauconite. Another characteristic feature is the system of sandstone dikes which traverse it. According to Professor Glenn these are fissures filled by sand forced up from below during periods of earthquake disturbances, which affected the region during Eocene times.

The formation contains some fossils. Besides unidentified plant remains, these consist of shells of marine mollusca; among them, *Crassatellites productus, Protocardia lenis, Venericardia alticostata, Cucullaea macrodonta, Leda protexta, Mysia ungulina* and *Turritella mortoni.* No economic products worthy of comment are known from this formation.

The Porters Creek occurs in a belt immediately west of the Ripley, reaching its greatest width—ten to fifteen miles—in Calloway and Marshall Counties. It also extends into McCracken and Ballard, crossing the Ohio from the latter county into Illinois.

The *LaGrange* (J. M. Safford, 1869) consists of clays, sands and lignite with an aggregate thickness of from 430 to 750 feet. It has generally been regarded of Eocene age, though on paleobotanical grounds F. H. Knowlton has been disposed to class it as Miocene. Leo Lesquereux wavered in his opinion as to whether it was Eocene or as late as Pliocene. W. J. McGee erroneously included it in his Lafayette formation in this part of the Mississippi embayment. R. H. Loughridge confounded the more lignitic portions of it with the Porter's Creek below, and thought that the beds at Hickman were even older than the latter, while in reality, according to Professor L. C. Glenn, these Hickman exposures are the very youngest beds in the LaGrange.

The fresh, or at least brackish, water character of the deposits are evidenced by the absence of marine fossils and the presence of lignite and imprints of leaves. The latter have been identified as belonging to extinct species of oak, willow, walnut, eucalyptus, cinnamon, fig, bayberry and soapberry, and to living species of moonseed and trumpet creeper.

The formation—as at Boas, Graves County—yields valuable pottery clay, often very white and very siliceous. The clay appears to have come originally from the decomposition of Paleozoic cherts.

The LaGrange occurs west and south of the Porter's Creek belt. It is nearly everywhere covered by a thick mantle of sand, gravel and loam of the Pliocene and Pleistocene. Its exposures are in the Bluffs of the Mississippi River, and banks of streams tributary to the latter, in the counties of Fulton, Hickman, Carlisle, Ballard, McCracken and Graves.

PLIOCENE STAGE

(Sir Charles Lyell. From the Greek: *pleion,* more; and *kainos,* new—meaning "more recent")

The Pliocene in Kentucky is represented by the *Lafayette* (Hilgard, 1885). This formation was included in the "Orange sand group" (J. M. Safford, 1864), and its synonym, LaGrange (J. M. Safford, 1869).

It consists, where it is best developed in the Jackson Purchase, of gravel and sand, usually red or orange in color from the presence in it of iron oxide which fre-

68. LOCATION OF PLIOCENE AND PLEISTOCENE OUTCROP

quently cements the material into conglomerates and sandstones.

The Lafayette occurs in the Purchase Region as a blanket twenty-five to fifty feet thick, everywhere covering the LaGrange, except where removed by erosion. W. J. McGee, in 1891, extended the term so as to take in with it the next later formation. R. H. Loughridge, in 1888, correlated the lower part of it with the LaGrange and the upper part with the Orange sand of Hilgard; assigning the former to the Eocene and the latter to the Quaternary (Pleistocene).

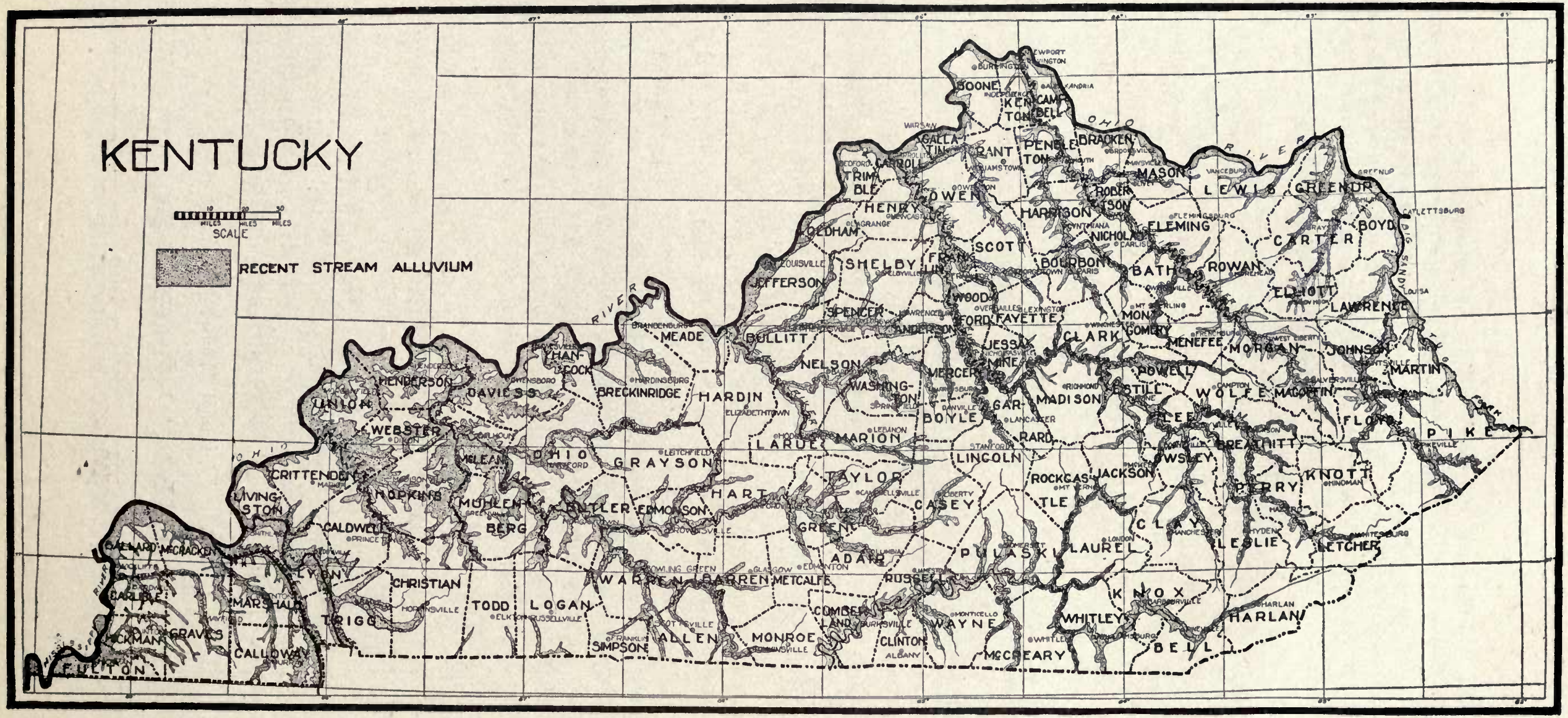
This deposit also mantles the surface of the country in the vicinity of the Tennessee and Cumberland Rivers east of the Purchase, and, extending up the other rivers and streams of Kentucky to their headwaters, it probably includes those high level river gravels, sands and clays, which on the Kentucky River were designated by Marius Campbell in 1898 the "Irvine Formation."

The character of these old high level deposits—quartz pebbles, sandstone boulders and occasional waterworn pieces of coal from the basal and higher Coal Measures; and quartz geodes and silicified fossils from the Mississippian, with the absence of granitic and other igneous and metamorphic rock pebbles from the drift covered region to the north—would seem to point to the Cumberland plateau and intervening highlands of Mississippian formation as the source of the materials.

The ferruginous character of the gravels in the Purchase has given them cementing qualities, and hence made them valuable for road surfacing. They have been rather widely used for this purpose under the name "Paducah gravels."

In the lower courses of the Cumberland and Tennessee there occur in this formation beds of limonite iron ore which in the days of "charcoal iron" supported a flourishing iron smelting industry in the counties of Trigg, Lyon and Livingston.

In some places in Kentucky these deposits of supposed Lafayette age have yielded fragmentary remains of mammals (such as the tapir and an extinct species of deer) which would support the view that this formation is Pliocene, or at the latest, very early Pleistocene.



69. LOCATION OF RECENT STREAM DEPOSITS

QUATERNARY SYSTEM

(Rebout, 1839)

The term means the fourth in a fourfold scheme of classification once in vogue. A modern synonym is Pleistocene, derived from the Greek words *pleistos,* most, and *kainos,* recent; meaning "most recent."

COLUMBIA SUB-STAGE

(W. J. McGee, 1888. Named from the District of Columbia)

Stratigraphy and Distribution.—In the Purchase Region the Columbia is a surface deposit of sand, gravel, loess and loam, the sand and gravel being at the base. The sand and gravel bed is usually five to ten feet, the loess fifty to seventy-five feet and the loam five to twelve feet thick.

The Loess.—The Loess is fine-grained, buff-colored dust deposit, which is an important accumulation both within and without the limit of the Purchase Region. Its present position has generally been attributed to the action of wind. Its greater thickness in the vicinity of the Ohio and Mississippi Rivers, however, points to its having been originally a river deposit. It appears to date in its original deposition back to a flooded condition of the rivers during the final (Wisconsin) stage of glaciation. It is a rock flour grist ground out by the glacial mill and fed into southward flowing streams. The Loess, while friable, has enough consistency to hold steep faces when undermined by side erosion of streams or exposed in artificial cuts, as those made for railroads. The Loess bluffs along the Mississippi River are known as "cane bluffs." Here occur the curiously shaped calcarious nodules—the "loess kindschen" of German geology—so characteristic of this formation.

The material of the Loess itself makes fine moulding sand, and in the vicinity of Cincinnati has been used for this purpose by stove foundries.

Glacial Outwash Deposits.—Other deposits which are probably of Columbia age are the glacial outwash deposits along the Ohio River a short distance south of the boundary of the glaciated district. They here constitute valley fill to the depth in some cases of 100 feet. They are especially in evidence in the vicinity of Louisville, where they consist of coarse gravel at the base followed by sand or clay.

Glacial Drift.—Typical glacial drift—that is, unstratified till with boulders and upland loess—occurs only in the counties of Campbell, Kenton, Boone, Gallatin, Carroll and Trimble, where it never extends further back from the river than ten miles, and is usually not further away than three or four. Within this belt occur Canadian granitic and quartzite boulders up to the size of one's head, and occasionally to a size weighing 500 to 1,000 pounds. These larger sized boulders have been found most frequently in the neighborhood of Florence and Erlanger in Boone and Kenton Counties.

Recent Deposits.—Deposits belonging to the recent or present epoch consist for the most part of alluvium, such as is now forming along the streams of the State.

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PART TWO

Physiographic Geology

CHAPTER VIII

THE PHYSICAL REGIONS OF KENTUCKY

Kentucky is divided into six well-marked physical regions, the outward expression of internal stratigraphic differences when acted upon by atmospheric erosion. These regions are as follows:

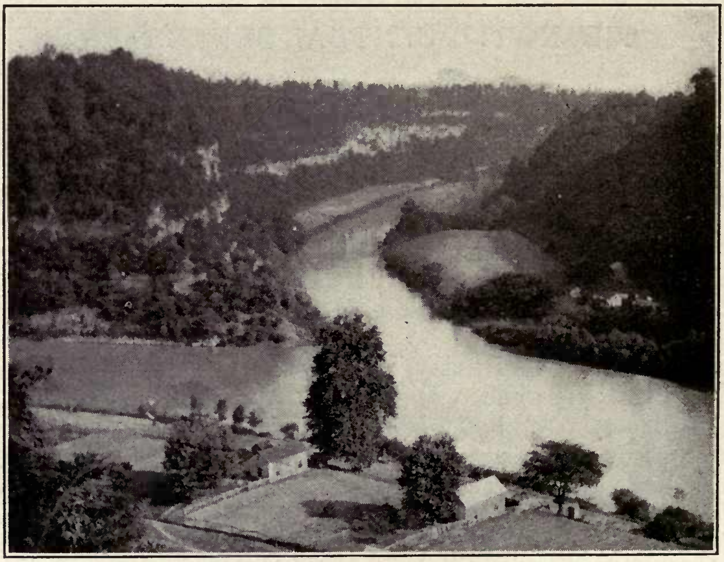
1. The North-Central Bluegrass.
2. The Knobs.
3. The Eastern Kentucky Mountains.
4. The Southern and Southwestern Lower Carboniferous Plateau.
5. The Western Kentucky Coal Field.
6. The Southwestern Mississippi Embayment.

THE NORTH-CENTRAL BLUEGRASS

Bounded by the semicircular belt of the Knobs on the east, south and west and by the Ohio River on the north is an area of about 8,000 square miles in which the soil has been formed from the decay of Ordovician strata. This soil, formed largely from limestone high in phosphorus content, is especially congenial to the growth of bluegrass (*Poa pratensis*); hence the accepted name for the region. This Bluegrass Region in the largest sense is also well adapted to the growth of a special variety of tobacco known as Burley, and is sometimes referred to as the "Burley Tobacco District." With the exception of a relatively poor belt of shale land, the Eden shale near the middle of the area, it is also well suited to the growth of hemp. Sometimes a portion at least of the Niagaran (Kentucky Silurian) outcrop is included in this area. Physiographically there is some justification for this as it lies at about the same level and presents an even topography. Agriculturally, however, this border strip of Niagaran is quite distinct, as its light colored shales and dolomitic limestones form "sobby", "crawfishy" soil on which bluegrass can be induced to grow only with difficulty. It is generally marked with a flatter topography than the Bluegrass Region proper. Such are the "Beargrass lands" in the vicinity of Louisville.

The *Bluegrass Region proper*, defined as that limited to the outcrop of Ordovician strata, is a rolling upland, the highest portions of which (excluding certain outliers of newer formations not yet removed from its surface) are about 1,050 feet above the sea. These highest portions are on the Jessamine Dome of the Cincinnati uplift. Elsewhere in the region the highest portions are about 950 feet above the sea. In general the upland level may be said to range between 800 and 900 feet above sea level. This is the surface about 500 feet below the plateau level of Eastern Kentucky which M. R. Campbell calls the "Lexington Peneplain" and postulates for it a base level condition during Tertiary time.

Recent Date of Elevation.—Unquestionably there has been in recent geologic time an uplift of the Eastern United States including the present State of Kentucky.



70. GORGE OF THE KENTUCKY AND DIX RIVERS
View from Highbridge. The cliffs are composed of Highbridge limestone. Photograph owned by the Cincinnati Southern Railway, and reproduced here by courtesy of the company

This uplift caused her rivers to sink themselves deeply into the underlying strata. Evidence of this is supplied by the "high level gravels," covering the shoulders of the present river gorges, and extending away from the streams some distance over the lower uplands. The coarseness, however, of these deposits, which are conglomerate gravels and sandstone boulders from the Coal

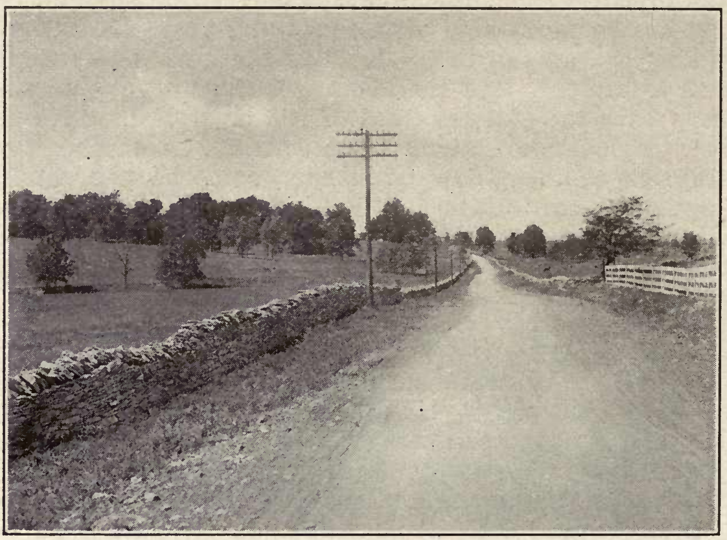
Measures, and large and small geodes from the Keokuk, in comparison with the fineness of the alluvial sand and silt deposits the rivers are now making does not seem consistent with the view that these had been laid down on a plain of low relief, across which the rivers ran in sluggish courses to a not very distant sea. Even the explanation of the present winding courses of the rivers as *intrenched meanders,* inherited from a peneplain condition, presents some difficulties. The gradual slope of the land on the point side of the meander from the general level of the upland to the level of the river itself would seem to indicate that the meanders were developed *pari passu* with the cutting down of the river bed. Also the deserted meanders along their courses, as on the Kentucky, especially below Frankfort, some so near to the present level of the stream that during exceptionally high water the river again occupies them, point to the development of these bends as a continuous process through all this period of down cutting of the bed.

Physiographic Subdivisions of the Bluegrass.—The Bluegrass area while as a whole exhibiting a certain physiographic unity, being immediately underlaid by gray and blue limestones and shaly marls of similar chemical and physical constitution, may be divided into subordinate areas in accordance with differences in topography and soils dependent upon differences in the underlying formations. These areas succeed each other outwardly from the innermost on the Jessamine Dome in the order of the successive outcroppings of the subordinate formations, that is, from older to younger.

There are three of these subordinate areas, enumerated from within outward: (1) the Lexington (Trenton)-Cynthiana Limestone Area, (2) the Eden Shale Belt, and (3) the Maysville-Richmond Limestone Belt.

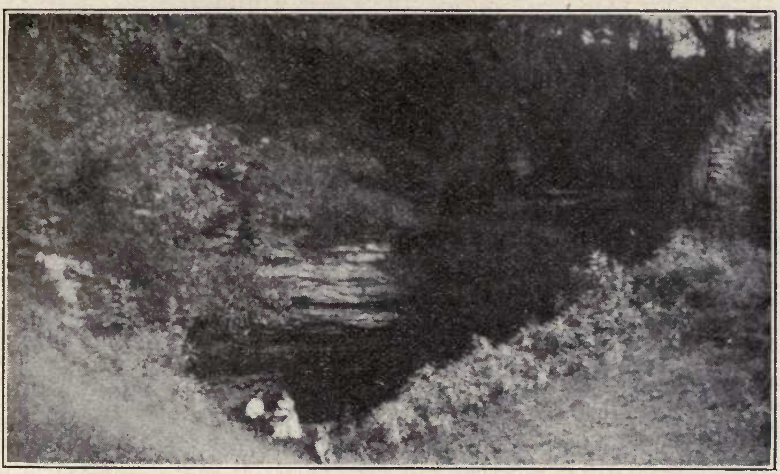
1. *The Lexington-Cynthiana Limestone Area.*—It is the Lexington limestone which, outcropping on and around the *Jessamine Dome,* gives the distinctive character of this area. The underlying Highbridge limestone, it is true, also outcrops in the region, but it is in narrow strips along the Kentucky River and main tributaries, and therefore enters very little into the formation of topography or soil of the uplands. This region possesses a gently rolling topography and a soil of inexhaustible richness, due mainly to its high phosphorus content.

There is a difference in the quality of soil formed on the Lexington and that formed on the Cynthiana limestones —the former being somewhat superior. Typical Lexington limestone soil is chocolate colored, while that from the Cynthiana is reddish. The area of the Lexington limestone outcrop is about 1,000 square miles and of the Cynthiana about 1,400 square miles, making a total for the *Inner Bluegrass Region* of 2,400 square miles. This



71. ROAD NEAR DANVILLE, KY.
Typical scene in the Blue Grass. The rock fence is made of Lexington limestone. Photograph owned by the Cincinnati Southern Railway, and reproduced here by courtesy of the company

region, which is the Bluegrass *par excellence,* has Lexington as its approximate geographic center. It is included mainly in the circle of counties of Harrison, Nicholas, Bourbon, Clark, Madison, Garrard, Boyle, Mercer, Anderson, Franklin and Scott; with Fayette, Woodford and Jessamine central within this circle. The woodland growth of this Inner Bluegrass Region has for its characteristic elements: burr and chinquapin oak (*Quercus macrocarpa* and *Q. muhlenbergii*), wild cherry, hackberry, white ash and walnut. The Lexington limestone portion of this area is a mildly karst country, being pitted with small sinks and with considerable underground drainage. These underground streams emerge as "big springs." A number of these big springs were chosen as settlement sites by the pioneers. These later became county seat towns of counties organized around them. Such was the origin of Harrodsburg (1774), Lexington (1779), Georgetown (1790) and Versailles (1793). The Cynthiana limestone outcrop forms mainly the outer



72. LIMESTONE SINK IN THE BLUEGRASS REGION
Photograph made by the United States Geological Survey, and reproduced here by its courtesy

border of the Inner Bluegrass, being widest in the counties of Clark, Bourbon, Nicholas and Harrison, where it forms the main cattle grazing district of those four counties. It also exists as patches and strips within the more central Lexington limestone area. The Inner Bluegrass Region is preeminently the fine stock raising center of the State.

2. *The Eden Shale Belt.*—Next outside of the Lexington and Cynthiana limestone area comes the *Eden Shale Belt* with an area of 2,500 square miles. This belt, in which shale predominates, has very tortuous boundaries. Lying farther out on the Jessamine Dome than the preceding area it is five to ten miles wide on the east and west slopes, ten to thirty miles wide on the north slope, and so narrow on the south slope, because of the very steep dip, that here it hardly deserves recognition as a physiographic feature. On account of the predominance of shale in the formation (though thin limestones are intercalated with them and "siliceous mudstone" occurs at the top) it has been eroded into a very uneven topography, being as maturely dissected by streams as the Eastern Ken-

tucky Plateau and with nearly as steep slopes, but with less vertical range. These ridges and valleys form a succession of upright and inverted "V's" as in Eastern Kentucky. Where the Garrard sandstone ("siliceous mudstone" of Owen) forms the summits of the ridges these are more rounded. Typical Eden topography is represented on the topographic sheet of the Lockport Quadrangle. This quadrangle is traversed nearly midway from south to north by the Kentucky River, which in this stretch exhibits beautifully a number of incised meanders several of them having been deserted by the river.

When denuded of timber and kept under cultivation, the steep slopes of the Eden, under the combined influence of freezing and thawing ground water and dashing rains, erode rapidly. The naturally poor yellow soil speedily sloughs to the valleys below and is carried away by the streams. Its place is taken by large slabs of limestone, which, intercalated between the shales, slip out upon the slopes as a result of the freezing and thawing process.

It is customary for the owners of these washed lands to turn them out as "old fields" to be grown up in cat briars, sassafras bushes and persimmon sprouts, until they are "rested." Once thoroughly grassed (and bluegrass takes kindly to these slopes), they cease to erode and make fine grazing land. It is unfortunate that the attempt to keep these lands under cultivation, induced especially in recent years by the high price paid for tobacco, is bringing about their constant deterioration. To the traveler traversing this belt on the railroad or by motor car over its highways it presents a "run down" appearance. The homes, even of the larger land owners, are apt to be dilapidated and with uninviting surroundings, while those of the tenants are positively shabby—being in many instances log cabin survivals from pioneer days.

A characteristic forest growth, remnants of which still exist, originally covered this region. Conspicuous elements of it were beech, sassafras, persimmon and hickory.

Within the boundary of the Inner Bluegrass Region there are two linear faulted outliers of Eden, which present such strong contrasts in their soil and timber growth to the surrounding region that they early attracted attention and invited explanation. The commonly accepted theory of their origin, suggested by their elongated form and unproductive soil, was, and is yet, that they are "old buffalo trails." One of these extends north and south just east of Lexington and the other is in Scott and Franklin counties, beginning near Great Crossings, *i. e.,* "place where the buffalo crossed," and extending northwest just south of Stamping Ground, *i. e.,* "place where the buffalo stamped."

For a fuller account of these strips, together with a discussion of their supposed relation to migrating herds of buffalo, see pages 235, 236.

The Eden Belt lies mainly in the counties of Mercer (western part), Washington (eastern part), Anderson, Shelby (eastern part), Franklin (northern and western parts), Henry (southeastern part), Owen (southern part), Grant (southern part), Scott (northern part), Pendleton, Harrison (eastern and western parts), Robertson, Nicholas, Bourbon (extreme eastern parts), Montgomery (western part), Clark (eastern part), Madison (western part), Garrard (northern part), Lincoln and Boyle. In the two last counties named the belt is narrowest—being only a mile or so across. It has its greatest width (thirty miles) in the group of counties composed of Owen, Scott, Harrison, Grant and Pendleton.

3. *The Maysville-Richmond Limestone Belt.*—Succeeding the Eden is the upper Cincinnatian (Maysville and Richmond) with an area of 3,200 square miles with its predominance of limestone over shale. The outcrop of these two formations forms the *Outer Rim of the Bluegrass.* The country has become more level—similar in appearance to the *Inner* or *Trenton Bluegrass.* Also, on account of the higher phosphorus content, the soil is better—more like that of the Inner Bluegrass. Hemp fields are seen again, and large stock and dairy farms are much in evidence.

THE KNOBS

Encircling the Bluegrass Region, from Vanceburg on to the Ohio to West Point on the Ohio again, is a belt of country characterized by the presence of conical knobs. It includes the scope of country lying between the outer edge of the Cincinnatian outcrop and the top of the escarpment formed of Warsaw and St. Louis limestone in the west and known there as "'Muldraugh's Hill" and the top of a similar escarpment in the east, which in addition to the Mississippian limestones, carries on its crest an area of about 5,600 square miles.

Geological Formations.—The geological formations of the Knobs Region include those represented in Kentucky between the base of the Silurian and the top of the Mississippian—with a little of the base of the Coal Measure included in the eastern portion. The knobs themselves are mostly composed of the sandy and shaly members of the Waverly—the portion called by Owen the "Knobstone." The valley floors from which the knobs rise are usually formed of Devonian shale (Ohio shale), and the inner flat border which skirts the region is formed of Devonian limestone and the still lower Niagara limestones and shales Where composed of Waverly sandstone and shale the knobs are conical; where capped by Mississippian limestone or the basal conglomerate of the Coal Measure they are flat topped.

Mode of Formation.—It is evident that these knobs are but detached outliers of a once more extended formation—mainly the Mississippian—the margin of which, retreating in the direction of the dip, forms from Bullitt to Rockcastle County the northward fronting escarpment known as *Muldraugh's Hill,* and from Rockcastle County north to the Ohio River in Lewis the westward fronting escarpment, here capped by Coal Measure conglomerate, and known as the *Coal Measure Escarpment.*

Physical Features and Related Sociological Aspects.—The flat interstream areas of the Silurian border strip range in altitude from 750 to about 900 feet above the sea. The valley floors from which the knobs rise are somewhat higher, reaching in some instances up to 1,050 feet. The tops of the knobs reach elevations from 1,200 to 1,400 feet above sea level. The soil of this region is characteristically poor. The residual soils, whether of the border strip, or of the valley floors of the inter-knob areas, being formed largely from shale, are close and drain poorly; hence are whitish and "crawfishy." Even the transported soils of the wide bottom lands, which are made where the region is traversed by the larger streams, are poor in comparison with most bottom lands. Evidently they derive a great deal of their material from the wash of the neighboring land. The soil of the knobs is thin and poor to the extreme. The tops and upper slopes are largely left to timber growth, which is usually scrubby. It consists chiefly of chestnut, hickory, pine and

73. TYPICAL LANDSCAPE IN THE KNOBS REGION
White Oak Creek, Estill County. Photograph by A. M. Miller.

a variety of oaks. Wherever the experiment has been tried, however, the tops of the knobs especially have been found to be admirably adapted to the raising of apples and peaches. The Knobs, outside of the quarry stone of Lewis, Rowan and Rockcastle Counties and the iron ore and oil of Bath, contain little mineral wealth .

The inhabitants are for the most part proverbially poor, getting only a scanty subsistance from the soil, supplemented by what they obtain from marketing tanbark (generally the bark of the chestnut oak) and a few railroad ties. A number of ax handle, pick handle and stave mills, established by outside enterprise, work up the oak and hickory which can be found suitable for such milling purposes.

Sociologically the native knobs people ally themselves with the inhabitants of the mountains, though there are lacking certain of those picturesque elements which have attracted the attention of the outside world to the Kentucky mountaineer and led to his being exploited in the field of fiction. Also there is wanting the occurrence of the occasional man of affairs, who, rising above his surroundings, develops unusual capacity for leadership both in affairs of state and of business. This lack of enterprise may be accounted for by the peripheral position of the Knobs insuring that those who remain here in sight of the Bluegrass, but content to perpetuate conditions as they find them, do so from choice and not from compulsion. In food preparation this region should be classed with the mountains. One meets here with the same large soda biscuit, yellow from excess of soda, with the inevitable eggs which swam in grease as they fried, with scrambled pie, with sorghum, and with what by every country store in both regions is sold for coffee, but which bears little resemblance to it in taste.

There is one locality within this area which is an exception to the general rule that its soils must be poor. This is Indian Fields (Indian Old Fields), eastern Clark County. Here is a tract composed of some two thousand acres perfectly level and covered with a deep dark soil equal in fertility to the finest land of the Bluegrass. This quality of soil seems to have been known to the Indians, since the Shawnees, in defiance of the prohibition by the other tribes of village habitation in Kentucky, settled for a time upon the tract, naming their town ''Eskippakithiki.'' Thus far no reasonable explanation has been offered to account for this soil anomaly.

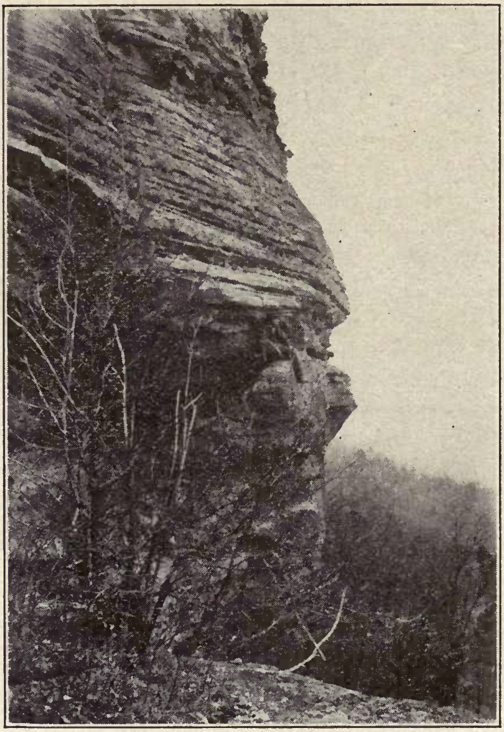
There are two exceptions within this area to the rule that sociological conditions are controlled by physiographic. At Ottenheim, Lincoln County, and at Gethsemane in Marion County, two colonies of foreigners—one German and the other French (the latter Trappist monks)—have demonstrated what excellent results can be obtained from this naturally poor soil, if only proper methods of cultivation be used. The Trappist monks especially have done wonders with their holdings, converting into a veritable garden that which they were able to purchase originally for a very low price because it was considered so unproductive.

THE EASTERN KENTUCKY MOUNTAINS

The Mountain Region of Kentucky, which stands out in such sharp contrast to the rest of the State, includes all that portion lying east of a much indented border stretching from opposite Portsmouth on the Ohio to the Tennessee boundary where touched by the Wayne-Clinton County line. Geologically it is the Eastern Coal Field, the sandstone and shale strata of which cover 10,450 square miles. Physiographically it is a maturely stream-dissected plateau—the Cumberland Plateau—the restored even surface of which would rise from an altitude of 1,000 feet above sea level at the Ohio River to 2,000 feet above the same datum plane at the Tennessee line.

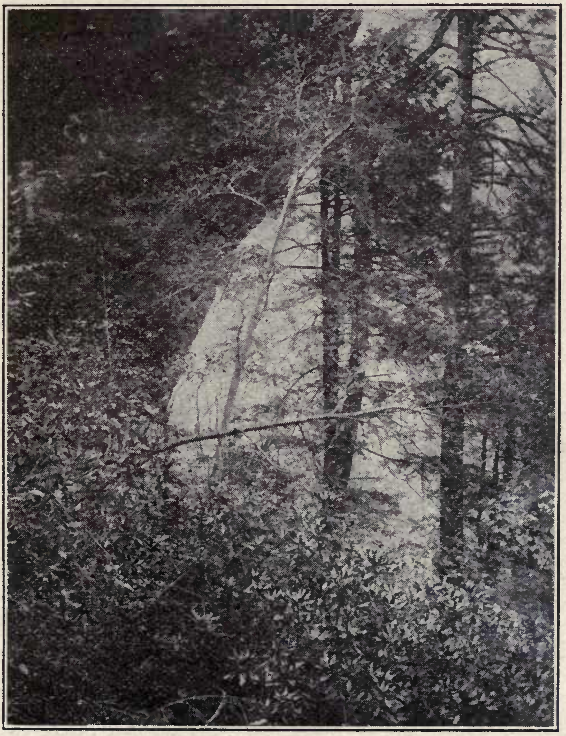
The Cumberland and Pine Mountain Ranges and the Region Between.—This plateau is surmounted in its southeastern portion by two mountain ranges which are true mountains of elevation. These are the Cumberland and Pine Mountains. Both are composed of sharply inclined strata, the dip being toward the northwest in the Cumberland range, and toward the southeast in the Pine Mountain range. In each range the summit is formed of the basal Coal Measure conglomerate. The Cumberland range forms the Kentucky-Virginia boundary for a distance of thirty-five miles—in which stretch it presents a steep face toward Virginia. The Pine Mountain range is a long even-topped erosion fault scarp, the steep face of which is presented to the northwest. These two ranges are parallel and the distance between them is about fifteen miles. Between the two ranges, and elsewhere in the plateau region, there is an intricate system of winding watershed ridges separated by narrow "V" shaped valleys. It is generally to these ridges that the physiographically uninformed writers on the Eastern Kentucky Mountains refer when they use the term "ranges." The same writers also hopelessly confuse "Cumberland range" and "Cumberland plateau." It is between the Pine and Cumberland ranges that these plateau ridges reach their highest elevation, overtopping indeed the height of the including ranges. The highest of these ridges constitutes the Black Mountains of Harlan County. Points on it slightly exceed 4,000 feet above sea level. The highest portions of the Pine Mountain range are about 3,600 feet in height.

The Western Border Strip of Conglomerate Sandstones.—Along the western border of the Coal Measure plateau the "Conglomerate series," continuous under the broad trough of the Eastern Kentucky syncline, again rises to view. It has been more vertically trenched by streams than the less resistant strata of the rest of the plateau and gives rise, therefore, to an exceedingly rugged border strip of country. This strip presents its steep face toward the lower Bluegrass and to the intermediate-in-height Lower Carboniferous Plateau, which it overlooks farther to the south. It is a region of picturesque scenery, abounding in bold headlands and isolated "pilot knobs;" in boulder-filled gorges, rapids and water falls; in cirques with overhanging walls ("rockhouses")



74. AN OUTLIER OF THE CUMBERLAND PLATEAU
Pilot Knob, Clark County. The top of this knob, the precipitous southern face of which is here shown, is composed of crossbedded coal measure conglomerate. Photograph by A. M. Miller

and in natural bridges. It carries a typical mountain flora. The ridges with scant soil are covered with a forest growth of pine and chestnut and an undergrowth of huckleberry. The trailing arbutus covers the brows of the cliffs and the laurel ("ivy" of the mountaineer) roots itself in the crevices of the bare faces of the cliffs themselves. In the deep moist hollows below the rhododendron ("laurel" of the mountaineer) flourishes, and from these hollows the hemlocks (spruce pine) send up very close to the cliff walls their long straight shafts. It is the home of numerous rattlesnakes and an occasional bear. It is a region of sparse settlement, where the one-room log cabin is a frequent type of dwelling, more so even than in the remoter sections of the mountains, and



75. ROCKHOUSE NEAR NATURAL BRIDGE, POWELL COUNTY
The rhododendron and hemlock, shown in the view, are vegetation characteristic of the conglomerate outcrop. Photograph by A. M. Miller

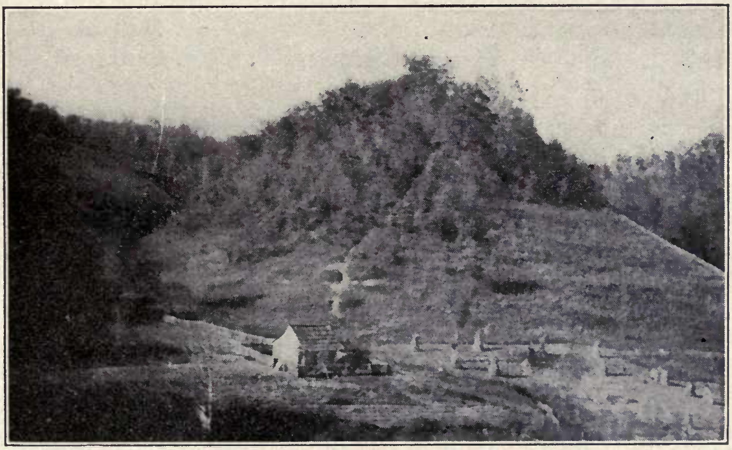
where the inhabitant thereof lives in most primitive fashion. For moonshining the country is ideal, and to the poor mountaineer not to turn his scanty corn crop into more profitable potable form in this way would seem like a waste of golden opportunities.

The conglomerate sandstone margin of this eastern plateau region, though breached by northwest and westward flowing rivers—the Licking, the Kentucky and the Cumberland—and frayed into many re-entrants by their tributaries, presents in the main a steep westward front, which has acted as a barrier to lines of communication reaching into the mountains. Until recently no highway penetrated it (the Boone Highway following the general route of the Old Wilderness Road of the pioneer now reaches through and beyond it), and no wagon road worthy of the name exists east of it. Until comparatively late in the State's history no railroad crossed this strip and entered Eastern Kentucky. Now six lines of railroad enter or cross the coal field, each penetrating it by a breach made in it by a river. These are, named from north to south, the Cincinnati-Ashland branch of the Chesapeake and Ohio, the Louisville-Ashland branch of the same, the Lexington and Eastern branch of the Louisville and Nashville, and Louisville and Atlantic branch of the Louisville and Nashville, and Cincinnati-Knoxville branch of the Louisville and Nashville, and the Queen and Crescent. The first enters and traverses the plateau by the Ohio River breach; the second enters by the Licking breach, but crosses to the Little Sandy drainage; the third enters by the Red River gateway of the Kentucky River drainage; the fourth enters by the main Kentucky River, and, uniting with the second, which has crossed over from the Red River after following one fork to the head, proceeds up the main or North Fork of the Kentucky to its head; the fifth enters by the Rockcastle tributary to the Cumberland, but crosses over to the Cumberland, where, dividing, one branch passes up the main river and through the Pine Mountains at the "Breaks" at Pineville, and the other crosses the Cumberland River at Williamsburg, and passing up the Clear Fork, pierces the Pine Mountain by way of the "Narrows;" the sixth enters by the South Fork of the Cumberland and traverses the conglomerate portion of the plateau for the remainder of its distance in the State. All these routes but the ones up the Ohio and the Kentucky must enter this plateau region by a steep grade and by one or more tunnels. It is seen, therefore, that this western rugged front has served as a Chinese wall to prevent free intercourse between the "men of the mountains" and the "men of the Bluegrass plain" ("men from the Settlements," in mountain phraseology).

Relation of Rugged Topography to Human Progress. —A maturely dissected plateau is a region unfavorable for agriculture. Such a plateau is Eastern Kentucky.

The strata which compose this plateau are sandstones and shales, materials out of which naturally good soils cannot be made. The region is one of great mineral wealth in the form of coal, but the physiographic obstacles, especially those of the western border strip, offered to the building of railroads into it have retarded the development of this form of wealth. Contributory to this under development of the resources of the region in mineral and timber has been its wretched land grant and boundary system inherited from the mother State—Virginia. Not having been covered by the Government range-township-section system of land survey—because this system was instituted after this region became the part of a State—boundaries of farms and mineral and timber tracts are indefinite and land titles in general are in a chaotic condition.

Isolation, therefore, combined with hard conditions for gaining sustenance, has resulted in a backward condition of the inhabitants. The Eastern Kentucky Moun-



76. A MOUNTAIN HOME
Magoffin County, Fall of 1917. Photograph by A. M. Miller

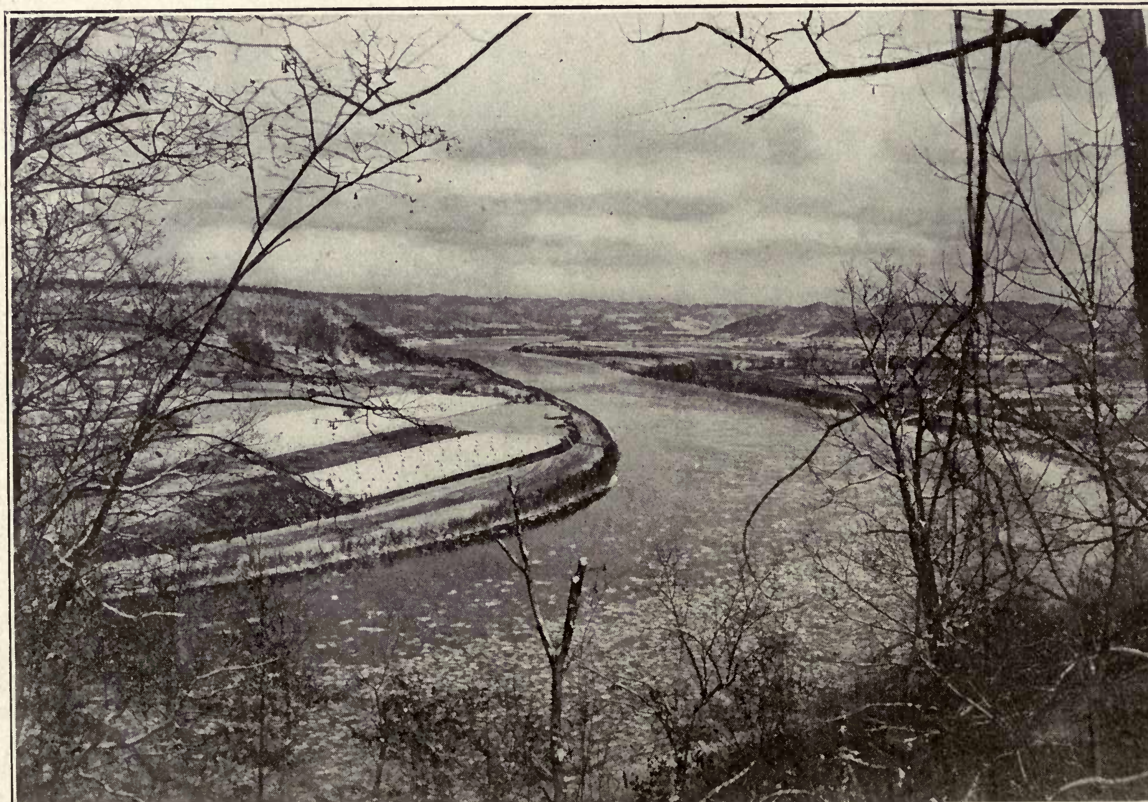
tains have remained a backwoods, where linger primitive methods and customs. Here live, as has been said, "our contemporaneous ancestors." In spite of some recent rapid progress made in the attempt to develop the natural resources of the region by extending into it railroads, which have brought the people into contact with the outside world and its supposed ameliorating influences—one of which is the mail-order-house catalog, serving as material in convenient form for papering the walls of houses—there are still considerable areas where no reaper, nor mower, nor cultivator other than a single "bull-tongue plow," has been even seen; where the women still card wool and spin and weave, and in washing clothes still "battle" them with a stick at the spring or stream; and where "lawlessness," as the outside world regards it, is prevalent—law there being considered largely as "just a neighborly agreement." Hence, though the mountain counties have all voted "dry," the moonshiner and bootlegger continue to ply their trade there with little molestation by the local authorities, and the feud still lingers as a means of redressing private wrongs. The pistol duel and the shooting from ambush, with the potent causes—moonshine whiskey and the carrying of concealed weapons—which generally lead up to it, while publicly and by statute condemned, are still in effect condoned—as is evidenced by the euphemistic title "killing" being applied to what in the majority of cases is downright murder; and by the visitation upon it of a less, or at least no greater, punishment than that for the crime of theft, which is usually summarily dealt with.

These people, however, have their compensating virtues. They are intensely loyal, having been strongly Union in sentiment during the Civil War, and in the recent war leading the rest of the State in voluntary enlistments. Hospitality is universal, the life and property and personal welfare of the "stranger within their gates" being considered sacred. Theft is almost unknown, and, as indicated above, is promptly and severely punished. The advance of civilization—for with the building of railroads into this region the old order is passing—has therefore some drawbacks, and we confess sympathy for the feelings of the noted feudist, who, while not opposing the movement for developing the resources of the country, expressed naively the fear that this would ultimately result in bringing into his community a "bad class of people."

Political History.—The Eastern Kentucky Mountains have been strongly Republican since the Civil War in contrast with the Bluegrass counties which in the same period have been just as strongly Democratic. An explanation of this must be sought primarily in the physiographic differences between the two regions which at the outbreak of the war determined that the one would be Northern and the other Southern in its sympathies.

It was Nathaniel S. Shaler who first commented upon these differences, and finding an explanation of them ultimately in the geological history of the State, uttered his celebrated aphorism, "there is such a thing as the geological distribution of politics." The reasoning of Professor Shaler, by which in his History of Kentucky he traced these connections, is somewhat as follows: The dwellers on Bluegrass Ordovician limestone land, with its deep rich soil suitable for cultivation in large plantations by slave labor, were naturally pro-slavery in their sentiments. The dwellers on the Carboniferous sandstone land of the mountains with its thin soils, not suitable for cultivation on a large scale by slave labor, were generally anti-slavery, or at least had no particular motive in fighting for the perpetuation of that institution. Therefore during the Civil War when it came to voting Kentucky in or out of the Union, "the dwellers on the limestone formation gave heavy pro-slavery majorities, while those living on the poorer sandstone soils were generally anti-slavery." The majority of the people of the State—its yeomanry—lived on poorer land, which thus became the deciding factor in preventing the withdrawal of the State from the Union. Professor Shaler also goes on to speculate upon some of the political "might-have-beens" had the geological history of the State been different. A higher arching up of the Cincinnati Anticline would by the greater ensuing erosion have exposed more Ordovician-Bluegrass-pro-slavery land, and correspondingly reduced in area the Coal-Measure-anti-slavery land. This might have given, when it came to the voting during the Civil War, a majority on the side of withdrawing Kentucky from the Union. One more State added to the Southern cause might have made the difference between failure and success. The South might have won and we might now have two countries here instead of one; and for it all *geology* would be primarily responsible.

Miss Ellen Semple, in her "American History and Its Geographic Conditions," while recognizing the force of Professor Shaler's reasoning, does not make the result hang entirely on a conflict of sordid self-interest. Agreeing that "mountain economy found no place for the negro or plantation cultivation in these sterile hillside farms, pathless forests and roadless valleys," she states in addi-



77. VIEW UP THE OHIO RIVER FROM TOP OF ALUM ROCK, VANCEBURG, LEWIS COUNTY
The even skyline of the supposed Cretaceous peneplain is shown. Photograph by A. M. Miller

tion that the region possessed "in contrast to the aristocratic social organization of the planter community, the democratic spirit characteristic of all mountain peoples, and likewise their conservatism, which holds to the established order."

THE CUMBERLAND PLATEAU AND THE PENEPLAIN THEORY.—Writers on Appalachian physiography (M. R. Campbell, Willard Hayes, and others) have sought to explain uniformity of heights in the ridges of the Cumberland Plateau—in other words, the "evenness of its skyline"—in accordance with a postulate that these ridges were carved out of a plateau that was formerly a peneplain; that is, a nearly featureless plain lying almost at sea level. The time when this surface was a peneplain is fixed by them as Cretaceous; because in being traced south into the Gulf States, after first rising to a maximum height in Tennessee, it then declines and finally passes beneath the Cretaceous strata of the Gulf coastal plain.

To one who, like the writer, does not see the necessity of reducing every land surface nearly to sea level in order to secure for it an even skyline, such evidence for peneplain origin of the Appalachian Plateau is not convincing.

As a matter of fact, in the range in altitude from 1,000 feet near the Ohio River to 4,000 feet on the crest of the Black Mountains near the Virginia line there are several sets of elevation on this plateau giving "even skylines." The Black Mountains give one at the 4,000-foot level, the Pine and Cumberland ranges present another near the 3,500-foot level, a third occurs west of the Pine Mountain Range in the southern part of the Kentucky portion of the Plateau at about the 2,000-foot level, and a fourth in the southwestern part of the same region at about the 1,500-foot level. These are entirely too many levels to select from in determining which must be the remnant of the surface peneplained during Cretaceous time. A more intimate study of these levels will show that they have been produced by atmospheric and stream erosion acting on definite stratigraphic and deformational units. Stratigraphy and structure have been the controlling factors in their formation. The part that stratigraphy has played in this even skyline production is well brought out in the southwestern part of the field where exist the 1,500 and the 2,000-foot levels. The former is drawn on top of the Corbin conglomerate, which has here on account of its resistance to erosion formed a local base-level known locally as the "Flatwoods." The latter is the highest surface of the plateau formed in this region by the softer shales and sandstones of the Pottsville above the basal conglomerate series. It has the general uniformity of level which any wasting land surface will assume that is composed of materials offering equal resistance to the wasting agencies. The greater width of the lower level in the southwestern part of the field is proportionate to its greater thickness in that region. Traced northwestward its width diminishes with the thinning of the formation, until at the northern part of the field both levels, which have fallen off in height, merge into one at about 1,000 feet.

SOUTHERN AND SOUTHWESTERN LOWER CARBONIFEROUS PLATEAU

This region, which occupies a total area of 8,000 square miles, includes, with the exception of the Western Coal Field, all the portion of the State lying south of the Knobs, west of the Eastern Kentucky Mountains and east of the Tennessee River. It has an altitude of from 1,000 to 1,200 feet along its northern edge, where it presents in Muldraugh's Hill a steep escarpment toward the Bluegrass. South and west from Muldraugh's Hill the general level falls to 800 feet and in the extreme southwestern portion to 600 feet above the sea. A large portion of this region was treeless in the early day and known as "The Barrens" to the first settlers, who without warrant associated a treeless condition with infertility of the soil. The geological formations exposed in the region belong to the Mississippian-Lower Carboniferous of earlier geological literature. The three main divisions of this system present marked lithological contrasts, and so form by outcrop three sub-regions: Waverly, Cavernous (Mammoth Cave) limestone, and Chester.

The Waverly Area.—The Waverly formation forms the surface rock over the greater portion of the Cincinnati Anticlinal, where it has declined to a low saddle between the Jessamine and Rutherford Domes. Outliers of later formations up to the very base of the Coal Measures may be found upon it, as in the northern portion of Casey and Taylor Counties. The surface, while level in places—as, for instance, in Taylor County—in general inclines to be quite hilly. The soil with few exceptions is of inferior quality, though it is an improvement on that formed from the same formation in the Knobs region to the north, where it is almost devoid of limestone. These limestones develop in the formation from north to south; there is, therefore, a general improvement in soil character in that direction. It remains throughout, however, highly siliceous and lacking in phosphorus. The district is lacking in enterprise. No railroads cross it and only two penetrate it. These latter are branches of the Louisville and Nashville system, the one extending southwestward from Lebanon in Marion County to Greensburg in Green, and the other northeastward from Gallatin in Tennessee to Scottsville, the county seat of Allen. Only three macadam roads enter it. One is the pike (a toll one in part) connecting Lebanon with Columbia; another is the Jackson Highway, which, entering at Glasgow, passes through Scottsville and continues southward into Tennessee; and the third is part of the pike which connects Scottsville with Bowling Green.

In general lacking in mineral resources, though oil has been found in Allen and Barren Counties, without a naturally fertile soil, and with little means of communication with the outside world, this region at present constitutes a rather backward portion of the State. However, where penetrated in recent years on the northern border, as in Taylor County, by a small influx of farmers from Ohio and Indiana, bringing with them up-to-date farming methods, the soil has shown itself capable of responding bounteously to proper treatment; with the result that one finds in this section, in the growing crops, spacious barns and attractive farm dwellings, abundant evidence of the prosperity of the people.

The Cavernous Limestone Areas.—On either side of the Waverly area—wider on the western than on the eastern side—is a belt of Mammoth Cave limestone outcrop. The term "'Cavernous Limestone Belt" is particularly applicable to that portion of country traversed by the main line of the Louisville and Nashville Railroad between Elizabethtown and Bowling Green. In this section the highly soluble limestones of the St. Louis and Ste. Genevieve formations have been excavated by underground waters into intricate systems of underground chambers and passages, through the lowermost of which they flow for a distance as "hidden rivers" and then find their way out into the Green River as "big springs." The largest caves, as Mammoth, Colossal and Hidden River, are where the Cypress sandstone of the Chester group still forms a protective covering over the surface, or has been removed only recently (speaking in a geological sense). The region from which the sandstone has been eroded, or where it exists only as cappings to the knobs dotted over the country, is now pitted with sinks forming a "karst" country. These sinks are the unroofed portions of former caverns. Many of them form entrances to the remaining portions of those caverns. One of these, in the center of the town Horse Cave, is the entrance to the celebrated cavern, formerly called "Horse Cave," but now known by the more poetic title "Hidden River." There are few streams above ground in this region. Hart County has only one considerable surface stream besides the Green River. The rain water which falls upon the surface is speedily drained away by these sinks and conducted by underground channels to the neighboring Green River. The sandstone-capped knobs which dot the surface are now wooded, though originally this region formed a part of the treeless Barrens. The soil formed over the Cavernous limestone is commonly red in color, being stained with iron oxide. Much chert is commingled with it—that from the St. Louis being solid and somewhat spherical, while that from higher horizons is a porous block variety. While superior in fertility to those of the Waverly area, these soils are much inferior to those of the Bluegrass, being deficient in phosphorus. Broom sedge tends to take the pasture fields and must be regularly burned off in early spring. This limestone area in the strip south of the Western Coal Field is, for the eastern portion of it, not so much pitted with sinks as it is in the Green River Country, probably because there are no large streams traversing it to give outlet to an extensively developed system of underground drainage. The surface in this region is quite level, the best farming section of the border tier of counties from Simpson to Trigg being included in it.

The Chester Area.—The Chester portion of the Mississippian, having sandstones and shales as its conspicuous stratigraphic elements, gives to its outcrop a rough topography and poor soil. It constitutes a strip five to ten miles wide when surrounding the Western Coal Field, but so narrow along the western border of the Eastern Coal Field that physiographically its presence there may be neglected.

The belt surrounding the Western Coal Field is generally marked off from the rest of the Lower Carboniferous District by a distinct rise in the level of the country. Just as further north in passing from the Bluegrass across the Knobs Region southward the knobs became more thickly placed and finally unite into the continuous Lower Carboniferous escarpment of Muldraugh's Hill; so in passing from Muldraugh's Hill southward and southwestward towards the Western Coal Field, knobs which dot the surface of the Lower Carboniferous Plateau become more crowded together and finally unite into a continuous ridge—the edge of the Chester sandstone terrace. This is the conspicuous feature of the landscape, which the traveler on the Louisville and Nashville Railroad between Elizabethtown and Bowling Green sees along the western horizon. It is composed of the Cypress sandstone—the main sandstone of the Chester. The Chester Terrace stretches from Breckinridge County on the Ohio River, through the counties of Grayson, Hardin, Hart, Warren, Logan, Todd, Christian and Caldwell, to the Ohio River again in Crittenden County. It forms the poor agricultural portion of all these counties, the soils in it, derived largely from sandstone and shale, being thin and poor.

Former Connection of the Eastern and Western Coal Fields.—Reference has already been made to the knobs capped with Chester sandstone (Cypress) which are scattered over the Lower Carboniferous plateau of Southern Kentucky. The loftiest of these—1,800 feet above sea level—is Green River Knob on the borders of Pulaski and Casey Counties. It is the highest detached elevation between the Eastern Kentucky Mountains and the Mississippi Embayment lowlands. From the summit of this knob on a clear day one may see plainly to the eastward the edge of the Cumberland Plateau, and dimly, about sixty-five miles distant along the horizon to the westward, the margin and outliers of the Western Coal Field. The region between is studded here and there with knobs capped with the sandstone on which he is standing. In this position, as remarked by Professor Shaler, it requires little imagination for the observer to

78. MAP SHOWING REMNANTS OF FORMER CONNECTION BETWEEN EASTERN AND WESTERN KENTUCKY COAL FIELDS

restore over the intervening area this bed of sandstone, and on top of that the basal sandstone of the Coal Measures. In doing this he will realize that the Coal Measure areas, now separated, were once continuous, and he will also have gained some conception of the vastness of geologic time when he farther reflects that this removal, amounting in this instance to something like 2,000 feet of strata, has all been accomplished since the close of Upper Carboniferous (Pennsylvanian) time—and that, too, by the slow process of reduction to soil and removal by streams which is now accomplishing the levelling of the continents.

The pregnant conjecture of Professor Shaler has been amply confirmed by subsequent discovery. It was the good fortune of the writer, while making a survey of the counties of Green, Taylor and Adair, in 1908, to discover some of the evidence supporting this view. On the highest ridges of that group of counties, and especially along the borders of Larue, Taylor and Green, he found gravel waste of the basal Coal Measure Conglomerate and even some considerable area—the Larue-Taylor-Green County area—where the conglomerate, amounting to upward of fifty feet in thickness, was yet little disintegrated. It was this latter area that lying at an elevation of between 1,000 and 1,100 feet had been maturely dissected into a rugged topography resembling that of Eastern Kentucky. And, most interesting fact of all, though separated from the nearest portion of the Cumberland Plateau by some seventy or eighty miles, its similar physiography had so reacted upon the same pure Anglo-Saxon stock of the type which peopled Kentucky as to reproduce here similar sociological phenomena. It need awaken no surprise, therefore, in the traveler traversing this region by the winding ridge roads through a forest of oak and chestnut, from openings in which he may look to the right or left down into deep coves, in which are one-room log cabins surrounded by small clearings, to learn that now and then a wild turkey may be seen, that the wild cat is not unknown, the feud not uncommon, and the moonshiner not entirely extinct. It was while the writer was in this country that a man of this class—a noted desperado—was hunted down and shot to death in his own dooryard by an officer of the law, assisted by a posse of citizens.

It would accordingly appear that Coal Measure strata in the southern Appalachians, and especially their conglomerate members, including spurs and outliers, wherever they are sufficiently high to be cut into rugged topography, carry a moonshine and feud fauna.

THE WESTERN COAL FIELD

This district with an area of 4,600 square miles has a maximum upland elevation of about 700 feet above sea level. Most of it lies between the 500 and 600-foot contours, while there are considerable tracts in the vicinity of the Ohio along the northern border and along Green River, which traverses the field through its middle part, where the land lies between the 400 and 500-foot contours.

The higher levels present a mature topography. The lower are quite flat, being areas of alluviation. The uplands are covered with an indifferent soil. The lowlands, when drained, are fertile. Taking the district as a whole it is much superior agriculturally to the Eastern Kentucky Coal Field. This is because, though the soil of the uplands is similar in quality, being formed from the decay of sandstones and shales, it does not wash so badly, the slopes on which it lies, in keeping with the lower altitude of the region, being more gentle.

THE SOUTHWESTERN MISSISSIPPI EMBAYMENT

The part of the present States of Tennessee and Kentucky west of the Tennessee River formerly belonged to the Chickasaw Indians. In 1818 this district was purchased by the National Government from the Indian owners, and in 1820 it was added to these two States—the dividing line being the parallel of 36 degrees and 30 minutes. The two Commissioners who negotiated the treaty with the Indians were Generals Shelby for Kentucky, and Jackson for Tennessee. The name of Jackson, the more prominent statesman, has become popularly associated with the transaction to the exclusion of Shelby's—hence the name "Jackson Purchase." The part allotted to Kentucky has an area of 4,600 square miles. It comprises all the Mississippi embayment region lying within the State.

Between the time Kentucky became a State and when this area was added, the Government land survey had been adopted, so this portion of the State was laid off in accordance with its range-township-section system. In consequence of this the farms in the region are rectangular, in contrast with those of irregular shape in other portions of the State.

The Purchase Region is one of low relief, the general level sloping from 500 feet near the Tennessee River to about 350 feet near the Mississippi. The bottoms along the Ohio and Mississippi range between 300 and 350 feet above the sea. The surface of the uplands in general is level, being a recent geological addition by uplift of the bottom of a portion of the northern end of a former Gulf of Mexico. It was as late as the Tertiary period that this gulf or embayment extended up the Mississippi Valley to and a little beyond the mouth of the Ohio. The deposits left in this region to a depth of several hundred feet, consist of gravels, sands, clays and loams. They form in general a level surface highly adapted to agriculture, though on account of their unconsolidated character some of the beds wash badly, especially in the neighborhood of streams in the eastern part. Here in some places the land is quite broken by the development of recent gullies.

CHAPTER IX

NATURAL FEATURES AND PHENOMENA OF GEOLOGIC AND SCENIC INTEREST

CAVERNS

Caves of greater or less extent occur in all the sections of the State where there is limestone near the surface of some considerable thickness and purity.

Caves of the Bluegrass Region.—In the Bluegrass conditions suitable for cave formation are supplied by the limestones of the Highbridge and Lexington (Trenton) series. Those of the *Highbridge* are generally found opening on the faces of the Kentucky and Dix* River cliffs. Such are the several ''Boone's caves''—one near Valley View, one near Camp Nelson, and one near Highbridge, in each of which that noted pioneer is said to have hidden from the Indians. Another cave is located on Dix River four miles from the mouth.

Those of the *Trenton* are situated in the uplands—frequently where a small stream issues from below ground and after flowing a short distance unites with the main stream. Such is Russell Cave, about six miles north of Lexington. This is a winding passage with its roof sufficiently high above the stream to permit its being entered for the distance of about three-quarters of a mile. Two other caves in the same county (Fayette) lie southwest of Lexington. One of these (Reed's) is about a mile from Lexington on the Harrodsburg pike. The other (Phelps') is about four miles from the city and a little west of the same pike. In Clark County is a cave (Jones') which, contrary to the rule in the ''Bluegrass caves,'' has a stream flowing into it.

The caves of the Bluegrass are not rich in stalactitic and stalagmitic formations.

Caves of the Lower Carboniferous Plateau.—The great cavernous portion of the State is the southern. Here the caves are found in the Warsaw, St. Louis and Ste. Genevieve limestones—chiefly in the two latter. The

*So appearing on recent maps only. It is "Dick's River" in Filson's report and map published in 1784, and on subsequent maps, as late as the one by the Shaler Survey in 1890. As it was named after "Captain Dick," a Cherokee chief, "Dick's" is unquestionably the correct spelling.

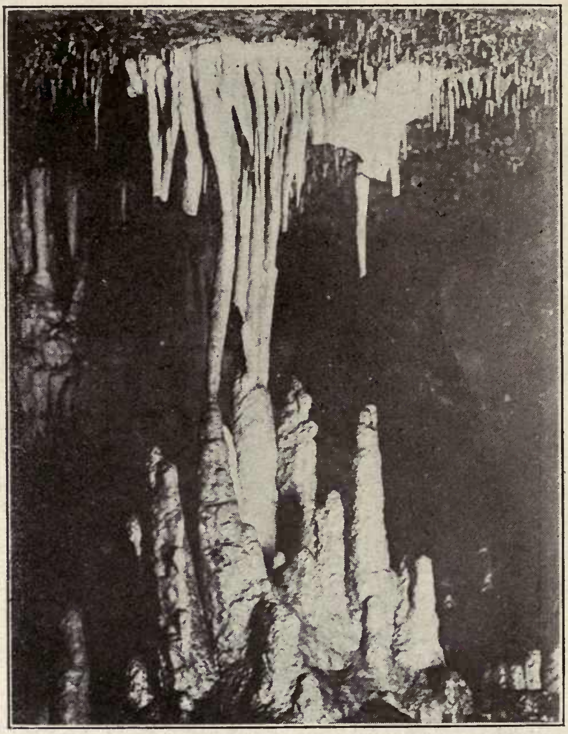
outcrop of these two latter formations is marked by a continuous succession of caves. The only cave of any notoriety in the Warsaw is *Todd's,* two and one-half miles west of Columbia in Adair County. It is reported to have been explored for a distance of one-half mile and to have had originally many stalactites. Most celebrated of the caverns of the St. Louis and Ste. Genevieve lime-

79. ENTRANCE TO MAMMOTH CAVE
Photograph owned by the Louisville and Nashville Railroad, and reproduced here by courtesy of the company

stones is *Mammoth Cave* in Edmonson County. It opens out into the valley of Green River, distant eighty-five miles by rail from Louisville. It can also be reached by steamboat from points on the Ohio River. Evansville is one of these. These boats pass up Green River to the cave, which is between Brownsville and Munfordville.

The entrance is 194 feet above the river. Routes of different lengths are offered to the tourist by the guides, one, the short route, requiring four hours, and the other, the long route, requiring nine hours to complete.

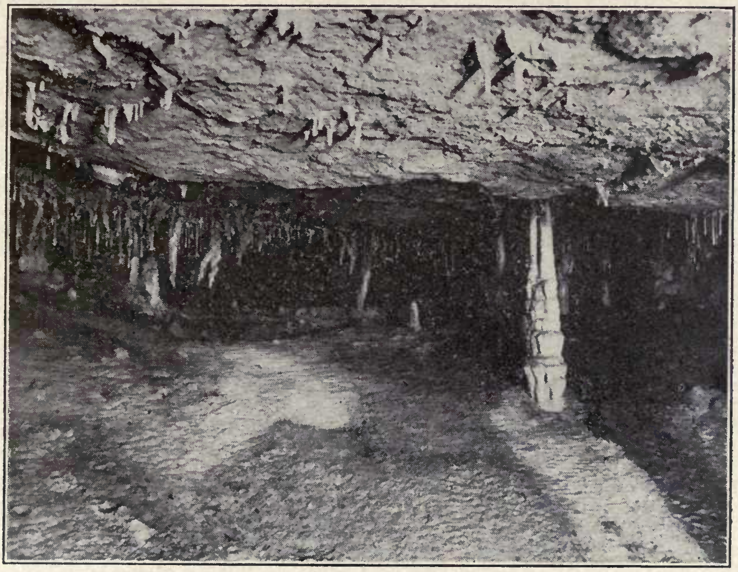
Different parts of the cave have received different names—as Audubon's Avenue, Gothic Avenue, Egyptian Temple, Mammoth Dome (with a waterfall in it 150 feet



80. STALACTITES AND STALAGMITES
Mammoth Cave, Edmonson County

high), Croghan's Hall, Bottomless Pit, Fairy Grotto, Fat Man's Misery, etc. A stream called Echo River (in reality only a small brook) flows through the lower reaches of the cave, emerging from this and emptying into the Green River a short distance below the entrance. In its course there are several pools—some of them navigable for small boats. Special names have been given to these pools, as Dead Sea, Lake Lethe, and, at one crossing, the River Styx. The fauna of Mammoth Cave is the same as that of other caves and in some instances of underground drains in this portion of the United States. Besides great numbers of bats, which hibernate near the entrance, there are blind crickets, blind fish and blind crayfish. In all some twenty-eight species especially adapted to an underground existence, have been enumerated. While there are stalactites and stalagmites in Mammoth and other caves in the vicinity, they are not so numerous nor so beautiful as in the caves of the Shenandoah Valley of Virginia.

Other caverns in the neighborhood are the Colossal and the Grand Avenue. Also in the same region is Hidden River Cave, which is entered through an immense sink hole in the center of the town of Horse Cave. It is reported that the original name for this cave (Horse)



81. COLOSSAL CAVERN.
A passage with low ceiling. Photograph owned by the Louisville and Nashville Railroad, and reproduced here by courtesy of the company

was so applied because in the days of the early settlement of this country a band of horse thieves quartered a portion of their stolen booty there.

The temperature of all these caves is quite uniform, being about 60 degrees Fahrenheit, summer and winter.

The Carter County Caves.—In the same formation as the Mammoth Cave, but in an entirely different portion of the State, are the caves of Carter County. There are two groups of these: the Carter Caves proper and the Oligonung.

They are reached over a small railroad which connects with the Chesapeake and Ohio at Garrison.

Ice Caves, or "Glacières."—There is in the State at least one "glacière," or cave in which ice accumulates and lasts till late in the summer. This one is near Powersburg, Wayne County. When visited by the writer in 1899 though it was late in summer the last of the ice had just melted. This cave is a sink hole with ramifying branches. The mouth of the sink is on the top of a "mountain" about 200 feet above the immediate surrounding country. The top formation is the Cypress sandstone of the Chester. The remainder of the mountain, or knob, is composed of Mammoth Cave limestone. The explanation of the phenomenal feature of this cave—the accumulation of ice in it till well into the summer—seems to be as follows: During the winter months cold air settles down into this sink, being encouraged to do so by the "Sprengle pump"-like action of the water draining away through the channels with which the knob is permeated. By this process the whole rock mass becomes thoroughly refrigerated, and freezing temperatures come to exist in all the cave ramifications. All the water which trickles down into the cave then freezes and this process continues till sometime in the early summer. Finally the warming up of the outside atmosphere and the decrease in the supply of water, with the cessation of the winter and spring rains, cause a reversal in the movement of the air. It begins to flow upward and outward from the sink at the top and inward and upward through the channel ways opening around the base of the knob. By this process the mountain or knob becomes warmed up and finally by late summer all of the ice is melted. This cave is known throughout the immediate neighborhood as the "ice house." People go there in the summer to get their ice. One such cave is reported in Caldwell County, and another in Madison County.

Cave Deposits.—Highly nitrogenous earths exist in some of the caves of Kentucky. During the War of 1812, and also during the Civil War, a certain amount of niter or salt peter for the manufacture of gun powder was obtained from these earths by leaching it out with water and then causing it to crystallize out of the latter by evaporation. It has been suggested that this earth might be used as a fertilizer on account of its available nitrogen content, but nothing has yet come of the proposal.

Extensive travertine (*Calcareous tufa*) deposits exist in some caves, especially those of Hart County, and some attempts have been made to exploit these for "Mexican onyx," but so far without success.

ROCKHOUSES

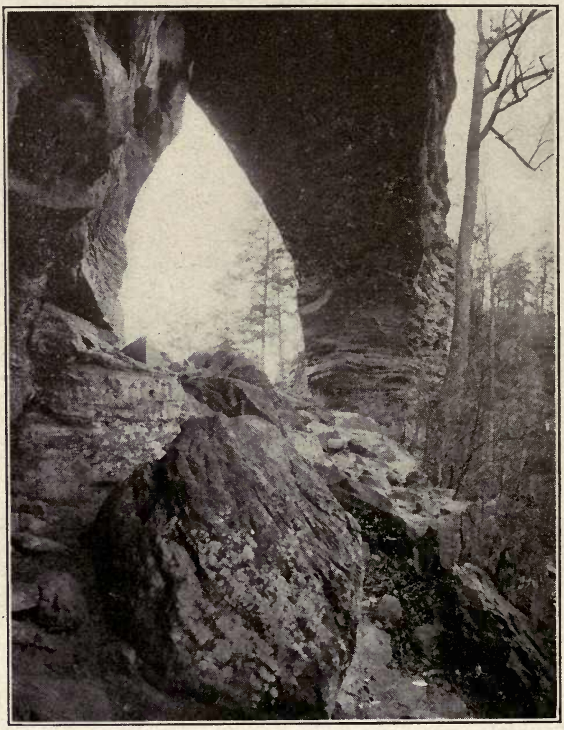
Cliffs with overhanging walls, constituting what are locally known as "rockhouses," are frequent in various parts of the State. They occur along the canyon walls of streams, as for instance on the middle Kentucky where it cuts its gorge through the hard Highbridge limestone; but particularly at the head of coves trenched in the Coal Measure conglomerate along the western border of the Eastern Coal Field. Here they exist in the form of semicircular structures properly known as "amphitheatres" or "cirques." They are frequently utilized by the inhabitants of the region as stables and granaries.

At Torrent, on the Lexington and Eastern Railroad, in Wolfe County, there is an especially fine illustration of one of these rockhouses. It is an immense amphitheatre at the head of a deep hollow opening out into Graining Fork of Middle Fork of Red River. The roof, formed by an overhanging cliff of conglomerate sandstone, at its outer edge is 160 feet above the floor. Over the edge of this cliff into a pool below falls during the wet season a stream of water, for the head of this hollow is not the real head of the stream which has excavated it. Offset at this point the stream may be traced on the ridge above the cliff to its actual source a mile or two farther on. The space under this cliff excavated by the sapping effect of weathering and the recoil of the water in the waterfall has been fitted with seats with a view to its being used as a place for public meetings, but this object has not been realized. It is visited, however, by tourists, and a hotel for their accommodation has been built at the mouth of the hollow.

Rockhouses as Archeological Repositories.—In Europe—especially in France and Spain—rock shelters, similar in form to the rockhouse structures just described, have yielded some of the most satisfactory evidences of the existence of primitive man in that continent during the Glacial Period. Those with southern exposures have yielded the richest reward to archaeological exploration.

It has been suggested that such situations in this country, and especially in Kentucky, should be explored for similar evidences of the existence of a primitive culture on this side of the water during the Glacial Period. Assuming that this continent was also inhabited by man during that period, it would seem reasonable to conclude that he must have resorted to similar shelters here as in Europe, and at about the same distance south of the southern limit of the continental ice sheet.

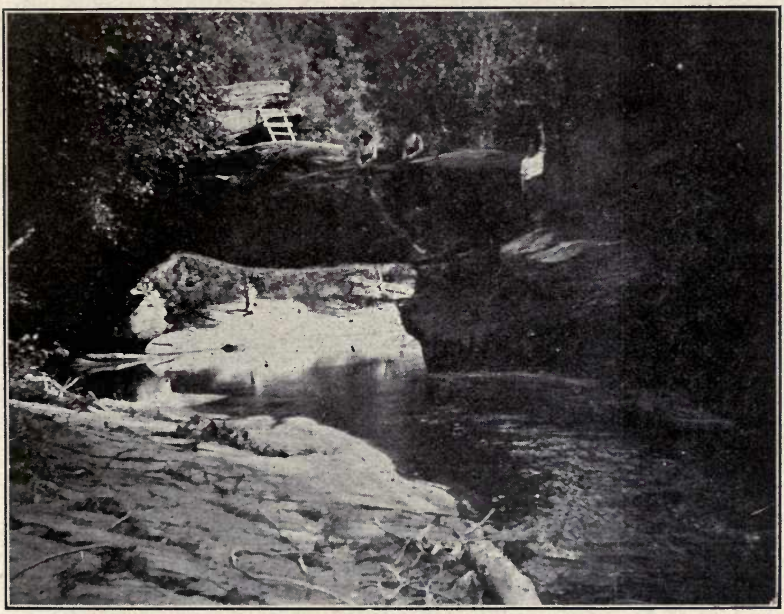
Kentucky in North America occupies the same relative position to the southern limit of this sheet as does France in Europe.



82. NATURAL BRIDGE, POWELL COUNTY
Photograph owned by the Louisville and Nashville Railroad, and reproduced here by courtesy of the company

NATURAL BRIDGES

There are a number of natural bridges in Kentucky, illustrating several different methods of formation. The most common type is the sandstone natural bridge found in the Rockhouse Formation belt along the western margin of the Eastern Coal Field. These have been formed by the combining of two rockhouses back to back. Stream sources tend to work back up slope to the interstream divides. Amphitheater rockhouses form the virtual sources of most of the streams in this conglomerate sandstone strip. It happens therefore that frequently by the heading of streams opposite each other, rockhouses back toward each other in pairs until they meet back to back. The back becomes perforated and a natural bridge results. These bridges are located, therefore, on the tops of divides. No water flows under the arches now, or ever has flowed in the past. In this respect they are very



83. NATURAL BRIDGE ON SWIFT'S CAMP CREEK, WOLFE COUNTY
Photograph by H. Cleland

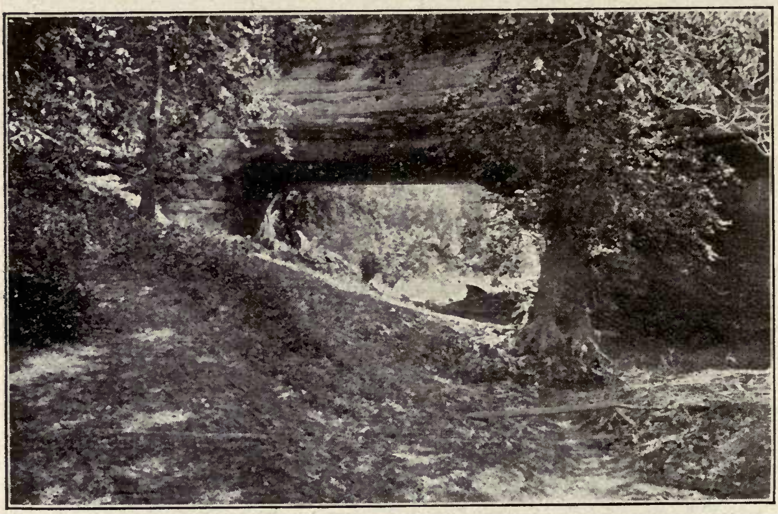
different from natural bridges of the Virginia Natural Bridge type, as they are different also in mode of formation.

The best known example of the sandstone natural bridge of the type just described is the one at Natural Bridge Station, on the Lexington and Eastern Railroad in Powell County. The railroad management has made of this quite a scenic resort, and many excursions from

Central Kentucky and points as far away as Cincinnati are run to it. Not far away to the west, but more difficult of access, is another bridge of the same type; and on main Red River near the mouth of Swift's Camp Creek is still another more imposing than either of the foregoing. Another bridge of this type which is accessible to the tourist, is one not far from the line of the Queen and Crescent Railroad in McCreary County.

There is a sandstone bridge in Wolfe County on Swift's Camp Creek near its mouth which spans the cut-off of a meander of the creek. It affords at this point a crossing for a road.

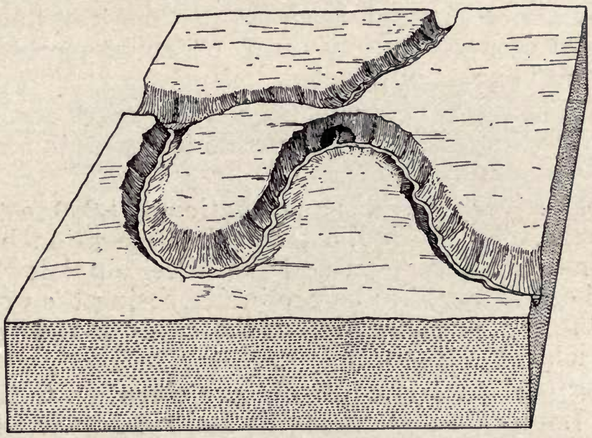
A bridge of a still different type is the one on the Cumberland River not far from Creelsboro, Russell



84. NATURAL BRIDGE ON THE CUMBERLAND RIVER NEAR CREELSBORO, RUSSELL COUNTY

Looking through the bridge from the Miller's Creek side to the Cumberland River. The rock is Upper Cincinnatian (Richmond) siliceous limestone. Photograph by A. M. Miller

County. This pierces a narrow rock divide, separating the river from Miller's Creek which empties into the river a little further downstream. It has evidently been formed by the meandering action of the river and the creek during high water, which resulted in throwing the current against the divide, first on one side and then on the other, until the latter was finally eaten through. It now happens that, when the Cumberland River has its flood stage, and Miller's Creek is rather low, a part of the current of the river flows through this hole in the divide into the creek and re-enters the river again further downstream. When Miller's Creek has its flood stage, and the Cumberland river is low, a portion of the creek's water empties through this hole into the river. The rock formation pierced in the forming of this bridge or tunnel is Richmond limestone of the Cincinnatian.



85. MODE OF FORMATION OF A NATURAL BRIDGE LIKE THAT NEAR CREELSBORO
Diagram after H. Cleland

OUTLIERS

Residuals of newer strata surrounded by older are known as "outliers." The more conspicuous of these are often called "pilot knobs," because they are eminences which command a fine view of the surrounding country. These are commonly detached portions of plateaus. Some are pure erosion forms while for others faulting is partly responsible.

Pure Erosion Type.—These are most common along the margin of the Eastern Kentucky Coal Plateau where it overlooks the Bluegrass, along the front of Muldraugh's Hill where it overlooks the same region, and around the margin of the Western Coal Field. Prominent examples of such elevations are Pilot Knob on the boundary of Clark and Powell Counties near Clay City, Indian Fort Mountain, three miles east of Berea, Joe Lick Knob in the same region, Green River Knob in Pulaski County near Casey line and Prewitt's Knob in Barren County.

Pilot Knob is 1,400 feet above sea level. It is reported to be the point from which Daniel Boone first saw the Bluegrass. [See plate 73 on page 185.]

Indian Fort Mountain was so named because at the point of easiest approach to the top a rough wall or pile of stones had been heaped up into a kind of breastworks. The wall is evidently the work of aborigines and was for the purpose of making the hill impregnable to attack. The remaining circumference of the brow of the hill is composed of a precipitous cliff of conglomerate sandstone that is not easily scaled.

Joe Lick Knob is a conspicuous landmark seen to the east of the Louisville and Nashville Railroad in traveling from Richmond to Berea.

Green River Knob has an elevation of 1,800 feet above sea level, being the highest detached elevation between the Cumberland Plateau and the Mississippi low lands. It has been referred to before in discussing the probability of the former connection of the Eastern and Western Coal Fields.

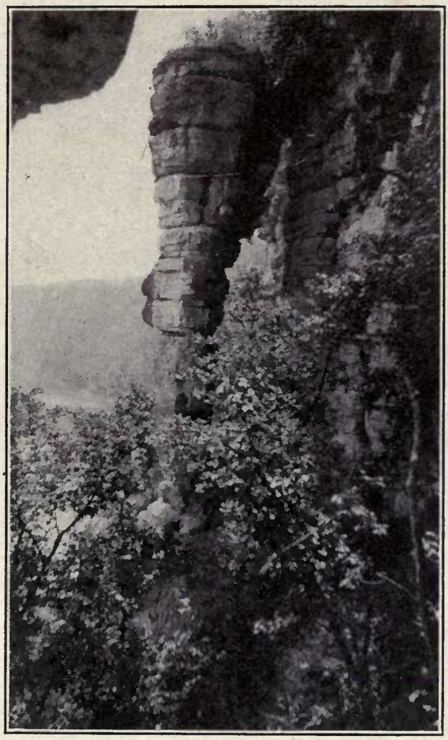
Prewitt's Knob is a conspicuous elevation to the east of the Louisville and Nashville Railroad near Glasgow Junction. It is about 975 feet above sea level and carries on its top Cypress sandstone.

Faulting and Erosion Type.—The downthrow side of faults protect strata from erosion. Hence on this side there is a tendency for outliers to form. Of this type are Jeptha Knobs in Shelby County and Burdett's Knob in Garrard.

Jeptha Knobs are a group of elevations east of Shelbyville which carry on their summits remnants of Niagara, the nearest continous outcrop of which are now near Louisville. The tops of the knob reach to about 1,300 feet above sea level. It is evident that the Niagara must have at one time covered all the intervening region between these knobs and the outcrops of Niagara in Jefferson County. Also it would seem highly probable that the same formation at one time extended eastward over the Cincinnati Arch to connect with the continuous outcrop of the same formation on the east flank.

Burdett's Knob, near Bryantsville, is on the downthrow side of the southern end of the Kentucky River Fault. It is about 1,090 feet above sea level and preserves on its summit a small patch of Waverly. This is evidence of the same kind as that furnished by Jeptha Knobs to show that formations at least as high as the Waverly once extended over the Cincinnati Arch at its highest point—the summit of the Jessamine Dome.

Other Types of Residuals.—Certain other residuals, either detached outliers of cliffs, prominences of a cliff, or detached blocks from same, are conspicuous enough objects in the landscape to have attracted attention and become the occasion of visit in the regions where they are situated.



86. "CANDLESTICK" (CHIMNEY ROCK), KENTUCKY RIVER

Such are the *Candlesticks* along the cliffs of the Kentucky River. One of the best illustrations of these is seen near Camp Nelson. It is an isolated column, approximately 100 feet in height, carved by slow erosion from the neighboring cliff of Highbridge limestone. Professor Shaler drew the conclusion from the presence of such insecure structures in Central Kentucky—evidently of great age in forming—that this portion of the State could not have been visited in recent time by violent earthquakes.

Dismal Rock in Edmonson County is a prominent cliff of conglomerate sandstone.

Anvil Rock in Union County is a detached block of the sandstone which David Owen selected in the Western Field as the top of his lower Coal Measures. It was so named on account of the detached block being shaped like an anvil.

Split Rock, overlooking the Ohio River near Petersburg in Boone County, is a somewhat detached mass of post—or interglacial—conglomerate, composed of fragments of Cincinnati limestone along with pebbles from the Canadian crystallines. These fragments and pebbles have been cemented together by calcium carbonate. The top of the mass is 185 feet above the Ohio River.

WATERFALLS

Not being within the glaciated district and hence not having had its drainage recently revolutionized, Kentucky has comparatively few waterfalls. Most of these are well up toward the heads of her river systems. The most important of them may be enumerated as follows: Falls-of-the-Ohio, Cumberland, Eagle, Seventy-Six, Torrent, and Elk Lick.

THE FALLS-OF-THE-OHIO.—These are at Louisville. Here the Ohio falls over resistant ledges of Devonian limestone. The obstruction to navigation which these ledges offered in the early days of flatboat traffic necessitated here a transfer of cargoes, and hence gave rise to a settlement which grew into the city of Louisville. After the flatboat gave way to the steamboat the importance of unobstructed river navigation so greatly increased that the Federal Government instituted improvements at this point which now permit passage of steamboats at virtually all stages of water.

CUMBERLAND FALLS.—The largest falls of the State, when both height and volume are taken into consideration, are the Falls of the Cumberland in Whitley County, forty-five miles by river and nineteen by nearest trail below Williamsburg. Here the Cumberland River, after having had a broad and shallow course for some distance over a hard ledge of Rockcastle conglomerate, suddenly contracts and falls over this ledge sixty-five feet into a narrow gorge choked with large detached masses of the same conglomerate. Through this boulder filled gorge, which marks the trail of the falls upstream retreat, the river has a tumultuous course for seven miles.

87. ELK LICK FALLS, FAYETTE COUNTY
The mass of calcareous tufa, 55 feet high, has been built up from the bottom to the top of the gorge by slow deposition from the small stream of water which here fell over the cliff. Photograph by W. R. Jillson

It has been proposed to utilize the power of these falls in the generation of electricity, and surveys to that end have been made. As a resort, which offers attractions to the fisherman and to the lover of wild scenery, this place is unexcelled in the State. A hotel for the accommodation of the visitor has been built on a broad shelf of conglomerate immediately overlooking the falls. It is best reached from Cumberland Falls station on the Queen and Crescent Railroad. [See frontispiece.]

Eagle Falls.—A short distance below Cumberland Falls a tributary of the Cumberland—Eagle Creek—drops into the river gorge over the same hard ledge of conglomerate as does the Cumberland. It is a small but beautiful waterfall.

Falls of Seventy-Six.—This waterfall, named from its height, is on Indian Creek in Clinton County.

The Torrent Waterfall.—This graceful waterfall, the "Staubach" of Kentucky, has already been described on page 209 in the account given of rockhouses.

Elk Lick Falls.—At the head of a side gorge of main Elk Lick Creek in Fayette County, a small stream issuing chiefly from a spring a short distance away, falls fifty-five feet over a cliff of Tyrone and Oregon limestone, constituting the locally celebrated *Falls of Elk Lick.* The remarkable feature of this waterfall is the mass of calcareous tufa it has built up from the bottom to the top of the cliff, the whole presenting the appearance of a "petrified waterfall." [See picture on preceding page.]

RAPIDS OR "DEVIL'S JUMPS"

Boulder-filled gorges in Kentucky are known locally as "Devil's Jumps." One of these has been referred to as setting in just below *Cumberland Falls* and extending downstream seven miles. Another is the *Narrows of the Rockcastle River* above Rockcastle Springs. Another is *Dick's Jumps* of the South Fork of the Cumberland at the mouth of Wild Dog Creek in McCreary County.

POT HOLES

If a stream is carrying much abrasive material in the form of hard pebbles, and rapids intervene in its course, at that point the swirling waters will excavate, with the aid of the pebbles, cavities of greater or less size in the bed and side walls. These on account of their prevailing form are called "pot holes." The best illustration of these in Kentucky are in the "Devil's Jumps" just described. The abrasive material consists of the quartz pebbles which have been set free from the conglomerate. Colloquially the pot holes are here called "devil's bean pots,'' and the trapped pebbles therein ''devil's beans'' —whirlstones (*Strudelsteine* of the Germans).

One of these devil's bean pots in the Narrows of the

88. "DEVIL'S BEAN-POT," ROCKCASTLE RIVER, PULASKI-LAUREL COUNTIES
Photograph by Richard Norwood

Rockcastle is in a detached block of conglomerate. It is as large as a good-sized cistern. A dozen people may get into it at one time.

SPRINGS AND LICKS

Big Springs.—Some of the large springs which are the exits of underground streams, have been referred to before under the treatment of *Caves*. There is one of these at the mouth of a cave on the *Cumberland* opposite *Sloans Valley,* which supplies enough water to run a mill. Another is at *Mill Springs,* Wayne County, the water of which cascading toward the Cumberland, is utilized to run a mill. There is still another, or rather a series of them, on the Green River in Hart County above Munfordville, called the *Hundred Springs.* Here great masses of calcareous tufa have accumulated.

Ebbing Spring.—Four miles east of Munfordville on the Green River is a spring which is reported to ebb and flow, twice each in twenty-four hours.

Blowing Spring.—There is a spring in Butler County near the Warren line that at certain seasons is accompanied by an outrush of air, giving to it this appropriate name.

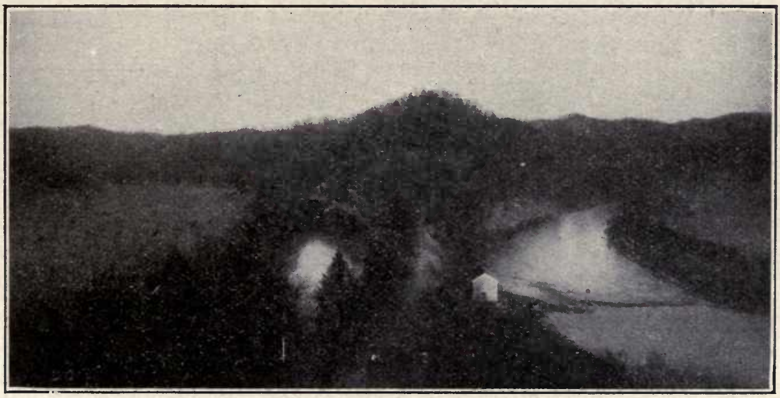
Fish Spring.—Issuing from an underground channel in Onondaga limestone at the level of Green River in Adair County is a small stream of water up into which a large number of fish are accustomed to go during the winter on a sort of hibernating trip, returning outward to the river when spring opens; hence the name given to the mouth of this channel.

Salt Springs and Licks.—Most celebrated of the salt springs of the State are *Big Bone Lick,* near the Ohio River in Boone County, and the *Upper* and *Lower Blue Licks* of the Licking in Nicholas County. Also the *Licks of Bullitt County* were important in pioneer days. These were resorted to in the early day for salt by the pioneers, Indians and the wild herbiverous animals. Great numbers of the bones of both recent and ancient extinct animals have been found where they were trodden down and covered up in the swampy soil surrounding these licks. Especially celebrated for the bones of extinct animals is *Big Bone Lick.* The first account of this Lick was given by de Longeil, a French traveler, who, accompanied by a band of Indians, camped here in 1739. He told of the great number of bones of huge animals he saw lying about. In 1751 the place was visited by the early pioneer explorer and surveyor, Christopher Gist, who brought away with him a very large mastodon's tooth.

Buffon, the great French naturalist, described the Mastodon from bones and teeth sent to him from this locality, giving to the animal a name which signified the "Elephant from the Ohio." In more recent years a great many bones, many of them of extinct animals, have been dug up at the *Lower Blue Licks* in excavations made to strike if possible the supposed diverted channel of the Blue Licks Spring, which had gone dry. All efforts to find this channel failed, so this formerly much frequented resort, with its famous hostelry, is now a thing of the past. The sudden drying up of the sources of this spring, which had been supplying salt to the soil in the vicinity since a past geological age, is a remarkable geological phenomenon. It is probable that the brine came up through a fissure which led down to the Calciferous sandrock at the base of the Ordovician. We have no explanation to offer as to why the supply was suddenly cut off.

STREAM MEANDERS

Present stream meanders, or oxbow bends, on the rivers and larger streams of the State are so common that in general there is nothing noteworthy about them. There are some cases, however, where the stream has looped so completely back on itself as to attract particular notice. Such is the elongated loop on the Licking, near its crossing by the Morgan-Magoffin County line. Another is the *"Pan-bowl"* on the North Fork of the Kentucky at Jackson. Another, or rather a series of them, may be seen on the main Kentucky, near where it is crossed by the Lee-Estill line. Still another is *Hanley's Bend* on the Kentucky at the boundary of Garrard and Jessamine Counties. This one is about seven miles



89. THE PAN-BOWL AT JACKSON, BREATHITT COUNTY
From a monograph on The Kentucky River by courtesy of the author, Miss Mary Verhoeff

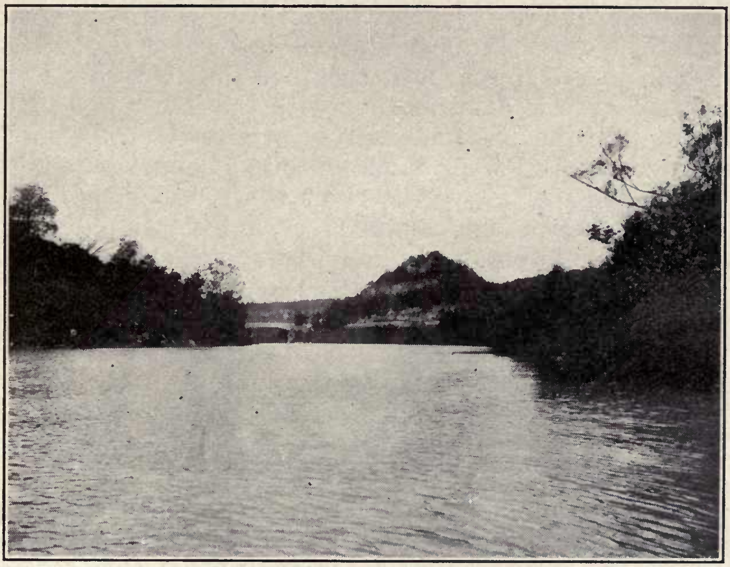
around and only a stone's throw across. It has been customary for raft men, running timber down the river, to get off at some of these narrow necks and walk across, while the raft is going around the bend. In some cases the total fall of the river in several miles has been utilized for water power by cutting a tunnel through the narrowest portion of the loop and locating a water mill at the downstream end of it. This was done at Jackson in Breathitt County and again at the *"Narrows of Pitman"* on Pitman Creek, in Green County. The Green River presents two remarkable bends in Butler County and another north of Central City in Muhlenberg County. Sometimes a series of elaborate contortions of this kind, or a wide detour made by a river, indicates the presence there of a pronounced folded rock structure that the river has found difficulty in crossing. Such is the probable explanation of the two or three such bends on the Licking at the Magoffin-Morgan line, and about an equal number on the Kentucky at the Lee-Estill line. The axis of the Caney-Paintsville Anticline crosses at the former point, and there is some support from the recent oil development in Lee County that a similar structure crosses at the latter place. The wide detour of the Kentucky in getting across the Jessamine Dome is also perhaps a case in point, though its keeping close to the line of the Kentucky River Fault for so much of its course here would rather indicate that it has been influenced in its detour by that structure.

It would appear from the study of a topographic map of the region that the Ohio from Owensboro downstream to the mouth of the Green River has been for some time steadily shifting its course northward. The Green River probably once entered the Ohio at a point where Berk City is now located, and as the Ohio shifted northward the mouth of the Green shifted westward (downstream), until it came to occupy for this distance down to its present mouth a course parallel to that of the Ohio.

At Henderson the Ohio is now engaged in developing a meander, which, when it is finally completed and the cut-off made where now a slender bayou extends across at its narrowest point, will leave Henderson on a crescentic lake five or six miles from the river.

In the extreme southwestern part of the State, the Mississippi, since the addition of the Jackson Purchase, has been engaged in developing a meander, which has resulted in its cutting south of the Tennessee line at this point, so that there is a portion of Fulton County, Kentucky (the extreme western tip of the State), to get into which by land from other parts of the county and State requires a detour down into Tennessee.

Deserted Meanders.—Some of the finest illustrations of deserted meanders are on the lower Kentucky, north of the mouth of Big Hickman Creek. The first of these is just below the mouth of the creek An isolated knob, called "Boone's Knoll," lies in the center of the old loop. It appears to have been Hickman Creek which made the valley here deserted.



90. BOONE'S KNOLL NEAR CAMP NELSON BRIDGE, KENTUCKY RIVER
The strata exposed are Highbridge. Photograph by A. M. Miller

From near Frankfort, northward, these crescentic valleys, deserted of the stream which excavated them, become more numerous. They occur both along the Kentucky and on Elkhorn Creek. Beginning three miles above Frankfort there is one of these deserted channels now occupied by the lower portion of Vaughn Creek. Another one at Frankfort forms the valley at the head of which the State Penitentiary is located. This valley opens out into the river again below the lock (No. 4). It is now occupied by a small branch through nearly its whole course. Fort Hill—an isolated eminence which overlooks Frankfort from the north—is situated in the southern portion of this loop. The deserted channel character of this valley was recognized as early as 1817, when the traveler and editor, Zadock Cramer, gave an account of it in his paper, the *Navigator*. He, however, in accordance with the catastrophic views of the time, invoked a "great convulsion of nature" to bring about the change in the course of the river.

Further down the river from Frankfort other examples of cut-off and deserted meanders may be seen. The positions of them show up well on the Lockport topographic sheet. One of these, now occupied by the lower course of Flat Creek, is near Polsgrove. Two more are at Monterey—one just above and one just below the village. The one just below is now occupied in part by Pond Creek. There is also another with the lower end opening out into the Kentucky River at Gratz. This one is higher above the river than the others enumerated. It is about 100 feet above the river at its upper end. The others are low enough for the river, at exceptionally high water stages, to enter and flow through them again.

On Elkhorn Creek below the Forks there is a succession of these deserted meanders of such pronounced amphitheater-like character as to indicate an exceptionally wide lateral sweep to the current of the stream when they were produced.

All of the foregoing give rise to exceptionally fine farming tracts.

There are doubtless a number of these on the Cumberland and other rivers of the State which have not been noted. The writer has recognized one of these at the mouth of the South Fork of the Cumberland. The town of Burnside is located in it at its lower end. He has also recently detected one on the Licking a short distance below West Liberty.

LAKES

Kentucky has entirely within its boundaries no natural body of water large enough to merit the name of lake.

Reelfoot Lake.—The northern end only of this body of water reaches into Kentucky. This lake was formed during the New Madrid Earthquake of 1811, when a considerable area of land there sank.

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PART THREE

Structural Geology

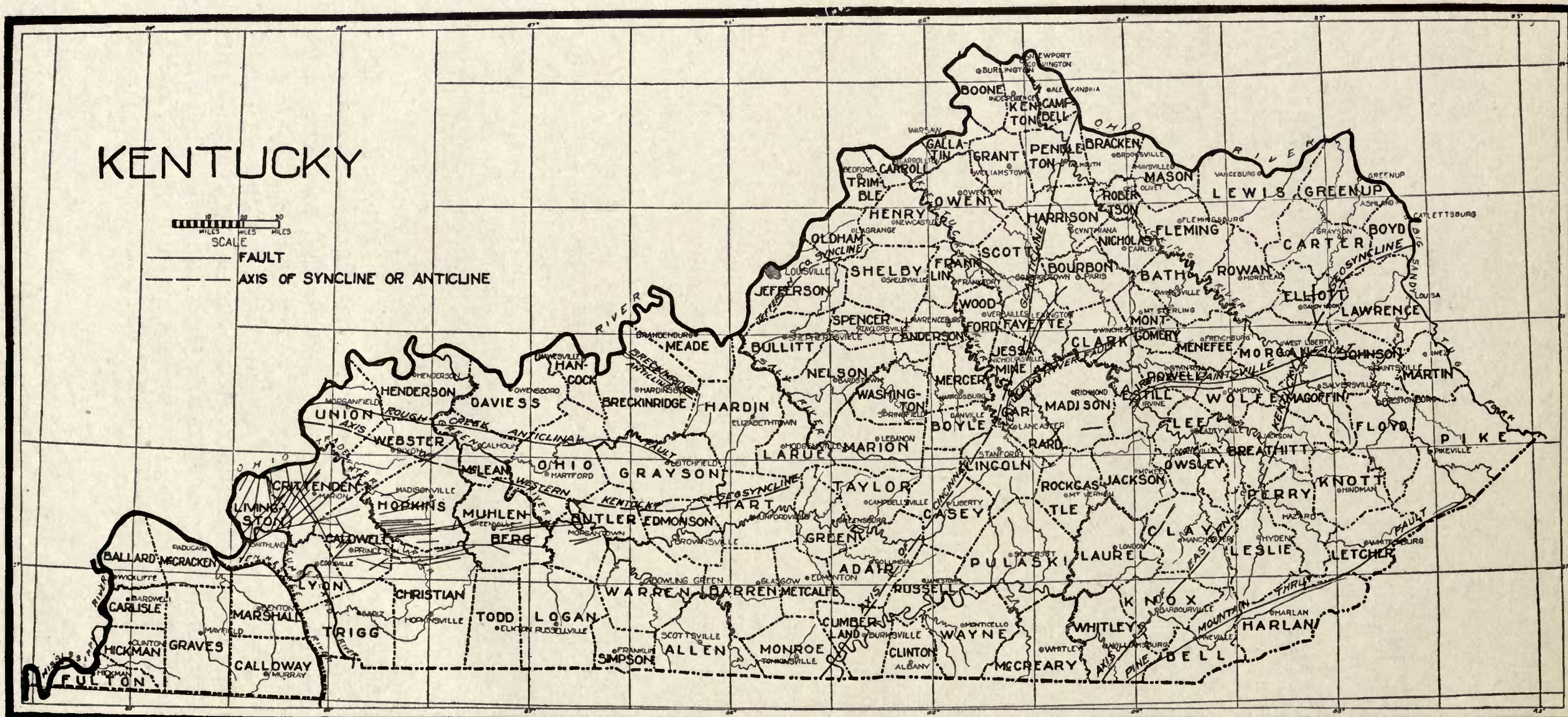
CHAPTER X

FOLDS, FAULTS, VEINS AND DIKES

THE LARGER STRUCTURES OF CENTRAL AND EASTERN KENTUCKY

THE CINCINNATI ANTICLINE.—Reference has been made on page 178 to the larger earth flexures which have controlled erosion and hence have determined areal outcrop of the formation within the State. Most central and dominating of these is the *Cincinnati Anticline* or *Arch.* Some prefer to call it the "Cincinnati Geanticline" on account of its great size. The first word in the term is due to the fact that the axis of this structure was once supposed to cross the Ohio River at Cincinnati. We now know it crosses at Point Pleasant about twenty miles above the city and in a southeasterly direction from it. Thence the axis rises to the summit of the Jessamine Dome near where this is trenched by the gorge of the Kentucky River. It then plunges southward to somewhere near the boundary between Kentucky and Tennessee. South of there it again rises into a dome—the Rutherford Dome of Tennessee. The dips east and west from the axis are very gentle near the crest of the arch, and also in all directions from the summit of the Jessamine Dome, being about ten to twelve feet per mile. Further out on the flanks the dip is steeper, being from thirty-five to seventy-five feet per mile, as, for instance, on the eastern side where the structure merges into the Eastern Kentucky Syncline. There are a number of faults in North-Central Kentucky evidently formed as the result of the bowing up of the strata in the Jessamine Dome.

Anticlines, or arches, expose strata involved in them to greater erosion and hence tend to form *inliers* (older strata surrounded by newer). Synclines or troughs protect strata from erosion and hence tend to form *outliers* (newer strata surrounded by older). It was by the relatively greater erosion of the northern portion of the Cincinnati Arch in Kentucky that the large North-Central Ordovician Inlier, constituting the Bluegrass Region, was formed; and by the relatively less erosion of the East and West Kentucky Synclines, that the Eastern and Western



91. LOCATION OF PRINCIPAL FAULTS AND AXES OF THE LARGER EARTH FLEXURES IN KENTUCKY

Kentucky Coal Fields were left as portions of what are structurally big outliers.

THE EASTERN KENTUCKY GEOSYNCLINE

(This Structure has been sufficiently described in Chapter I of Part One)

THE PINE MOUNTAIN FAULT.—Bounding the Eastern Kentucky Syncline on the southeast is the Pine Mountain Fault—a break in the strata along the northwest flank of this overturned mountain fold accompanied by a slip of considerable extent. The movement on the upper side of this break was from the southeast to the northwest along an inclined plane not many degrees from horizontal. On the under side of the inclined plane of fracture there was a movement of strata in the opposite direction. The two movements resulted in a thrust fault with a vertical throw of about 2,000 feet. Erosion has carved this overturned and faulted fold into a mountain range—the only true *mountain of elevation* in Kentucky. Along the steep western face of this mountain range, which measured above the foot is 1,500 feet in height, strata are exposed from near the top of the Ohio black shale to and inclusive of the top of the Lee conglomerate. At the western base of the range on the upthrow side of the fault, Ohio shale abuts against Pottsville measures. There is a place at the foot of Pound Gap in Letcher County where one facing the north may stand astride the fault with the left foot on Devonian shale and the right on Coal Measure shale, and have the latter geologically at least 2,000 feet higher than the former.

THE BLACK MOUNTAIN SYNCLINE.—After dipping away from the Pine Mountain Range, at first steeply and then more gently, to an axis, the strata rise to a steep upturning along the Kentucky-Virginia border, forming another syncline—the Black Mountain Syncline. This is included in the counties of Bell and Harlan. In Harlan, near the middle of this syncline, lie the Black Mountains, some of the peaks of which rise to a height of upwards of 4,000 feet.

THE SMALLER STRUCTURES OF EASTERN KENTUCKY

THE IRVINE-PAINTSVILLE ANTICLINE AND FAULT.—An illustration of lesser anticlinal structure somewhat parallel to the two structures just described, though it is rather transverse to the Eastern Coal Field, is the fold bounded on the north side of the crest by a fault which may be traced from near Irvine in Estill County to near Paintsville in Johnson County. The main fault is generally paralleled by another, or secondary fault, a little south of it. In that case the two, which are faults of the normal, or gravity type, hade (that is to say they have the slope of their fault planes) toward each other and inclose between them a *fault block*. The maximum throw of the main fault is from 150 to 200 feet. An excellent section of the fault plane of the main or primary fault is afforded by the first cut of the Lexington and Eastern Railroad found south of Glencairn Station. The hade of the fault is here nearly vertical. The anticlinal character of the fold is well shown near the village of Caney in Morgan County, where it is trenched by Caney Creek almost transversely. Near Paintsville the fold culminates in a dome—the Paintsville Dome. This anticline and fault have played an important part in accumulation of the oil and gas, which have been or are being exploited in the Irvine, Campton, Stillwater and Cannel City pools.

The Joe Lick-Combs Mountain Fault.—A smaller structure, or perhaps an offshoot from the one just described, is the fault which can be traced in Madison County from Joe Lick Knob through Combs Mountain into Estill County. It also seems to be accompanied on the south side by an anticlinal fold, which, on being traced eastward, accounts for the Station Camp Oil Pool at the mouth of Middle Fork.

The Warfield Anticline.—As an illustration of a fold which has resulted in the trapping under its crest of a large amount of gas, may be mentioned the one which crosses the Tug Fork from West Virginia into Kentucky opposite the village of Warfield in Martin County, and is generally known, therefore, as the *Warfield Anticline*.

It is from wells sunk on this structure that the natural gas comes which is piped to Lexington, Louisville and other North-Central Kentucky and Ohio River towns.

The Newcomb Creek Anticline and Fault.—There is a north and south anticlinal structure in the eastern part of Elliott County which is somewhat parallel with Newcomb Creek, and hence is here designated the *Newcomb Creek Anticline*. It is transected near the middle of its course by a fault. This fault is in line with the dikes of Elliott County to the east, and is no doubt a part of the same disturbance which resulted in the intrusion of these igneous rocks.

The Newcomb Creek Anticline appears to be an offshoot from the Paintsville Dome.

THE BURNING SPRINGS ANTICLINE OF CLAY COUNTY.—In Clay County west of Manchester is an anticline which culminates in a dome near Burning Springs, a village which received its name on account of several springs in the locality from which have arisen since pioneer days gaseous emanations susceptible of ignition. In more recent years wells were drilled in that locality which in the "Big Injun" sand struck flows of gas ample for the supply of the settlement.

The trend of the structure is northeast and southwest roughly parallel with Pine Mountain.

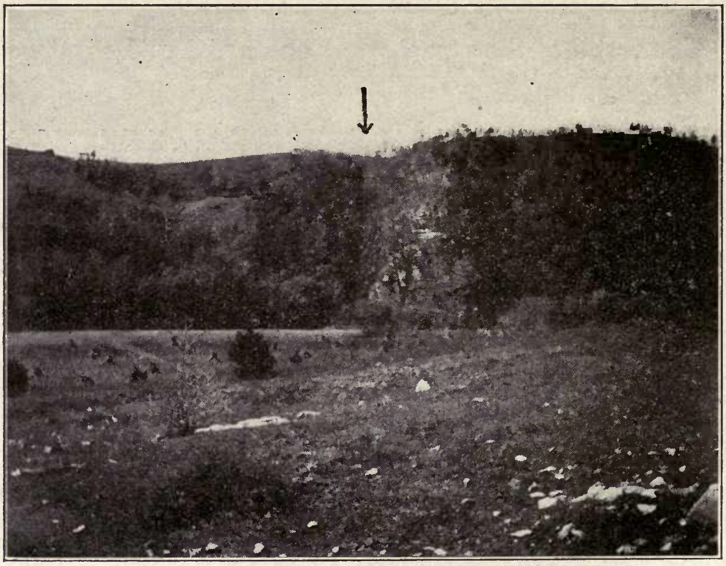
THE FAULTS OF NORTH-CENTRAL KENTUCKY

CHARACTERISTICS.—Characteristic of the faults of North-Central Kentucky is the great width of the *drag zone;* that is, of the belt on the downthrow side in which the edges of the strata turn up. Another common feature is the occurrence of the faults in pairs, the two differing in the amount of their throw, in the direction of their hade, and in the time of their formation. The one first formed, and with the greatest amount of throw, may be designated the *primary fault.* The other may be called the *secondary fault.* These two faults, constituting a pair, hade toward each other, thus inclosing a *fault block* or fault strip.

These fault strips tend to form outliers; as, for instance, in the case of the Glencairn Fault in the stretch between Estill Furnace and Glencairn; and in the case of the Kentucky River Fault in the valley of Big Hickman Creek.

AGE.—The fact that wherever these faults can be traced eastward into the Eastern Kentucky Coal Field, they are found to involve coal-bearing strata, proves that the faulting was post-Pennsylvanian. The relation of the Kentucky River Fault to the old river meanders with their late Tertiary gravels on the shoulders of their gorges, showing that the fault was formed before the gorges were cut and the meanders made, proves that this and presumably all the faulting of North-Central Kentucky is pre-late Tertiary. It is probable that the faulting was coincident with the Appalachian revolution which produced the folded and faulted structure of the Appalachian Mountains at the close of Pennsylvanian time.

THE KENTUCKY RIVER FAULT ZONE.—The most pronounced belt of rock disturbance in North-Central Kentucky is the Kentucky River Fault Zone, which extends from near Burdett's Knob in Garrard County probably as far as Ragland in the southern part of Bath County. The main structure in this is the Kentucky River Fault proper, which extends without a break in surface continuity from the southern end of the strip to Ruckersville



92. KENTUCKY RIVER FAULT NEAR CLAYS FERRY
View taken looking south from the Fayette County side of the river. On the right is Highbridge surmounted by Lexington limestone; on the left (downthrow) side is Lexington and Cynthiana limestone surmounted by Eden shale and sandstone. Photograph by A. M. Miller.

in Clark County, exhibiting its maximum throw of 350 feet somewhat midway in its course. It is double for a portion of its course, being divided into a primary and a secondary break. The southwest diversion of the Kentucky River from Boonesboro to Camp Nelson is evidently related in some way to this fault. In this stretch the river in its meanderings crosses the fault nine times, exposing in its gorge, when on the northwest (relative upthrow) side, the hard massive limestones of the Highbridge series, and when on its southeast (downthrow) side, the softer limestones and shales of the Trenton and Middle Cincinnatian series. The throw, where greatest, displaces Lexington (Trenton) on Highbridge in the river gorge, and Middle Cincinnatian on Lexington in the uplands. Toward the two extremities, where it reaches the border of the Bluegrass, it displaces higher beds at the surface.

From where the main Kentucky River Fault begins to die out as a surface feature toward the northeast, it is offset and continued by the Jackson Ferry-Camargo Fault, which may be traced from the former point on the Kentucky River in Clark County to the latter place in Montgomery County. This fault crosses the Irvine-Winchester Branch of the Louisville and Nashville Railroad at Agawam station, and the Lexington and Eastern Branch between Lexington and Eastern Junction and Indian Fields. The total length of the Kentucky River Fault, with its continuation in the Jackson Ferry-Camargo Fault, is about fifty miles.

From Camargo it is thought that the structure still continues as a monocline as far as Ragland, where it is responsible for the accumulation of oil in the Ragland Pool.

At the other extremity it contributes to the formation of Burdett's Knob—the altitude of which is 1,090 feet. This knob preserves on its top a small outlier of Waverly, whose situation so high up on the Jessamine Dome indicates that the formations up to and inclusive of the Waverly at one time extended over the Bluegrass.

THE WEST HICKMAN FAULT STRIP.—Another one of these fault blocks or strips is the *West Hickman.* This extends for about twenty-five miles from Union Mills in Jessamine County through Fayette nearly to Paris in Bourbon County. It is about one mile across at its widest point, which is just east of Lexington. In the three counties traversed, it has preserved Eden shale and sandstone sandwiched between Lexington limestone, and hence it gives a strip of poor land stretching through a region of good land. This sharp soil contrast early attracted attention and invited explanation. The common one given and accepted was that this strip was an old *buffalo trail*—the tightness with consequent non-productiveness of the soil being attributed to its trampling down by migrating herds of buffalo. The main reservoir from which Lexington derives her water supply lies in this West Hickman Fault Strip. The stiff, impervious quality of the soil, which renders it inferior for agricultural purposes, has admirably adapted it to hold water within a storage basin. This strip was originally covered with a growth of beech and sugar-maple, and today it is the only place in the uplands of Fayette County where beech trees may yet be found.

THE SWITZER FAULT STRIP.—Still another such strip, bounded by two faults, is the *Switzer*. It stretches from near Great Crossings in Scott County, passing a little south of Stamping Ground in the same, to near Camp Pleasant in Franklin, the fault which bounds it on the north being the primary one. This strip has resulted in the formation of an outlier of Eden with a patch of Maysville on it near its western end. In view of what we have seen was a popular attempt at explanation of the relative poverty of the soil in the West Hickman Fault Strip of Fayette County, the names denoting buffalo activities in such close relations with the Switzer Fault strip are significant. They raise the question in the mind of a geologist, always somewhat of an iconoclast in the matter of traditional beliefs, whether buffalo were actually wont to cross at Great Crossings on North Elkhorn and stamp at Stamping Ground, or whether these names simply record the naive attempt of the early settlers to explain a natural phenomenon, for the true explanation of which they lacked the necessary equipment in the way of geological knowledge.

THE JEPTHA KNOBS FAULTED AREA.—The Jeptha Knobs in Shelby County show faults at their base in several places, and there is every indication that this outlier, crowned with Niagara on its summits, owes its protection from erosion to sinking of the area on which it is situated.

MINERAL VEINS OF NORTH-CENTRAL KENTUCKY.—Associated with the faults of the Bluegrass Region are fissures which have been filled with mineral deposits, thus constituting mineral veins. The material in these veins are mostly barite and calcite. In some cases they contain fluorite. These veins are described under the head of fluorspar, heavyspar and calcspar in Chapter XV.

FOLDING IN SOUTHERN KENTUCKY

That portion of Southern Kentucky lying between the Queen and Crescent and the main line of the Louisville and Nashville Railroad between Louisville and Nashville and south of Muldraugh's Hill is characterized by numerous slight folds unaccompanied by faulting. The presence of these folds (in some cases domes) is indicated frequently by *inliers.*

The Taylor County Ordovician-Devonian Inlier.—There is on upper Robinson Creek in Taylor County an inlier of Upper Ordovician overlaid by Devonian, which indicates an arching or doming of the strata in that region.

The Adair County Inliers.—Two of these are Ohio shale inliers, one near Knifley in the northern part and the other near Gradyville in the southern part of the county. Another on Damron Creek is an inlier of Upper Ordovician. All three indicate doming or arching of the strata in these localities.

The Pulaski County Fishing Creek Inlier.—On Fishing Creek west of Somerset there is an inlier of Richmond, surrounded by Clinton and that by Onondaga limestone and Ohio shale, which indicates an uplift of strata in that region.

The Sunnybrook Anticline of Wayne County.—At Sunnybrook in Wayne County there is a small patch of Waverly exposed on the crest of an anticline which in 1901 proved to have oil trapped in it under considerable pressure.

The Folds of the Cumberland River Below Burnside.—In several trips the writer has made along this river below Burnside, he has noted where a number of gentle folds have been sectioned by the stream. These are as follows:

At Waitsboro Shoals. Here a strong dip upstream brings Ohio shale to stream level.

At mouth of Forbush Creek. A dip here at the rate of fourteen feet in 1,000 brings up and exposes argillaceous beds of the Richmond.

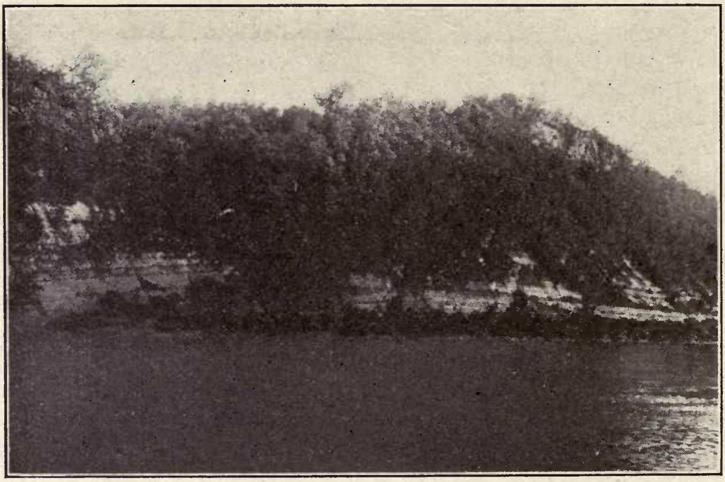
At mouth of Cub Creek dipping layers of Clinton are exposed, indicating the crossing of an anticline.

At big bend of the River below mouth of Thomas Creek. An anticline with a gentle dip on each side of the axis crosses the river at this point.

One-half mile below Harmon Creek. Here, about thirty-five miles below Burnside, the Ohio shale sinks from a height of sixty feet above the river at the crest of an anticline to river level in the trough of the syncline at the mouth of Grassy Creek.

Just below Belk Island. The exposure here of considerable thickness of Upper Cincinnatian rocks indicates the crossing of an anticline at this point.

At mouth of Crocus Creek. A very marked anticline crosses the river here. It has a north and south trend, and exposes about 100 feet of Upper Cincinnatian below the Ohio shale.



93. ANTICLINE ON THE CUMBERLAND RIVER
View near Scotts Ferry, a short distance above Burksville, Cumberland County. Strata involved are Richmond. Ohio and Waverly.
Photograph by A. M. Miller

At Scott's Ferry. A fine anticline shows here in the cliff just below the ferry. It exposes 145 feet of Upper Cincinnatian rocks below the Ohio shale.

Some of the foregoing anticlines have yielded oil to the prospector in former periods of drilling along this river. For instance, the Crocus Creek well, which produced abundantly in the sixties of the last century, was on the crest of the anticline which crosses the river at the mouth of this creek.

The Folds of Allen County.—There is probably some form of structure which accounts for the various oil pools of Allen County, but this relation between production and structure has not been made out in every instance.

The oil pools in this county known to date are the North Petroleum, Rodemer, Wildwood, Hinton, Miller, Fisher and Gainsville. It is known that the strata in the North Petroleum and the Rodemer pools are arched upward into well defined domes. It is thought that the Hinton and Miller pools are synclinal. As instances of anticlines in the county as yet undeveloped, or unproven as regards their relation to oil, may be mentioned, the one which crosses Rough Creek a mile and a quarter above the Miller Pool, and the one west and northwest of Adolphus. All the foregoing pools and structures, except the Gainsville Pool, are south of Scottsville.

FOLDING AND FAULTING IN WESTERN KENTUCKY

THE WESTERN KENTUCKY GEOSYNCLINE

(This Structure has been sufficiently described in Chapter I, Part One)

The Rough Creek Anticlinal Fold and Fault.—The most prominent structure in Western Kentucky, next to the geosyncline of the Western Coal Field itself, is the Rough Creek Anticline or Fault. This sharp upfolding of the strata accompanied by displacement, which in the main is due to thrust, passes almost through the middle of the Western Coal Field, extending from Shawneetown on the Ohio River as far as Leitchfield, Grayson County. In the western part of its course it passes through the town of Sebree. This disturbance was first noted by David Owen under the name "Shawneetown fault," in his first report for the Kentucky Geological Survey issued in 1856. He had at that time traced it by Bald Hill as far as the Henderson-Union County line. Professor C. J. Norwood later recognized the same disturbance on Barnett's Creek and near Iron Mountain on Rough Creek, and described it in 1874 as in the main an anticlinal or monoclinal fold. He named it the *Rough Creek Anticline.*

Subsequent work on the structure by James Gardner, Wallace Lee, and Professor L. C. Glenn has demonstrated that in the Shawneetown Quadrangle and neighboring Sebree it forms the northern boundary of an asymmetrical sycline with a maximum deformation of 2,200 feet, and that the faulting itself is quite complex. In some places it assumes the character of a thrust, and in others that of a normal fault. Throws, varying from 1,600 to 2,200 feet, have been noted, with dips in the strata toward the axis of the syncline of from four to six degrees. In some cases in the vicinity of the fault the dip is from fifteen to sixty degrees, in the general direction south, twenty to thirty degrees west. In the northern part of the Hartford Quadrangle, where described by Mr. Gardner, it partakes of the nature of a dip fault, as the effect on the outcrop of the Elm Lick coal is to offset it nine miles.

The Grayson, Edmonson, Butler and Warren County Folds and Faults.—Near *Leitchfield* in Grayson County is an anticline which is a continuance of the Rough Creek Anticlinal disturbance. It has been prospected some for oil without much success.

According to J. Owen Bryant there is a syncline in Grayson County with its axis between Pigeon and Dismal Creeks. This would place it in line with the axis of the Western Coal Measure Syncline itself. Mr. Bryant also mentions five other structures in the Nolin River district—three folds and two faults. The axes of these folds, which are anticlinal, are located as crossing the Nolin River near Snap, Beaver Dam Creek and Green River, respectively. The more northernly of the two faults noted is in Grayson County. It has a strike of north 84 degrees west. The other follows the course of Longfall Creek and has a stratigraphic throw at one place of seventy feet.

Mr. Iley Browning was unable to verify the existence of this Longfall Creek Fault, but he located another with a throw of 100 feet as crossing Green River at the Asphalt Mines and extending nearly to Brownsville. Mr. Browning also locates an anticline with a curving axis extending from mouth of Bullock Branch on Green River to Bylew Creek near mouth of Pine.

An Anticlinal structure has been traced for some distance in the Gasper River drainage, and a well put down on it made quite a good showing of oil.

The Hawesville Fault.—Near Hawesville in Hancock County, on the northeast border of the Western Coal Field, a fault has been noted by Mr. P. N. Moore.

Faulting in the Counties of Butler, Muhlenberg, Hopkins, Webster, Christian and Caldwell.—Extensive faulting of the normal type prevails along the southern margin of the Western Coal Field and the region adjacent outside of the Coal Field. Those in the counties of Butler, Muhlenberg, Hopkins and the northern part of Christian and Caldwell have been described by Mr. A. F. Crider in his reports on the geology of the Little Muddy, Dunmore, Drakesboro, Nortonville, Earlington and Dawson Springs Quadrangles (1913). Those further west have been referred to by Professor L. C. Glenn in his Report of the Tradewater Region, 1912. These faults tend to occur in zones one and one-half to two miles wide, having a general trend north, 70 to 80 degrees east, and extending in some instances as far as twenty to thirty miles on the surface. The mechanics of the faulting process and the surface effects are similar here to those in the Bluegrass. There are fault blocks bounded by primary and secondary faults, and these fault blocks have protected from erosion the included coal-bearing strata, here carrying seams Nos. 9 to 11, the most important of Western Kentucky. But for this faulting these seams would long since have been carried away by erosion, and this region would not be, as it now is, the most important coal mining district of Western Kentucky. This consideration should reconcile the coal operator to the provoking difficulties in mining presented by the structure.

The most important of these faults in Butler County is the *Hickory Stand School Fault* with a maximum downthrow on the north side of 160 feet, and the *Rochester Fault,* traceable upon the surface for twelve to thirteen miles, and having a maximum throw on the north of about 300 feet.

The most pronounced faulting in Muhlenberg County is in the vicinity of Drakesboro, where three approximately parallel faults—*Rocky Ford, North Browder* and *South Browder*—are intersected by the *Peanut (cross) Fault.* The Rocky Ford has a maximum downthrow on the south side of 120 feet, and North Browder a downthrow on the south of 105 feet. The South Browder has a maximum downthrow of 356 feet.

South of the foregoing, and extending over into Christian County, is the *Sharber's Store Fault,* having a surface extent of about twenty-seven miles, and a maximum throw of 350 feet on its north side. Branching off from this fault are the *McCleland School* and *Twin Tunnel Faults.* In the same zone as the Sharber's Store Fault in northern Christian County are the *Clardy* and *Apex-Adams* and the *Crofton.* The latter has its downthrow (maximum 467 feet) on the north. Further west, in that portion of the county in the Dawson Springs Quadrangle, are the *Adams School House* and *Whitehorn Faults.*

Common to both Caldwell and Christian Counties in the north are *Haile, Ruth* and *Claxton Faults.* The Haile has its downthrow (maximum 250 feet) on the north. Confined to Caldwell alone is the *Mt. Hebron Fault,* downthrow (maximum 250 feet) on the north.

North Hopkins is traversed by the *Webster-Hopkins-McLean Syncline,* an east and west structure, the axis of which crosses the Louisville and Nashville Railroad between Slaughtersville and Hanson. South of this syncline the county is much cut up by faults. In the southwestern portion of the Earlington Quadrangle is the *Stony Point Church Fault,* and in the southeastern portion is the *Richland Fault.* The latter has its downthrow (maximum 350 feet) on the north. In the Dawson Springs Quadrangle—northern part, and still in the same county—is a zone of five east-west faults, which from north to south with their maximum throws are as follows:

Bishop, downthrow (276 feet) on the south.
Crabtree-Dozier, downthrow (70 feet) on the north.
St. Charles, downthrow (175 feet) on the south.
Dawson Springs, downthrow on the south.
Norton School, downthrow (250 feet) on the north.

The foregoing zone extends eastward into Muhlenberg County, north of the Rocky Ford and Browder Fault Zone. Still further south in Hopkins County are the *Martins Chapel, Thomas Store* and *Oak Hill Faults.* The last two have their downthrows on the south side. The Thomas Store has a maximum throw of 119 and Oak Hill one of 210 feet.

Traces of faulting may be seen still further west and northwest extending into Webster County as far as the town of Clay, but, though referred to by Professor Glenn in his report covering this region, they have not been named and mapped in detail.

THE FAULTS AND FRACTURES OF CRITTENDEN AND LIVINGSTON COUNTIES

Crittenden and Livingston Counties are much cut up by fractures and faults which fall into two systems: one with strikes northeast and southwest (about north, 30 to 40 degrees east), and the other with strikes northwest and southeast (about north, 10 degrees west). In most cases fracturing has been accompanied by down-slipping of one of the walls along the fracture plane. Whether followed by slipping or not, these fracture planes afforded easy passageways for mineralizing solutions, and in at least two instances for upward injection of highly basic molten magma. In the former cases there were formed fluorspar veins carrying varying amounts of lead and zinc ore; in the latter case peridotite dikes.

These faults, veins and dikes have been mapped in Crittenden and Caldwell Counties by E. O. Ulrich, Julius Fohs and others. Wallace Lee has described for the northern part of the county a fault block with a drop of 200 feet. It displaces Coal Measures and has resulted in the offsetting of the outcrop of the Bell coal one and one-half miles.

There are other places in Crittenden County, and even as remote from the Western Coal Field as Livingston County, where Coal Measure strata are involved in the faulting. These give rise to outliers of the basal conglomerate, which show how much more widely extended to the southwest the Coal Measure strata were at one time than they are now. The most remote of these from the present margain of the Coal Field is the small patch of massive basal Coal Measure sandstone near Smithland, Livingston County.

Belonging to the northeast-southwest systems of faults and veins in Crittenden County, beginning in the northwest, are the following: Hurricane Island Fault, Lola Fault, Larue Fault (with its Sheridan dike branch), Columbia Vein and Fault (with its Memphis and Klondike vein branches), Sinkhole Vein, Marion Vein, Hodge Vein and Yandell Vein.

To the northwest-southeast system belong the Deer Creek Fault (strike north, 10 degrees west), Tolu Fault, Hurricane Fault (strike north, 35 to 45 degrees west), Miller Vein, and the Blue and Nunn Dike.

THE PADUCAH FAULT.—There is an indication that this faulting, which probably took place, or at least began, shortly after the close of the Pennsylvanian, extended into the Jackson Purchase and there involved Mississippian strata. Evidence of this, as noted by R. H. Loughridge in his report on the Jackson Purchase in 1888, was disclosed by a well drilled for gas at Paducah. In this well a stratum of Chester limestone, which outcrops near drainage level on the Illinois side of the Ohio River opposite Paducah, was struck at a level 1,350 feet lower. This shows the presence of a fault with a throw of 1,350 feet marking here the border of the Mississippi Embayment, and suggests that the subsidence, which rendered possible the accumulation of such thick unconsolidated Cretaceous, Tertiary and later sediments in this region, was in the nature of down faulting of the embayment side of the area.

DIKES

THE ELLIOTT COUNTY PERIDOTITE DIKES.—Under the head of *Faults* reference has already been made to these intrusions of igneous rock. So unexpected was the occurrence of igneous intrusion in the Ohio drainage that the first announcement by Professor Crandall of the finding of such in Elliott County was received by other geologists with incredulity. A subsequent examination of the locality by J. S. Diller, of the United States Geological Survey (account published in American Journal of Science, August, 1886) fully confirmed the discovery. Professor Crandall's account, with a reprint of Mr. Diller's, appeared in the report on Elliott County by Crandall, published by the State Geological Survey in 1886.

The dike rock is a highly basic igneous variety known as *peridotite.* It is a generally much brecciated; that is, it contains as inclusions angular fragments of different stratified rocks torn off from the walls of the fissure through which the molten magma broke in ascending to or towards the surface. It contains as conspicuous original minerals, ilmenite (a titanium-iron oxide) and pyrope (a magnesia garnet). From its composition so similar to the peridotite (kimberlite) of South Africa, which is there the original matrix of the diamond, expectations were raised that diamonds might be found in this rock in Elliott County. However, none have been found, though diligent search for them has been made.

The peridotite of this county is exposed in four separate small areas. Three of these are in the drainage of Isom Creek, and one is in the drainage of Creech's Creek—both tributary to Little Fork of Little Sandy River in the eastern portion of the county. They come within the area of the Kenova Quadrangle, and were accurately mapped by W. C. Phalen in his report on that quadrangle for the United States Geological Survey.

THE CRITTENDEN COUNTY MICA-PERIDOTITE DIKES.—The dikes of Crittenden County are composed of a variety of basic igneous rock known as *mica-peridotite.* These dikes form very limited areas of outcrop. Two fissures filled with this rock are known to occur in the county. This peridotite readily disintegrates under the influence of weathering as does also the Elliott County variety. It breaks down into a peculiar mealy substance, which forms the surface capping to the dikes. It has also been found altered to a serpentine. The Crittenden County peridotite more closely resembles the Arkansas peridotite than does that of Elliott County, and as diamonds are known to occur in this Arkansas peridotite the dikes of Crittenden County invite careful investigation in the hope of finding diamonds in them or in the washings from them.

CHAPTER XI

DISCONFORMITIES

The discordances in the stratigraphic succession of rocks in Kentucky all come under the head of *disconformity,* which may be defined as a break in the vertical succession of horizontal strata which has been due to a pause in deposition—the attitude of the strata on both sides of the plane marking the break being the same.

The Highbridge-Lexington (Intra-Ordovician) Disconformity.—All natural outcrops in Kentucky show that the demarkation between the top of the Tyrone (upper member of Highbridge) and base of the Curdsville (lower member of Lexington) is very sharp. [See plate 6.] Well records furnish the same evidence. There is never any gradual lithological transition, though fragments of Tyrone are frequently found intermingled with the lowest Curdsville, in some cases pronounced enough to constitute a *contact breccia.* This contrast between the white compact ''Birdseye'' limestone of the Tyrone and the grayish crystalline limestone of the Curdsville is such a conspicuous feature of every outcrop of this horizon that it cannot fail to attract attention. The paleontological contrast is also as sharp as the lithological. The fossils of the overlying Curdsville are numerous and quite different from those of the underlying Tyrone, which are few. The contact between the two formations constitutes in almost every instance a nearly perfect plane, and it is also almost always a very perfectly cemented contact. The strata tend to part more readily above or below this contact than along it.

Some evidence that the sea in which the Tyrone was being deposited was getting shallow toward the close of Tyrone time is afforded by the presence of ripple marks and sun cracks in the upper layers of this formation. These facts, taken in conjunction with the contact breccia above referred to, would seem to indicate that an erosion period intervened between Highbridge and Lexington time in Kentucky, and that this erosion was in all probability subaerial.

The Champlainian-Cincinnatian (Intra-Ordovician) Disconformity.—A disconformity at the top of the Champlainian is evidenced by a thinning of the Perryville (top member of the formation) as this is traced northward along the western flank of the Cincinnati Arch, and also by its almost entire absence from the section on the east flank of the arch. The lithological similarity to the Tyrone of a portion of the Perryville would seem to indicate a recurrence of conditions in the sea similar to what prevailed at the close of Highbridge time. Rock from the Salvisa bed of the Perryville can scarcely be distinguished lithologically from the "birdseye" limestone of the Tyrone, and the same is true in regard to rock from these two horizons in the Nashville region of Tennessee.

Where the Perryville is absent the Cynthiana member of the Cincinnatian rests directly upon the Woodburn member of the Lexington. Here then is evidence of an erosion period—probably subaerial—intervening between the Champlainian and Cincinnatian in this section of the United States.

Cynthiana-Eden (Intra-Ordovician) Disconformity.—Evidence of at least a slight disconformity exists here, in the wavy layered basal limestones of the Eden, showing shallow water deposition and the presence in the Ohio River exposures at this horizon of the feather edge of the Utica in the Fulton bed five to ten feet thick. Further south this bed is wanting, indicating a hiatus between the Cynthiana and Eden in Kentucky which in regions to the north is represented by the Utica in whole or in part.

Maysville-Richmond (Intra-Ordovician) Disconformity.—A slight disconformity between the Auburn bed of the Maysville and the Arnheim bed of the Richmond has been detected in the western portion of the Bluegrass.

Richmond-Clinton (Ordovician-Silurian) Disconformity.—Evidence of shallow water and subaerial conditions, both during the closing (Saluda) stage of the Richmond and the whole of the Clinton, is afforded for the former by the ripple-marked and sun-cracked fine-grained sandstones and argillaceous limestones of the Cumberland River region and the coral reefs outcropping from Marion into Oldham County; and for the latter by the cross-bedded, granular, and in some places, wavy-bedded limestones showing current action. [See plate 26.]

Waldron-Louisville (Intra-Silurian) Disconformity.—Evidence of a slight disconformity between the

Waldron shale and the Louisville limestone has been noted by Charles Butts in Jefferson County.

NIAGARA-ONONDAGA (SILURIAN-DEVONIAN) DISCONFORMITY.—The Silurian-Devonian Disconformity is a very pronounced one in Kentucky, all the uppermost Silurian (Cayugan) and lowermost Devonian (Helderbergian and Oriskanian) being absent. Yet so conformable in dip are the beds above and below the plane of disconformity, represented in quarry exposure sections by a perfectly horizontal line like that of any other bedding plane, that to the eye there is no suggestion here of the great stratigraphic hiatus—the equivalent, according to Professor Charles Schuchert, "of the last third of Silurian and the first third of Devonian time." [See plates 36 and 94.]

94. COLUMBUS LIMESTONE RESTING DISCONFORMABLY ON RICHMOND
The Columbus is not over two feet thick. Near Merrimac, Taylor County. Photograph by A. M. Miller

It is in connection with this and several succeeding discordances that we have the first undoubted evidence of the existence of the Cincinnati Anticline. Professor August Foerste has shown that the different members of the Niagaran series, where overlaid in Kentucky and Tennessee by Devonian (Onondaga limestone or Ohio black shale), drop out in descending order as the axis of the Arch is approached. In other words, the Devonian was deposited upon gently inclined edges exposed on a truncated arch, making the relation of the two sets of strata therefore one of *unconformity* rather than *disconformity*. Professor Foerste concludes from this evidence that the Cincinnati Arch had been elevated and eroded after the deposition of the Louisville (Silurian) and before the deposition of the Onondaga (Devonian) limestone. Most of the evidence he presents, however, would seem to show that the real truncation took place later than this—between the deposition of the Onondaga and the Ohio shale.

Hamilton-Genesee (Intra-Devonian) Disconformity. —Though not representing so great an interval of time as the disconformity just described, the Hamilton-Genesee disconformity is more sharply defined stratigraphically. This is because the contact being between a limestone and a firm shale (the latter black and bituminous) the contrast is obvious.

This is the discordance of which Professor Foerste cites so many instances in the Kentucky-Tennessee region in support of the view that the Cincinnati Anticline had already been "considerably developed before the deposition of the so-called Corniferous limestone and of the Black shale." The belt in Southern Kentucky along the crest of the Cincinnati Anticline, where the Silurian is commonly absent, is about forty miles wide. Along this belt the Ohio black shale nearly everywhere rests directly upon the Ordovician (Richmond or Maysville beds). Within this belt there are many localities where this phenomenon may be observed, for instance, in the upper Salt River drainage of Marion and Boyle Counties, the upper Dix and Green River drainage of Lincoln and Casey Counties and in Russell, Cumberland and Monroe Counties along the Cumberland River south of the mouth of Cub Creek. Generally along the plane of contact in this region there are a few inches of sand or clay, often phosphatic, intervening between the Ordovician limestone and the Devonian shale. Sometimes, however, the shale rests directly on the limestone, and, where the latter is fossiliferous, may have on its under side impression of Ordovician fossils.

The most productive oil horizon of the State is that just below the Ohio black shale. In this situation the oil is generally accredited to the Onondaga, but on account of the discordance here, it may in some cases be in some member of the Niagara, or even in the Ordovician, where its accumulation may be consequent upon pre-Devonian warping of the beds. Such structure would not be registered upon the surface, and therefore the presence of the oil below could not be anticipated by the application of the usual methods known to the oil geologist for working out structure.

OHIO-SUNBURY (DEVONIAN-MISSISSIPPIAN) DISCONFORMITY.—Professors Morse and Foerste have shown that the Bedford-Berea formations, on being traced southward along their outcrop from Ohio into Kentucky, thin out, bringing the two black shales—Ohio and Sunbury—closer together, until south of Indian Fields in Clark County they unite into one stratigraphic unit, separable only on the basis of faunal differences. [See plate 45.] Further away from outcrop under cover—down toward the trough of the Eastern Kentucky Syncline—deep oil and gas well drilling shows that this rapid thinning of the Bedford-Berea interval does not take place. It is evident that the Ohio-Sunbury disconformity is due to lack of deposition rather than to erosion, and it points to the influence on deposition of the existence of the Cincinnati Arch.

SUNBURY-CUYAHOGA (INTRA-MISSISSIPPIAN) DISCONFORMITY.—Both before and after they have united in one lithologic unit the Ohio and Sunbury shales thin southward along the line of their outcrop, showing a diminution from an aggregate of 250 feet where they are separate on the flank of the Cincinnati Arch at Vanceburg, to forty feet where they are united on the axis of the Arch at Junction City. Southward from this point, along the axis, the thinning continues, till, where the structure passes out of the State into Tennessee along the Cumberland River, the combined thickness is only about twenty-five feet. Further south, in the Cumberland River region of Tennessee, it diminishes to fourteen feet, to four feet, and finally in places disappears entirely, thus allowing the Waverly (in a region where the Silurian and the remainder of the Devonian are also absent) to rest directly on the Ordovician. Here then is additional evidence of the influence of the Cincinnati Arch in reducing sedimentation.

WAVERLY-ST.LOUIS (INTRA-MISSISSIPPIAN) DISCONFORMITY.—Evidence of a Waverly-St. Louis disconformity is best seen in the outcrop along the western border of the Eastern Coal Field from Carter to Rockcastle County. It is the most sharply defined to the eye of any rock discordance in the State. Unlike that of the previous stratigraphic breaks described, the section of the contact surface of the separated formations is a very undulating line. The two formations are also strongly contrasted in color and other lithological characteristics. From Carter to Jackson County the top of the Waverly is an impure yellowish limestone which probably represents a portion of the Warsaw. On this surface, plainly made undulatory by erosion, the light colored, compact, cherty

95. ST. LOUIS LIMESTONE RESTING DISCONFORMABLY ON UPPER WAVERLY (KEOKUK) YELLOW LIMESTONE
Mouth of a cave, Estill County. Photograph by A. M. Miller

limestone of the St. Louis was laid down. South and westward from Rockcastle County the Warsaw thickens, but everywhere at the top there is evidence of a stratigraphic break between it and the St. Louis. The evidence points to the hiatus between the Waverly and St. Louis, being greater toward the northeast than toward the southwest. [See plates 47 and 95.]

St. Louis-Ste. Genevieve (Intra-Mississippian) Disconformity.—Westward from Kentucky an evident disconformity between the St. Louis and Ste. Genevieve has been noted, but in Kentucky, though a stratigraphic break probably exists (the change from compact to oolitic textured limestone is an indication of this), it is difficult to detect this by the eye.

Chester (Intra-Mississippian) Disconformities.—Since any protean formation consisting of an alternation of limestones, sandstones and shales must exhibit as many disconformities as there are changes in the strata, numerous slight disconformities are found in the Chester. They are hardly important enough, however, to be described in detail.

Mississippian-Pennsylvanian Disconformity.—The Mississippian-Pennsylvanian disconformity is the most pronounced in the State. Up to the close of the Mississippian marine conditions had prevailed in this portion of North America now included in the Mississippi basin.

96. PENNSYLVANIAN-MISSISSIPPIAN DISCONFORMITY
The head of the hammer is at the plane of contact where Pottsville conglom erate rests on a two-foot layer of impure Pennington (Chester) limestone. Blairs Mill, Morgan County,
Photograph by A. M. Miller

The lithologic character of the deposits with their included fossils bear testimony to this. To these undoubted marine strata now succeed deposits which are largely of fresh water origin. Limestones become rare; and there are abundant sandstones and shales with included plant impressions and plant-remain beds (coal seams). In Western Kentucky there is some indication in the interbedding of marine limestones with thin coal seams and plant-remain-carrying sandstones and shales of the upper Chester, that a transition from marine to terrestrial conditions had begun; but in the main the stratigraphic succession from marine Mississippian to terrestrial Pennsylvanian is abrupt. There is always an evidence of an erosional disconformity between the two formations.

Correlated with this abrupt stratigraphic break in passing northeastward along the Mississippian-Pennsylvanian border of the Eastern Coal Field there is a thinning in the upper Mississippian series, here mostly limestones, and a more frequent absence of the upper members. Also the lower Pennsylvanian series, prevailingly conglomeritic, thin in the same direction. This has been interpreted as indicating that the erosional disconformity is greater toward the northeast—that there was a progressive uplift of land beginning in the northeast at the close of Mississippian time and proceeding southwestward, which subjected the land surface, composed of Mississippian strata, to erosion for a longer period in the northeast than in the southwest. Conversely the land to the southwest, lying longer at or near sea level, was less subject to degradation, and, indeed, for a long time must have been subject to the reverse process of aggradation, by receiving the erosional products from the higher lands to the northeast. Thus is explained the greater thickness of the basal beds of the Pennsylvanian toward the southwest. Not altogether in harmony with the view just stated is the comparative thinness of the basal conglomerate measures forming the border of the Western Coal Field, and the evidence that the thinning of the upper Mississippian (St. Louis, Ste. Genevieve and Chester) northeastward along the western border of the Eastern Coal Field is due not so much to the removal by erosion of the upper beds as to a thinning of each individual bed.

Despite the great extent of the sinuous outcrop of the plane of contact between the Mississippian and Pennsylvanian—the most extensive of any other formational contact in the State—good sections, showing clear exposures of the contact are rare. This is because shales predominate on the upper side of the plane of contact and by sloughing creep down over this plane and obliterate it. Hence the best exposures are in artificial excavations, such as railroad cuts and quarries, where, if recent, they have not yet become obliterated by this sloughing action. The sharpest contrast is afforded where conglomerate forms the upper contact. In such cases the conglomerate is apt to be channel gravel-bar deposits, which were due to checking of rapid currents, such as were responsible for the gouging out of the channels. In other words, we have here cases of contemporaneous erosion-discordance. Sudden variations in the thickness of the conglomerate are to be expected in such cases, and also sudden changes in the nature of the underlying contact. For instance, in the Roundstone Creek drainage of Rockcastle County the basal Pennsylvanian is a true channel-filling conglomerate, composed entirely of pure quartz pebbles. In some cases this conglomerate rests on a bed of the Chester, in others on the Ste. Genevieve or St. Louis; or it may be the filling of a channel cut down into the upper Waverly.

Another instance of sudden changes in the nature of the underlying contact is near Blair's Mill on the North Fork Railroad in northern Morgan County. Here at one point the basal conglomerate may be seen resting on the limestone layer at the top of the Pennington—the most northernly post-Mississippian and pre-Pennsylvanian formed outlier of Pennington yet identified in the State; and again only a short distance away, the same conglomerate rests on Olive Hill fire clay, which in other sections close by is a short distance below the top of the Pennington.

INTRA-PENNSYLVANIAN DISCONFORMITIES.—There are numerous minor disconformities within the Pennsylvanian. These are generally marked by contacts between shales and overlying sandstones, where the sandstones are deposits in eroded stream channels in the shales. These instances of *contemporaneous erosion* have frequently resulted in the cutting out of coal seams by sandstones.

PERMIAN-CRETACEOUS DISCONFORMITY.—But this pronounced hiatus in the stratigraphic series is nowhere indicated in Kentucky by an exposed Permian-Cretaceous contact. It is probable that some Permian strata once existed as a top formation over a portion of Kentucky, but no trace of this formation is now found even in the most central parts of those portions of the east and west geosynclinals extending into the State. It would appear that all traces of this Permian have been removed in the long erosion interval between it and the Cretaceous.

West of the Tennessee River, where Cretaceous strata occur, the bottom layers are not exposed. Well records in the Jackson Purchase near the boundary of the region show that the Cretaceous (upper portion) rests on Mississippian. Faulted outliers of the Pennsylvanian not far away make it probable that it once extended into the Jackson Purchase and has been removed by erosion before the deposition of the Ripley division of the Cretaceous. How many additional intervening beds may have been deposited in this region and then removed by erosion we have no means of determining.

LAGRANGE-LAFAYETTE (EOCENE-PLIOCENE) DISCONFORMITY.—A disconformity between the LaGrange and Lafayette, representing an erosional interval during Miocene time, may be seen at a number of places in the Jackson Purchase.

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PART FOUR

Economic Geology

CHAPTER XII

COAL

Distribution of Area.—The coal of Kentucky—all of Pennsylvanian age—occurs in two fields: a Western of 4,680 square miles, and an Eastern of 10,450 square miles.

The Western Field is contained in twenty counties, twelve of which possess only a small amount of the margin. These are Crittenden, Caldwell, Christian, Todd, Logan, Butler, Warren, Edmonson, Hart, Grayson, Breckinridge and Hancock. The eight counties which lie entirely within the field are Daviess, Henderson, Union, Webster, Hopkins, Muhlenberg, Ohio and McLean.

The Eastern Field is contained in thirty-seven counties. The western border counties of this field are eleven in number: Lewis, Rowan, Menefee, Powell, Estill, Madison, Rockcastle, Pulaski, McCreary, Wayne and Clinton. The twenty-six counties which lie entirely within the field are Greenup, Boyd, Carter, Elliott, Lawrence, Morgan, Johnson, Martin, Wolfe, Magoffin, Floyd, Pike, Lee, Breathitt, Knott, Jackson, Owsley, Perry, Letcher, Laurel, Clay, Leslie, Whitley, Knox, Harlan and Bell.

Coal Production.—On account of superior transportation facilities the Western Field was the first to be developed, and until 1911 it led in output. In 1910 the Western Field produced 8,428,752 tons and the Eastern Field 6,291,259 tons. In the next year the production fell off in the Western Field, being only 6,959,541 tons, and that in the Eastern Field increased slightly, being 6,965,270 tons. Since then the output of the Eastern Field has steadily increased over the Western, until in 1916 it led by over 7,700,000 tons. This increase has been due to increased transportation facilities for Eastern Kentucky coal. In 1916 the commercial production of coal in the Western Field was confined to ten counties, and in the

Eastern Field to seventeen counties, the statistics being as follows:

Production of Coal in Kentucky in 1916

Eastern Field		Western Field	
Counties	*Tons*	*Counties*	*Tons*
Letcher	3,807,397	Hopkins	2,605,812
Pike	3,675,607	Muhlenberg	2,015,859
Bell	2,237,340	Webster	1,575,748
Harlan	2,204,553	Union	666,966
Johnson	1,061,481	Ohio	471,610
Perry	995,091	Henderson	169,572
Whitley	947,783	Christian	102,068
Floyd	814,610	McLean	72,482
Knox	771,685	Daviess	40,811
Carter	130,436	Hancock	10,500
Laurel	77,321		
Boyd	72,439		
Morgan	47,727		
Breathitt	12,825		
Lawrence	10,612		
Jackson	9,397		
Lee	6,623		
Total	25,292,767	Total	17,565,239

Relative Fuel Values of the Coals in the Two Fields.—The Eastern Kentucky coals are, as a rule, superior in heating quality to the Western. This is in accordance with the general law for the North American Continent that the heat units of Carboniferous coal per unit of weight increase eastward in keeping with an increase in that direction of the fixed carbon content of the coal. The percentage of fixed carbon in coal increases with the dynamic metamorphism to which it has been subjected. Since coal beds were laid down dynamic metamorphism in the Eastern United States has been most intense along a middle zone of the Appalachians, where folding was greatest. The increase in the intensity of the forces tending to produce metamorphism was a gradual one from a minimum in the Mississippi Valley to a maximum in the Appalachian zone. Hence the gradual improvement in the quality of coal in following the beds from west to east.

Results of tests made at the University of Kentucky on the heating value of Kentucky coals, which were published in the Inspector of Mines' report for 1895, were in harmony with the above law. Computations from chemical analyses and actual tests under the boiler showed that the Eastern Kentucky coals contained more heat units, both theoretical and actual, than the Western Kentucky coals.

The best Eastern Kentucky sample, from near Beattyville, in Lee County, showed that it possessed as theoretical heat units 7,564 net calories, and that, burned under the boiler, it was able to evaporate 6.03 pounds of water per pound of coal. The best sample of coal from Western Kentucky by the same tests shows it contained only 7,241 net calories and was able to evaporate under the boiler but 5.72 pounds of water per pound of coal.

THE EASTERN FIELD

In treating of the coals of the Eastern Field the identifications will be made as far as possible with the seams of Pennsylvania, and these names will be used as their primary designations. The numbers which have been applied to them by the Geological Survey of Kentucky will also be given together with the local names by which they are known. For the correlation of these seams with those of Virginia, West Virginia and Ohio, the reader is referred to the stratigraphy of the Coal Field as given in Part One. The treatment here will be by counties.

Boyd County.—The workable coals in this county are mostly in the northern part. They range from the Lower Mercer in the Pottsville to the Lower Freeport in the Allegheny. From upper to lower these coals are as follows:

Lower Freeport, No. 8. Opened to some extent in the drainage of the East Fork of Little Sandy above the mouth of Garner Creek, where it reaches a thickness of 48 inches.

Middle Kittanning, No. 7. This coal is rather thin and pockety in this county. Its thickness ranges from 36 to 72 inches. It was formerly mined extensively at Coalton, by which name this seam is best known in this section of the State.

Lower Kittanning, No. 6. Mined extensively on Keyes Creek, by which name this seam is best known in this section. It is from 30 to 36 inches thick.

Upper Mercer, No. 4. This is known in other parts of the State as the "Fire Clay" Seam. Worked formerly in the environs of Ashland and Catlettsburg, and also extensively on Shope Creek, where it is 42 inches thick.

Lower Mercer, No. 3. This coal is worked on Hood's Creek, west of Ashland.

The total aggregate thickness of the coal in the seams of this county is about sixteen feet.

References.—A. R. Crandall's report on Boyd, Carter and Greenup Counties, Vol. C, State Survey, 1884; and W. C. Phalen's report on Kenova Quadrangle in Kenova Folio for the United States Geological Survey, 1912.

Carter County.—The coals in this county range from Numbers 1 to 9 (Sharon to the Upper Freeport). From upper to lower they are as follows:

Upper Freeport, No. 9. This coal is exposed near the head of Lost Fork and Bell's Trace.

Interval 40 to 50 feet.

Lower Freeport, No. 8. Generally known in this region as the "Hatcher" coal. It is sometimes 48 inches thick.

Interval 40 to 55 feet.

Middle Kittanning, No. 7. This seam is mined along the Eastern Kentucky Railroad south of the Chesapeake and Ohio Railroad, and along the Chesapeake and Ohio from Eastern Kentucky Junction to Kilgore. On the Eastern Kentucky it is chiefly mined at Willard. It ranges in thickness from 36 to 72 inches.

Interval 40 to 45 feet.

Lower Kittanning, No. 6. This is the "Keyes Creek" coal of Boyd County. It is not of much importance in Carter.

Interval 45 to 60 feet, containing the Vanport limestone.

Brookville, No. 5. This is the Pennington and the "Cooksie Fork" coal of Lawrence County. It is mined on Straight Creek, Boyd County, where it is 38 to 40 inches thick.

Interval 30 to 50 feet.

Upper Mercer, No. 4. "Fire Clay" or "Dean" coal. This coal is cannel in places—"the Cannel of Stinson Creek," but better known by its Greenup County name—"Hunnewell Cannel."

Interval 35 to 40 feet.

Lower Mercer, No. 3. "McHenry" coal, or the "Torchlight" of Lawrence County. Also known as the "Turkey Lick" coal. It is about 36 inches thick.

Interval 150 feet.

Quakertown, No. 2. "Kibby," "Jones," "Lewis" coal. It is workable on Barrett's and Everman's Creeks.

Sharon Interval(?), No. 1. "Barrett's Creek" coal, or "Jackson Shaft" of Ohio. Mined on Barrett's and Everman's Creeks, where it is 36 inches thick.

The coals of this county will aggregate about twenty-six feet in thickness.

As references consult publications listed under Boyd County, at top of this page.

Greenup County.—This county is not listed as one in which commercial mining is carried on at present. The workable coals are almost entirely confined to the southern and eastern part, where they lie in the drainage of the Little Sandy, and along streams flowing into the Ohio east of the mouth of the Little Sandy. The stratigraphic range of the coals is from the Sharon to the Middle Kittanning (Numbers 1 to 7). The lower seams (Numbers 1 to 2, inclusive) are found on the west side of the Little Sandy. The remainder (3 to 7, inclusive) are on the east side. From upper to lower these coals are as follows:

Middle Kittanning, No. 7. This seam is low enough to be workable only between the East Fork of the Little Sandy and the Ohio, where it has its usual thickness, ranging from 36 to 72 inches.

Lower Kittanning, No. 6. This seam is found in the same region as No. 7, and also in the hills to the east of old Hunnewell Furnace. It barely reaches a workable thickness in the county.

Brookville, No. 5. Present, but hardly of workable thickness.

Upper Mercer, No. 4. Mainly a cannel in this county—the famous "Hunnewell Cannel," so long worked near the old Hunnewell Iron Furnace.

Lower Mercer, No. 3. "Turkey Lick" coal. It is generally well defined in this county, in the area where it has been described as occurring. Known as the "Top Hill" coal near Raccoon and Buffalo Furnaces, where it was formerly worked. It is also the important coal worked on Chinn's Branch, and near the old Amanda Furnace on Bush Creek.

Quakertown, No. 2. "Kibby" coal of Carter County. Opened in the hills back of Riverton, where it shows a thickness of 30 inches. It shows up also near Raccoon and Buffalo Furnaces, and on Oldtown Creek.

Sharon, No. 1. "Barrett's Creek" coal. This is near drainage level at Riverton, where it is 12 to 18 inches thick. It is 30 inches thick near old Raccoon Furnace, and 36 inches thick on Little Sandy, opposite old Buffalo Furnace.

The aggregate thickness of all the coals in this county is probably about twenty-one feet.

As references consult publications listed under Boyd County, at top of page 262.

Lawrence County.—The stratigraphic range of the seams in this county is from the Sharon to the Upper Freeport. From upper to lower the coals are as follows:

Upper Freeport, No. 9. Opened on the Big Sandy near Zelda, where it is 40 inches thick; and near Fallsburg, where it is from 27 to 36 inches thick.

Middle Kittanning, No. 7. The "Coalton" of Boyd County. Opened only in the region near Webbville, where it is 40 to 45 inches thick.

Lower Kittanning, No. 6. The "Keyes Creek" of Boyd County. Too thin in this county to be commercially valuable.

Brookville, No. 5. The "Cooksie Fork" of this county. Too thin to be worked where above drainage on the Big Sandy near Louisa. In the western part of the county, as on Cooksie Fork, it reaches a thickness of 60 inches, but is here too far from railroad transportation to be commercially mined.

Upper Mercer, No. 4. The "Fire Clay" Seam. Known in this county as the "five-foot" seam. It is worked near Torchlight in the southern part of the county, and it extends over into the drainage of Big Blaine Creek.

Lower Mercer, No. 3. The McHenry of Carter County. It has the same distribution as the foregoing, being the mainstay of the mining industry at Torchlight. Its range in thickness is from 30 to 45 inches.

Sharon, No. 1. The Barrett's Creek. This seam is called "Little Cannel" in this county because it commonly has a few inches of cannel in it. Its total range in thickness is from 20 to 30 inches.

The total aggregate thickness of coal in this county is about twenty feet.

As references consult publications listed under Boyd County, at top of page 262.

Johnson County.—The coal stratigraphy of this county away from the immediate vicinity of the Big Sandy River has not been worked out in detail. The commercial seams appear to be confined to the Pottsville, which, with its thickening in this direction (south and east), has new seams intercalated in it. The range of the commercial seams is from the Van Lear (Quakertown?, No. 2) to the Broas.

Broas. Winifrede of West Virginia. Thickness 48 inches.

Upper Mercer(?), No. 4. Lower Thacker Chilton of West Virginia. Thickness 48 inches.

Two Mile Cannel. Thickness 40 to 46 inches.

Lower Mercer(?), No. 3. Peach Orchard, Elkhorn(?) Thickness 40 inches.

Ivel. Thickness 24 to 36 inches.

Quakertown(?) No. 2, Van Lear. This is the most important seam of the county. It ranges in thickness from 30 to 48 inches. It was identified by Professor A. R. Crandall as the No. 1, but Mr. J. B. Hoeing thinks it is higher in the series.

The aggregate thickness of these commercial coals is about twenty feet.

References.—State Geological Reports, Bulletin 4, 1905, by A. R. Crandall, and Series IV, Vol. 1, Part 1, 1913, by J. B. Hoeing.

MARTIN COUNTY.—The Inspector of Mines' report for 1916 does not list Martin with Eastern Kentucky counties having commercial mines within their limits. Coal is mined, however, on the West Virginia side of Tug Fork. This is locally known from exposures on the Kentucky side as the "Warfield" coal. It correlates with the Vulcan of West Virginia. It is probably the same as the Van Lear of the Levisa Fork drainage, which is provisionally correlated with the Quakertown of Pennsylvania.

FLOYD COUNTY.—Five or six seams have been worked commercially in this county. They appear to be confined to the Pottsville. In descending order a section of them on Beaver Creek will serve pretty well for the whole county.

Coal.

Coal. Thickness 28 to 40 inches.

Lower Mercer(?), No. 3, Elkhorn. Thickness 42 to 72 inches.

Interval 90 to 100 feet.

Ivel. Thickness 30 inches.

Interval 30 to 40 feet.

Quakertown(?), No. 2, Van Lear. Thickness 30 to 43 inches.

Interval 30 to 40 feet near mouth of Beaver; less near the head.

Sharon(?), No. 1, Dwale. Thickness 30 inches.

The most important seam of the foregoing is the Van Lear which receives its name from a locality where it is extensively mined. This is the seam principally mined along the Levisa Fork of the Big Sandy. Aggregate thickness of the seams, fourteen feet.

Consult as references publications listed for Johnson County, at bottom of page 264.

PIKE COUNTY.—This county is well supplied with coal, being second only to Letcher in the number of its seams and in the commercial output from them. The coals of the two drainage areas—Tug Fork on the one hand and Levisa and Russell Forks on the other—have not yet been completely correlated. The following tabular presentation expresses the views of Mr. J. B. Hoeing on the equivalency of these coals:

Levisa and Russell Fork Drainage	*Tug Fork Drainage*
	Coalburg, **Winifrede, Broas,** 64 to 70 inches thick.
Four-foot Seam.	**Upper Thacker,** 36 inches thick.
Interval 530 feet.	
Upper Mercer, No. 4, Fire Clay Seam, 123 inches thick.	**Lower Thacker,** 49 inches thick.
Interval 400 feet.	
Lower Mercer(?), No. 3, Elkhorn, 84 to 96 inches thick.	**Alma,** No. 2 Gas. 60 inches thick.
Interval 135 to 160 feet.	
Ivel, 36 inches thick.	**Powelton,** No. 1 Gas. 32 inches thick.
Quakertown(?), No. 2, Van Lear. 46 inches thick.	**Freeburn,** Vulcan, Warfield. 40 inches thick.
Interval 180 to 200 feet.	
Sharon(?), No. 1, Syck. 36 inches thick.	
Interval 150 to 180 feet.	
Presbyterian School. 50 inches thick.	
Interval 200 to 300 feet.	
Auxier, 46 inches thick.	
Interval 190 to 200 feet.	
Ellswick, 40 inches thick.	

The aggregate thickness of coal in these seams is about forty feet. Of these seams the Elkhorn (named from Elkhorn Creek, this county) is probably the most important on account of its great thickness and its fine coking properties. However, the Van Lear, on account of its wide distribution, is hardly second to it.

References.—For a fuller account of these coals and their supposed equivalency, consult reports referred to under Johnson County, at bottom of page 264.

Elliott County.—No railroad enters this county, and no commercial coal mining is carried on in it. The same coals from Numbers 1 to 7, inclusive, are known to occur in this county as in Carter to the north and have been opened for neighborhood use. The higher coals from Number 7 down to Number 4, inclusive, occur in the Little Fork drainage in the eastern part of the county. The lower coals are known as far west as the main Little Sandy and its extension headward in Open Fork. Of these Number 3 is the most widely distributed and important.

References.—A. R. Crandall's Report on Elliott County for State Survey, 1886; W. C. Phalen's Report on Kenova Quadrangle, United States Geological Survey, 1912.

Morgan County.—Coals from Number 1 up to about Number 7 are known to occur in this county, but Number 2 is the only one commercially mined. This is the cannel seam extensively worked at Cannel City in the southern part of the county, and shipped out over the Ohio and Kentucky Coal Road which connects with the Lexington and Eastern of the Louisville and Nashville system at O. and K. Junction, near Jackson. The Cannel part of the seam at Cannel City is about twenty-four inches thick. The same seam is mined in the northern part of the county, and shipped out over the Morehead and North Fork Railroad, which connects with the Chesapeake and Ohio at Morehead. In the vicinity of Cannel City another higher cannel coal (one about 200 feet higher than Number 2, and erroneously identified as Number 4) was formerly mined, but not with much success. It is even a better grade of cannel than the Number 2. The real Number 4, or Fire Clay Seam, is thin in this portion of the county, showing up as a thin bloom between the Number 2 and the upper cannel seam. Eastward it thickens, and is the persistent seam mined for neighborhood use along the Licking in this and adjacent Magoffin County for most of the stretch between West Liberty and Salyersville.

References.—A. R. Crandall's Preliminary Report on Morgan, Magoffin, Johnson and Floyd Counties, for State Survey, Part 5, Vol. 6, Second Series, and issued as a separate. Also by same author and survey, coals of the Licking Valley, 1910.

Magoffin County.—Except for a branch line of the Big Sandy Division of the Chesapeake and Ohio, which barely enters the eastern portion, this county has no railroad facilities and hence no commercial coal mining. Professor A. R. Crandall in his Report on the Coals of the Licking Valley describes these coals, but does not make much of an attempt at their correlation. Mr. James Hodge in his Report on the Coals of the Headwaters of the Licking River in Magoffin County, correlates these coals as ranging in the southern part of the county from Numbers 3 to 7, inclusive, the most important being the Number 6, Lower Kittanning (Hazard of the region farther south). This seam ranges from sixty to 102 inches. The Number 4, Upper Mercer, or Fire Clay seam, is the important coal in the lower part of the county. In the days when poplar (tulip) logs were rafted down the Licking, cannel coal from an opening on this seam near the mouth of Ben Branch was loaded on the rafts, and carried down to the "Settlements."

References.—A. R. Crandall's reports listed under Morgan County, and James Hodge's Report on Coals of the Headwaters of Licking River, Magoffin County. Series IV, Vol. I, Part II, pages 889-988.

Menefee County.—This county contains very little of the Coal Measures above the Sharon(?) Conglomerate Series of the Pottsville; and as this series in northeastern Kentucky contains little in the way of thick coals, no commercial mining is at present carried on in it. The lowest seam of the Coal Measures in this portion of the State—the so-called "Sub-Conglomerate" coal, the one lying close to the top of the Mammoth Cave limestone—has been mined for local use near Frenchburg, and to a limited extent shipped out over the railroad connecting this county seat with Mount Sterling. It is seldom over thirty inches thick.

An account of this coal is given in Professor A. R. Crandall's Report on Menefee County, Part II, Vol. IV, Second Series, Shaler Geological Survey of Kentucky. Also see Joseph Lesley's Report on Bath County (then including what is now Menefee), pages 465-467, Vol. 4, Owen Geological Survey of Kentucky, 1861, and Report on the Coals of Menefee County by the writer in Bulletin No. 12, Norwood Geological Survey of Kentucky, 1910.

WOLFE COUNTY.—No commercial mining is done in this county because, being on the border of the Eastern Coal Field, its coals are low in the series. Starting at the top of the Sharon Conglomerate, three seams—the Sharon, Quakertown and Lower Mercer (Numbers 1, 2 and 3) have been recognized. The lowest is mined for local use near Zachariah and along both sides of the Lexington and Eastern Railroad from Torrent to Fincastle, where it lies high in the hills, and near Campton, where it is just above drainage. It ranges in thickness from twenty-four to thirty-six inches. The Lower Mercer is near the tops of the hills near Campton, and lower down near the mouth of Holly Creek. It reaches a thickness of fifty-nine inches, including a number of partings.

References.—For further information concerning these coals see Mr. P. N. Moore's account of "Some Coals along a Line from Near Campton in Wolfe County to the Mouth of Troublesome Creek in Breathitt County," Bulletin 10, Geological Survey of Kentucky, 1910. This is a reprint from an earlier report. Also see "Coals of Wolfe County" in Bulletin No. 12, previously referred to.

POWELL COUNTY.—There are no commercial mines in this county. The first coal above the Mammoth Cave limestone is the only seam occurring here. It has been opened in a few places for neighborhood use.

Reference is made to this seam by Joseph Lesley and also by the writer in the reports previously referred to (Volumes 4 and Bulletin 12).

ESTILL COUNTY.—The same statements may be made in regard to this as have just been made in regard to Powell County; also the same references may be consulted.

LEE COUNTY.—The only coal mined commercially in this county is the "Beattyville Seam"—a sub- or inter-conglomerate coal. It lies about 140 feet above the top of the Pennington, here constituting the top of the Mississippian, and is the equivalent probably of the Barren Fork or the Beaver Creek Seam of the Cumberland River region. It is mined along the Kentucky River and some distance up its tributaries from the mouth of Sturgeon Creek, where it lies high in the hills, to the junction of the North and Middle Forks of the Kentucky, where it sinks below drainage. It ranges in thickness from thirty-six to forty-one inches. The Sharon, or Number 1, seam is mined in the northern part of the county for neighborhood use. It is here known as the "Zachariah Coal."

References.—Joseph Lesley's Report on Owsley County (then including part of Lee) in David Owen's Report, Vol. 4, 1861, and Report by writer on this county in Bulletin No. 12, previously listed.

Breathitt County.—The coals in this county range from the Sharon to the Upper Freeport, inclusive. As in other counties to the east and south of this county there are certain seams below the Upper Mercer—but still in the upper Pottsville—which cannot be correlated with coals north of the Ohio River. They appear to be additional seams intercalated in the series as they thicken in this direction. Some of these have not as yet been correlated even with seams in adjacent counties. To two of these Julius Fohs, who made an examination of the coals of the Quicksand drainage, gave local names. These are the "Wilson Fork" and "Big Branch." These seams, given in descending order are as follows:

Upper Freeport, No. 9, Hindman. Occurs on the head of Leatherwood and on South Quicksand Creek. It ranges from 48 to 114 inches thick.

Interval 65 feet.

Middle Kittanning, No. 7, Flag. Opened sparingly on South Quicksand Creek, where it is from 42 to 57 inches thick, and on Troublesome and Lost Creeks, where its thickness ranges from 42 to 108 inches.

Interval 60 feet.

Lower Kittanning, No. 6, Hazard. High in the hills near the mouth of Troublesome, where it is from 54 to 60 inches thick. In the Quicksand drainage it has an average of 80 inches.

Interval from 100 to 200 feet, with a thin coal—the Leatherwood.

Brookville, No. 5, Haddix. On Lower Troublesome 48 inches thick; thin on Lost Creek; averages 70 inches on Quicksand Creek.

Interval 70 to 200 feet, carrying the Fire Clay Rider.

Upper Mercer, No. 4, "Fire Clay" coal. On the North Fork of the Kentucky 36 to 60 inches thick; on Quicksand 72 to 180 inches.

Interval 45 feet.

Wilson Fork (J. Fohs). In the Quicksand drainage, where it is 48 inches thick.

Interval 12 feet.

Whitesburg. Mostly below drainage on Troublesome and Lost Creeks, and on the North Fork of the Kentucky above the mouth of Troublesome. Thin on Middle Fork. In the Quicksand drainage it averages 49 inches.

Interval 70 feet.

Big-Branch (J. Fohs). On waters of Quicksand, where it is 45 to 84 inches thick.

Interval 58 feet, containing a thin coal (Round Bottom).

Lower Mercer, No. 3, Elkhorn. Above drainage on the North Fork below the mouth of Troublesome, and is above drainage on all of the Middle Fork of the Kentucky in this county. It is the coal mined at Jackson. It is also on Quicksand Creek. It ranges from 30 to 50 inches thick.

Sharon, No. 1. This is the coal mined on Frozen Creek. It is about 36 inches thick there.

The minimum aggregate thickness of coal in this county is forty-three feet.

References.—Bulletin 11, by James Hodge, 1910, and Bulletin 18, by Julius Fohs, 1912, both reports for the Geological Survey of Kentucky, dealing with the coals of this county; also more recent report by James Hodge, Coals of the North Fork of the Kentucky River in Perry and portions of Breathitt and Knott Counties, Geological Survey of Kentucky, 1918. James Hodge, 1918, gives a succession for coals for this county differing somewhat from the foregoing. See his list of the coals for Leslie County on page 275.

Knott County.—The coals of this county range from about the Lower Mercer horizon of the Pottsville to the Upper Freeport of the Allegheny. These, with their thicknesses and intervals, as given by James Hodge for their occurrence in the Kentucky River drainage, are as follows:

Upper Freeport, No. 9, "High Splint," Hindman, 120 inches thick.

Interval 50 feet.

Lower Freeport(?), No. 8, Francis; 36 to 48 inches, on Gregory Branch.

Interval 50 feet.

Middle Kittanning, No. 7, Flag, Cornett; 36 to 87 inches.

Interval 40 to 80 feet.

Lower Kittanning, No. 6, Hazard; 40 inches.

Interval 50 feet.

Brookville, No. 5, Haddix, Pardee of West Virginia; 36 to 60 inches.

Interval 200 to 235 feet.

Upper Mercer, No. 4, "Fire Clay" Seam, Hyden, Dean; 36 to 44 inches.

Interval 25 to 100 feet.

Whitesburg; 36 to 55 inches.

Interval?

Amburgy; 24 to 50 inches.

Interval?

Lower Mercer, No. 3, Elkhorn, Taggart of Virginia, Cedar Grove of West Virginia.

In 1918 Mr. Hodge added another coal—the Hamlen—in the interval between the Upper Mercer and the Brookville.

The above gives thirty-five feet as about the minimum aggregate of all the seams in Knott County.

References.—James M. Hodge's Report, Coals of the Three Forks of the Kentucky River, Bulletin 11 of the Kentucky Survey, 1910, and also by the same author and published by the same organization, Coals of the North Fork of the Kentucky River in Perry and Knott Counties, in Series IV, Vol. 1, Part 2, 1913. By the same author, Coals of the North Fork of the Kentucky River in Perry and portion of Breathitt Counties, Geol. Survey of Kentucky, 1918.

ROCKCASTLE COUNTY.—All the coal of this county belongs in the Sharon(?) Conglomerate Series of the Pottsville. As many as three seams occur here. The two lower of these were formerly mined near Livingston and shipped out over the Louisville and Nashville Railroad. The upper seam was formerly mined at Pine Hill and also at Brush Creek. At the latter place it reached a thickness of seventy-two inches. These seams are probably the equivalent in ascending order of the Hudson, Beaver Creek and Barren Fork seams of the Cumberland River region. Openings on them to obtain coal for neighborhood use have been made in the Skegg's Creek drainage. The lower one, or Hudson Seam, is the most important here. No commercial mining is now carried on in the county.

References.—George Sullivan's Report on the Geology of parts of Jackson and Rockcastle Counties, Geological Survey of Kentucky, 1891. A. M. Miller's Report on this County in Bulletin 12, previously listed.

Jackson County.—With the addition of the first seam above the Conglomerate (Corbin conglomerate), the seams in this county are the same as those in Rockcastle. The Hudson Seam may reach a thickness of forty-five inches. It was formerly mined in the vicinity of Big Hill in the northwestern part of the county. It was marketed by wagon to Richmond. It was also mined for neighborhood use on Horse Lick and on Middle Fork and Rockcastle River. Two of these coals—probably the Hudson and Beaver Creek—have been mined in the northeastern part of the county near Turkey Foot, and shipped out over the coal road of the Turkey Foot Lumber Company connecting with the Louisville and Atlantic Railroad at Heidelburg. The first coal above the Corbin Conglomerate—the Lily coal of Laurel County and probably the Sharon of Pennsylvania, occurs in the southwestern part of the county. It is thin in this section. The Turkey Foot Lumber Company has done the only commercial mining in the county.

References.—Same as for Rockcastle County above.

Owsley County.—No railroad enters this county and no commercial mining is carried on in it. The Beattyville ("Beaver Creek or Barren Fork") seam is above drainage for only a short distance up the South Fork of the Kentucky. The Sharon(?) or Manchester (Number 1) is above drainage throughout the county. Higher coals are known to exist in the hills along the divides between this county and Breathitt and Perry on the east, and between this county and Clay on the south.

References.—James Hodge's Report on the Three Forks of the Kentucky and A. M. Miller's Report in Bulletin 12, both previously referred to.

Perry County.—The same series of coals described as occurring in Knott County are also found in Perry, the Upper Freeport (Hindman), Middle Kittanning (Flag) and Lower Kittanning (Hazard) coals are here in workable thickness in the southern part of the county. They are high in the hills, however, and do not offer much coal mining area. In this part of the county it is the Brookville (Haddix) and the Upper Mercer (Hyden) which are the important coals. Still lower coals are present—as the Whitesburg and Amburgy, seams unrepresented further north in the Pottsville, but are unsatisfactory for mining. In the northern part of the county, below the mouth of Big Creek, it is the Middle Kittanning (twenty-four to forty-eight inches), and Lower Kittanning (thirty to forty-eight inches), and the Brookville (thirty-six to forty-eight inches), which are the important coals. The Upper Freeport is here too high in the hills, and the lower coals—the Whitesburg and the Lower Mercer(?) (Elkhorn)—are too thin to be of much value.

References.—Consult same reports as listed under Knott County on page 271.

Pulaski County.—No commercial mining is at present carried on in this county, all the coals of which belong in the Pottsville below the horizon of the Corbin conglomerate. The lowest of these under the name of the Hudson or McKee, was formerly the mainstay of the Cumberland River mining industry, when the coal was shipped out to Nashville by barge. The opening on this seam at the old McKee mines showed sixty-three inches of coal.

References.—Joseph Lesley's Report, pages 484-488, Vol. 4, Geological Survey of Kentucky, 1861.

A. R. Crandall's Report, Vol. C, Part 2.

A. M. Miller's Report, Bulletin 12, 1910.

Laurel County.—While the coals below the horizon of the Corbin conglomerate occur in this county it is only the first seam above it—the Sharon(?) or Number 1 coal—the Lily seam, which is the one commercially mined. This seam is worked almost continuously along the Louisville and Nashville Railroad from Altamont to Lily—the mining places in between these two stations being East Bernstadt, Pittsburg, London and Fariston.

Clay County.—The report of the Inspector of Mines for 1916 gives no coal as commercially mined in Clay County, but with the building of a railroad from Barbourville to Manchester, and the increased demand for coal during wartimes, a considerable amount of it has been mined there and wagoned to the railroad at Manchester for shipment. This coal was almost exclusively from the Sharon (Manchester) seam. Higher coals than this are known to exist in the eastern part of the county. These are the same as those of Perry and Leslie Counties, which in descending order are the Upper Freeport, Middle Kittanning, Lower Kittanning, Brookville, Upper Mercer, Whitesburg and Howard. The latter is named from the owner of a well-known entry on Goose Creek. It has not been correlated with seams elsewhere. Of the others, the Brookville (Haddix) Number 5, occurs in best thickness, which is about forty inches. It is only towards the head of Redbird Creek, which constitutes the East Fork of South Fork of the Kentucky River, and toward the head of Goose Creek, which forms the West Fork, that any of these higher coals are low enough in the hills to furnish much coal acreage.

Reference.—James Hodge's Report on the Coals of the Goose Creek Drainage, in Series IV, Vol. 2, Part 2, pages 76 to 146, Geological Survey of Kentucky, 1914; and James Hodge and Philip Russell's Report for Clay County, Series IV, Vol. 4, Part 3, 260 pages, Geological Survey of Kentucky, 1918.

Leslie County.—There being no railroad, there is no commercial mining carried on in this county. It is known to have about the same seams of coal in it as Perry County. One name for the Upper Mercer in this county is the "Hyden," named from the county seat.

Hilton
  Interval 150 feet
Upper Freeport, Hindman
  Interval 50 feet
Francis
  Interval 100 feet
Middle Kittanning, Flag
  Interval 60—100 feet
Lower Kittanning, Hazard
  Interval 60—80 feet
Brookville, Haddix
  Interval 100 feet
Hamlin
  Interval 60—90 feet
Fire Clay Rider
  Interval 0—50 feet
Upper Mercer, Fire Clay Coal
  Interval 20—60 feet
Whitesburg
  Interval 200 feet
Amburgy

Reference.—James M. Hodge's report on the Coals of the Middle Fork of the Kentucky River in Leslie and Harlan Counties: Kentucky Geol. Surv., 1918.

LETCHER COUNTY.—This county at present leads in the coal production of the State. Some twenty different seams of coal are known to occur in it. Most of these are in the Pottsville Series. With such a large number of coals in this formation it follows that many of them cannot be correlated with those in the same formation farther north where the series is much thinner and these seams are not represented. As determined by Mr. A. F. Crider, the seams of Letcher County in descending order, with their thicknesses and their intervals, are as follows:

Coal.

Interval 40 feet.

Coal.

Interval 50 feet.

Stamper. Thickness 50 inches.

Interval 235 feet.

Upper Freeport, No. 9, Hindman, "High Splint." Thickness 78 inches.

Interval 120 to 170 feet, with one thin coal—the Francis.

Middle Kittanning, No. 7, Flag, Cornett. Thickness 48 inches.

Interval 40 to 80 feet.

A fossiliferous limestone—Vanport(?)

Interval 40 to 80 feet.

Brookville, No. 5, Haddix, Pardee, Parsons. Thickness 120 inches.

Interval 150 feet with a thin coal—the Hamlin.

Upper Mercer, Rider. "Fire Clay Rider."

Interval 30 to 60 feet.

Upper Mercer, No. 4, "Fire Clay" Seam, Hyden. Thickness 30 to 36 inches.

Interval 40 to 60 feet.

Whitesburg. Thickness 48 inches.

Interval 170 feet.

Amburgy, "Low Splint." Thickness 42 inches.

Interval 175 to 210 feet with three thin coals.

Lower Mercer, No. 3, Elkhorn, Taggart. Thickness 100 inches. Often in benches up to 25 feet apart.

Upper Bench, Penny, thickness 30 inches.

Lower Bench, Collier, thickness 30 inches.

Interval 70 to 100 feet.

Harlan, Shelby Gap, Standiford (Va.). Thickness 37 inches
Interval 70 to 80 feet.
Kelly. Thickness 36 to 75 feet.
Imboden. Thickness 85 to 90 inches.
Interval(?)
Spring Branch of Poor Fork. Thickness 37 inches.
Interval(?)
Meadow Branch of Poor Fork. Thickness 30 inches.
Interval(?)
Bad Branch of Poor Fork. Thickness 33 inches.

The most important seam of the foregoing in Letcher County is the Elkhorn which correlates closely with the Number 3, or the Lower Mercer of Pennsylvania. It reaches its maximum thickness near Pound Gap, where it is extensively mined near the new towns of Jenkins, Fleming and McRoberts. Jenkins is the terminus of the railroad system built up the Big Sandy, and McRoberts is the terminus of the one built up the North Fork of the Kentucky. Each lies at the very head of the two river systems of the Kentucky. The coal is found here on the downthrow (northwest) side of the Pine Mountain fault. It is an excellent coking coal.

References.—A. R. Crandall's Report on the Pound Gap Region, Vol. C, Part 2, Geological Survey of Kentucky, 1885.

M. R. Campbell's Report on the Geology of Big Stone Gap Coal Field of Virginia and Kentucky, Bulletin 111, United States Geological Survey, 1893.

A. R. Crandall's Report, Bulletin Number 4, Geological Survey of Kentucky, 1905.

Ralph W. Stone's Report on the Coal Resources of Russell Fork Basin in Kentucky and Virginia, Bulletin 348, United States Geological Survey, 1908.

James Hodge's Report on the Upper Cumberland Coal Field, Bulletin No. 13, Geological Survey of Kentucky, 1912.

J. B. Hoeing's Correlations of the Coals of Letcher and adjacent counties in Series IV, Vol. 1, Part 1, Geological Survey of Kentucky, 1913.

Charles Butt's Report on the Coal Resources of the Pound Quadrangle, Bulletin 541-F, United States Geological Survey, 1914.

A. F. Crider's Report on Coals of Letcher County, Geological Survey of Kentucky, 1916.

CLINTON COUNTY.—No commercial mining is carried on in this county, there being no railroad entering it. The coals, which are therefore mined for neighborhood use only, are in the lower, or conglomerate member of the Pottsville.

References.—Joseph Lesley's Report on this county on pages 493-4, in Vol. 4, Geological Survey of Kentucky, 1861.

R. N. Loughridge's Report on the Geology of Clinton County, Geological Survey of Kentucky, 1890.

WAYNE COUNTY.—No railroad enters or touches this county, hence no commercial mining is carried on in it. The same coals of the conglomeritic portion of the Pottsville, as occur in McCreary and Pulaski Counties, are found here.

Reference.—Joseph Lesley's Report, pages 488-493, Vol. 4, Geological Survey of Kentucky, 1861.

MCCREARY COUNTY.—No commercial output of coal is listed from this county for 1916, but commercial mining has been carried on by the Stearns Lumber and Coal Company. The coals occurring here are the three of the conglomeritic portion of the Pottsville (the Hudson, Beaver Creek and the Barren Fork), and the Sharon or Number 1 coal, here lying almost immediately on top of the Corbin conglomerate. The Hudson and Beaver Creek seams are mined by the Stearns Lumber Company on the South Fork of the Cumberland. A branch road has been built by the company from the Queen and Crescent Railroad at Stearns to the mines for the purpose of getting out the product. The Number 1 (Sharon-Lily-Manchester-Zachariah Seam) has been mined from time to time along the Queen and Crescent from Pine Knot south to the State line.

The order of the coals in this county from above downward with their thicknesses are as follows:

Sharon, No. 1. Thickness from 36 to 40 inches.
Barren Fork. Thickness about 36 inches.
Beaver Creek. Thickness 52 inches.
Hudson. Thickness 30 inches.

Aggregate thickness of the seams thirteen feet.

References.—A. R. Crandall's Report on Whitley and a Part of Pulaski Counties (McCreary was formerly partly in Pulaski and Whitley), Vol. C, Part 2, Geological Survey of Kentucky.

A. M. Miller's Report on same section in Bulletin 12, Geological Survey of Kentucky, 1910.

WHITLEY COUNTY.—The coals of this county, so far as they have been identified and correlated with the seams further north, range from Numbers 1 to 4, inclusive. Within this range there are five or six unidentified seams and one above the Number 4.

In descending order, with their thicknesses where determined, and approximate intervals, they are as follows:

Cannel Coal.

Interval 75 feet.

Upper Mercer, No. 4, Dean.

Interval 115 feet.

Coal.

Interval 70 feet.

Caddell.

Interval 100 feet.

Lower Mercer(?), No. 3, Jellico. Thickness 30 to 62 inches.

Interval 55 feet.

Blue Gem, "Upper Blue Gem." Thickness 8 to 22 inches.

Interval 85 feet.

Bacon Creek, "Lower Blue Gem." Thickness 300 inches.

Interval 150 feet.

Sharon, Lily, Williamsburg. Thickness 30 inches.

The workable coal in this county aggregates about ten feet. The Jellico, which has been correlated with the Number 3 or Lower Mercer Coal, is by far the most important seam in the county. It is the one mined under the name "Jellico" coal on the south side of the Cumberland River in the Clear Fork drainage. It occurs at its proper horizon everywhere in the Jellico Mountains on the west side of the Louisville and Nashville Railroad, and has been traced east of the railroad to where it terminates against the Pine Mountain fault. It extends southward into Tennessee. North of the Cumberland River it is mined east of the Corbin-Jellico-Knoxville Branch of the Louisville & Nashville Railroad as far as Rockhold. It is known to extend eastward from here and is probably the coal mined at Straight Creek in Bell County.

The Bacon Creek is probably the next in importance. It is mined on Bacon Creek near Corbin. The Upper Blue Gem is generally mined in connection with the Jellico, when it is exposed above drainage in the same hill. The Sharon, or Lily coal, is mined on both sides of the Cumberland River in the vicinity of Williamsburg. Opposite Williamsburg it is the seam on top of the river hill.

References.—The same two listed for McCreary County above.

Knox County.—Little satisfactory work has been done on the stratigraphy of the coals in this important coal mining county.

It is known, however, that the same main coals from the Blue Gem to the Dean inclusive, which are found in Whitley County, occur here.

References.—A. R. Crandall's and George M. Sullivan's Report on the Coal Field Adjacent to Pineville Gap in Bell and Knox Counties, Bulletin No. 14, Serial No. 17, Geological Survey of Kentucky, 1912.

Bell County.—The same thing may be said of this as of the preceding county. Some thirty different seams have been enumerated in the thick series of beds that are exposed in this county from the base of the conglomerate member of the Pottsville to the basal part of the Conemaugh—a stratigraphic range of over 3,000 feet in a vertical range of about 2,300 feet, due to the synclinal nature of the region between the Pine and Cumberland ranges. Only about ten of these coal seams are workable. These have not been definitely correlated with the seams further north. It appears certain that the Blue Gem, Jellico and Dean seams occur in this county—the Jellico being represented by the Straight Creek coal.

Reference.—Same as for Knox County above.

Harlan County.—There are exposed in the synclinal basin of this county a greater thickness of coal-bearing strata than in any other county of the State. The total range in thickness, due to the dip of the strata, may be 4,000 feet, within a vertical range of about 3,000 feet. The strata exposed range from the base of the Coal Measures on the upthrow side of the Pine Mountain fault to some distance up into the Conemaugh Series found on the tops of the Black Mountains. The coal seams with their thickness and intervals are presented in order from above downward in the following table:

A Splint Coal. Thickness 48 inches. Found in a small area at the head of Pounding Mill Branch of Clover Lick Creek.

Interval 540 feet.

Upper Freeport, No. 9, Hindman. Thickness 48 to 72 inches. Found in Big Black Mountain, some 500 to 700 feet below the top.

Interval 40 to 80 feet.

Middle Kittanning, No. 7, Flag, Cornett. Thickness 48 to 84 inches. Found in Big Black Mountain. Also two openings known in Little Black Mountain.

Interval 150 to 300 feet.

Brookville, No. 5, Haddix, Pardee. Thickness 48 to 72 inches. Found on Yokum and Childs Creeks of Clover Fork and on Poor Fork above mouth of Big Looney Creek.

Interval 360 feet.

Upper Mercer, No. 4, Dean, Hyden, "Fire Clay" Seam. Thickness 36—42 inches.

Interval 360 feet.

Amburgy, "Low Splint;" 36 to 54 inches thick. Found on Clover Fork above Bailey's Creek.

Interval 200 to 250 feet.

Lower Mercer(?), No. 3, Elkhorn, Taggart, Keokee. Thickness 24 to 48 inches. Extensively opened on Clover Fork and on Poor Fork above mouth of English Creek. This and the next lower bed are the most important seams of the county.

Interval 160 to 180 feet.

Harlan, Shelby Gap, Wilson (Virginia). Thickness 48 to 72 inches. Extensively opened near Harlan Court House, and on Clover and Poor Forks.

Interval 240 feet.

Imboden. Thickness 72 inches. Possibly extends from Virginia into Harlan County at the head of Clover Fork and Big Looney Creeks.

Interval 280 feet.

Dorchester. Thickness 48 to 96 inches. Found at Dorchester, Va. Not known with certainty on the Kentucky side of the divide.

Total aggregate minimum thickness for the coal of this county about forty feet.

References.—James Hodge's Report on Letcher, Harlan, Leslie, Perry and Breathitt Counties, pages 35-52, Vol. C, Part 2, Geological Survey of Kentucky, 1885.

M. R. Campbell's Report on the Estillville Quadrangle, in Estillville Folio, United States Geological Survey, 1894.

James Hodge's Supplementary Report on the Coal of

Clover and Poor Forks, Harlan County, Geological Survey of Kentucky, 1916.

James Hodge's Coals of the Middle Fork of the Kentucky River in Leslie and Harlan Counties, Geological Survey of Kentucky, 1918.

THE WESTERN COAL FIELD

Springfield and Herrin the Most Important Seams.—Of the eighteen coal seams numbered by Owen in the Western Field, by far the most important are his Numbers 9 and 11, to which afterward the Illinois names Springfield and Herrin were respectively applied.

Of these two seams the lower, or Number 9, is the more persistent and reliable for mining purposes. The interval between the two coals ranges from sixty to 125 feet—eighty to ninety feet being the average. Number 9 has a pretty uniform thickness of about fifty-four inches. The usual range of the thickness in Number 11 is between sixty and seventy-two inches. These two seams, which belong in the Carbondale or Allegheny series, are the mainstay of the coal mining industry of Western Kentucky. They furnish almost exclusively the commercial output of the counties of Hopkins, Muhlenberg, Webster, Union, Ohio, Henderson, McLean and Daviess. In the more southerly of these counties, Hopkins and Muhlenberg, which lead all the others of the Western Field in the production of coal, the Numbers 9 and 11 are found in down-faulted areas in an east and west zone of block faulting. But for this down-faulting, which has protected from erosion these higher coals in certain relatively small areas, they would long since have been completely removed—swept away without leaving a trace—in the general denudation to which the surface of Kentucky has been subjected.

Other Coals Below the Horizon of the Springfield.—In Christian and Hancock, the other two counties of the Western Field in which commercial mining is carried on, the seams worked have not yet been definitely located in the stratigraphic series, though they are known to belong between the Caseyville conglomerate and the Number 9 coal.

In *Christian County* the seam mined is known as the Mannington or Empire. It is the same as the Dawson

Springs of Hopkins County. As mined at Empire this seam averages forty-four inches thick. It is suspected to belong at a horizon between Numbers 3 and 4.

In *Hancock County* four seams are mined. These in descending order, with their thicknesses and intervals, are as follow:

Lewisport. Thickness 48 to 60 inches.

Interval 30 to 60 feet.

Adair. Thickness 24 to 42 inches.

Interval 25 to 35 feet.

Lead Creek (Limestone Seam). Thickness 36 to 42 inches.

Interval 25 to 35 feet.

Hawesville. Thickness 42 inches.

Interval 75 feet.

Top of Caseyville Conglomerate.

Of the foregoing the Hawesville and the Lewisport are the most important seams. There is little certainty as to the identity of these coals. It has been suggested that the lowest may correlate with the Number 1-B, or perhaps the Number 2, and the upper with the Number 9.

In *Breckinridge*—an adjacent county—there occurs a cannel coal of very fine quality with a thickness of from twenty-two to thirty-eight inches. Its place there is about forty feet above the base of the Coal Measures. The Conglomerate is absent in this section and for this reason it is impossible to say whether this is a coal correlating with one below or above the Caseyville conglomerate horizon.

Around the margin of the Western Field seams lower than the Number 9 have been mined for neighborhood use, as for instance, in the *Nolin River District of Grayson and Edmonson Counties,* where there is a coal coming on top of the lower bed of conglomerate and below the Bee Spring sandstone, sometimes conglomeritic. It has an average thickness of thirty-six inches. This coal has been correlated with Owen's Number 1-B. If this identification is correct, the coal would be "interconglomerate," proving that Dr. Owen unwittingly began numbering his coals below the top of the "Conglomerate" instead of on top as he intended.

This same coal has been opened in *Warren County.* In *Butler* and northern *Logan County* a number of openings have been made on coals belonging below the horizon of the Number 9 Seam. These are all "wagon mines," though in at least one case in the past the product was "trammed" to the Green River and thence shipped out in barges. These coals with their average thicknesses and intervals are as follows:

Mining City, No. 6(?). Thickness 36 inches.

Interval 75 feet.

Mannington, Dunbar, Topmiller. Thickness 36 to 48 inches.

Interval 100 feet.

Elmlick, No. 3, Aberdeen, Deanfield, Mud River. Thickness 36 inches.

Interval 100 feet.

Foster. Thickness 30 inches.

Interval 20 feet.

Gidcomb. Thickness 48 inches.

Interval 245 feet.

Main Nolin, No. 1-B(?). Thickness 36 inches.

Interval 10 to 160 feet.

Chester Group.

The above section will also serve for the coals which have been mined below the horizon of the Number 9 in *Ohio and Muhlenberg Counties.*

In *Hopkins* and also, as stated before, in *Christian County,* the only important coal mined below the Number 9 is the Mannington.

In the *Tradewater Region* of *Webster* and *Union Counties,* three of these lower coals have had openings made on them. The most important of these in descending order are as follows:

No. 6. Thickness 36 inches. Formerly worked near Dekoven, Union County.

Interval 25 to 30 feet.

Dekoven, No. 5. Thickness 48 inches. Mined at Dekoven.

Interval 400 feet.

Bell, No. 1-B. Thickness 36 inches. Worked near Caseyville, Union County.

REFERENCES

For an account of the coals of the Western Field in general see the old Owen State Survey Reports, Volumes 1 to 4, inclusive. For more recent information see Reports of the Geological Survey of Kentucky, as follows: For *Hopkins County,* A. F. Crider's Reports on Dawson Springs and Earlington Quadrangles in Series IV, Volume 2, Part 1, 1914; on Nortonville Quadrangle in Series IV, Volume 3, Part 1, 1915, also F. M. Hutchinson's Report on the Madisonville Quadrangle, Bulletin No. 19, Serial No. 26,

1912. For *Muhlenberg County,* A. F. Crider's Report on Nortonville, Drakesboro and Dunmor Quadrangles, same volume as mentioned above, and Hutchinson's Report on Central City Quadrangle in Bulletin 19. For *Ohio County,* same Report by Hutchinson as just mentioned and Report by James H. Gardner on the Hartford Quadrangle, Bulletin No. 20, Serial No. 27, 1912, and C. J. Norwood's Report on a Part of Ohio County in Volume D, 1884. For *McLean County,* Hutchinson's Report on Calhoun, and Central City Quadrangles in Bulletin 19. For *Daviess County,* Hutchinson's Report on the Calhoun and Newberg Quadrangles in Bulletin 19, and Crider's Report on Owensboro and Tell City Quadrangles in Series IV, Volume 1, part 1, 1913. For *Hancock County,* P. N. Moore's Report on the county in Volume D, Western Coal Field, 1884, and Crider's Report on Tell City Quadrangle mentioned above. For *Union County,* L. C. Glenn's Report on the Coals of the Tradewater Region, Bulletin No. 17; Serial No. 24, 1912, and Wallace Lee's Report on the Kentucky Part of the Shawneetown Quadrangle, U. S. G. S. and Kentucky Geological Survey, 1916. For a part of *Webster County,* Glenn's Report just mentioned, and Crider's Report on the Earlington Quadrangle, previously listed. For *Breckinridge County,* C. J. Norwood's Report on the Cannel coal in Volume D listed above; Report on the Nolin River District in Volume D listed above, and J. O. Bryant's Report on the same region in Series IV, Volume II, Part 1, 1914. For the southern part of *Butler County,* Crider's Report on the Dunmor and Little Muddy Quadrangles, in Series IV, Volume 3, Part 1, as listed above.

CHAPTER XIII

THE BITUMENS

PETROLEUM AND NATURAL GAS

These substances have been found in widely separated portions of the State and at geological horizons from the Trenton limestone up to the sandstones of the conglomeritic member of the Pottsville Coal Measures.

The order of succession of the geological formations with the average thickness of each and the positions of the leading oil and gas horizons (sands) is presented in the following condensed tabular outline.

Geological Formations for Kentucky, Showing Position of Leading Oil and Gas Sands

Eras	*Periods*	*Epochs*	*Average Thickness*	*Oil and Gas Horizons*
Cenozoic	Recent and Pleistocene		50	
	Tertiary		300	
Mesozoic	Cretaceous		300	
	Jurassic	Wanting		
	Triassic	Wanting		
	Permian	Wanting		
	Pennsylvanian	Coal Measures above the Conglomerate	1500	
		Conglomerate Coal Measures	500	In descending order, Wages, Jones and Epperson Sands of Knox; and Beaver, Horton, Pike and Salt of Floyd and Knott and other northeastern counties.

Geological Formations for Kentucky, Showing Position of Leading Oil and Gas Sands—Continued

Eras	*Periods*	*Epochs*	*Average Thickness*	*Oil and Gas Horizons*
		Chester	100	Gas sand of Breckinridge County. Bituminous sandstone.
		Mammoth Cave	200	"Big Lime" Horizon for some of the gas of Martin County.
		Logan	300	"Big Injun" Sand of Martin County gas wells.
	Mississippian	Cuyahoga	100	Beaver Sand of Wayne County, where Berea-Bedford is wanting.
		Sunbury Black Shale	10	
		Berea	20	Oil Sand of Lawrence County.
		Bedford	50	
Paleozoic	Devonian	Ohio Black Shale	125	Meade County gas sand.
		Onondaga (Corniferous)	25	Ragland, Irvine, Campton, Cannel City, Allen County oil sand, and Menefee gas sand.
	Silurian	Niagara	100	Barren County oil sand, according to Hoeing.
		Clinton (Brassfield)	15	
	Ordovician	Cincinnatian	600	Oil horizon of the old Burkesville well, and that of some of the other wells of Cumberland County.
		Trenton	270	Oil horizon of the Sunnybrook wells of Wayne, and of some of the Cumberland River wells of Cumberland County.

HISTORY OF THE DEVELOPMENT OF OIL AND GAS—FIRST PERIOD OF THE PETROLEUM INDUSTRY, 1819-1860

Oil Struck in Drilling for Salt Water.—As in other Eastern States, the discovery of oil and gas in Kentucky was closely connected with the salt industry. The first oil strike in the State was made in 1819, when Martin Beatty of Abington, Virginia, put down a well "for the benefit of sault" in the valley of the South Fork of the Cumberland River not far from the Tennessee line in what was then Wayne, but is now McCreary County. At a depth of several hundred feet a thick black oil was struck, which oozed to the top and flowed out on the waters of South Fork. It caused considerable annoyance to the good housewives of the region by reason of its getting on to the feathers of their geese and adhering there tenaceously. On this account it was locally called "devil's tar."

Burkesville Well and Burning Cumberland River.—The next notable instance of an oil strike in this early day was in 1829, on Renox Creek near Burkesville in Cumberland County. In drilling a well for salt here at a depth of 175 feet oil was struck under such strong pressure that it flowed out of the top, and running down the creek and out upon the Cumberland River, covered the latter for some forty miles downstream. Becoming ignited at this point, and burning back upstream toward the source in the well, it presented the strange spectacle of a "burning river." This phenomenon was heralded far and wide in the newspapers of that day as one of the "seven wonders of America" (see Niles' Register, Vol. 13, page 4). The flow continued for three weeks, and oil was then bailed or pumped from the well until 1860, the product being bottled and sold for fifty cents a bottle under the name "American Oil." It had a wide reputation in this southern and middle western country as a "sovereign remedy for all the ills that flesh is heir to." It is estimated that during this period the well produced 50,000 barrels of oil. This well began near the top of the Cincinnatian and ended near the middle of the same formation.

Oil Distilled from Cannel Coal and Black Shale.—After the discovery in 1830 of the substance paraffine as a residue from the distillate of the bituminous matter in cannel coal and black shale, and its recognition as a substitute for spermaceti in the making of candles, the derivation of paraffine oil from cannel coal grew into quite an industry in Europe and was finally transplanted to this country. Such an oil distilling plant was established in Breckinridge County in 1856, the celebrated Breckinridge cannel coal being the crude material from which the oil was obtained. About the same time, or perhaps a little later, a similar plant was erected at Vanceburg, Kentucky, the Sunbury black shale there being the material subjected to heat in the retorts.

OIL EXCITEMENT IN THE SIXTIES

Impetus Given to Oil Industry by Professor Silliman's Discovery.—In the late fifties Professor Silliman of Yale discovered that it was not necessary to rely on the distillate from cannel coal and black shale in the manufacture of paraffine, but that the substance could be more economically obtained directly from crude petroleum as this was furnished by oil springs and by wells drilled in exploring for salt water. This started a great speculative excitement in the early sixties. The excitement died down, especially south of the Ohio River, during the Civil War, but at its close, broke out afresh. Many Northern soldiers campaigning in Kentucky during the war were on the lookout for "surface indications" (oil seepages) and returned after the cessation of hostilities to develop the prospects. It was this that brought to Kentucky General Don Carlos Buell. He bought the celebrated Airdrie Furnace Tract in Muhlenberg County, and tried unsuccessfully to develop it for oil. There was scarcely an oil seepage in the State that escaped detection during this period, and did not become, either during the war, or in the late sixties after its close, the site of a well put down with the expectation of finding oil.

Cumberland River Oil Field.—It was during this period that the oil of the Cumberland River District in Wayne, Russell, Cumberland and Clinton Counties was discovered. Successful wells put down were as follows: the Gabbert in 1861, opposite the mouth of Crocus Creek, 182 feet deep; the Ebert in the same year, 270 feet deep; the Sherman in 1866, 276 feet deep; the Phelps in the same year, on Oil Fork, fifty feet deep; the Gilbreath, date uncertain, twenty feet deep; and the Huffaker in 1897, on Otter Creek, 533 feet deep.

The Gabbert is estimated to have produced during its life 50,000 barrels of oil, and the Crocus, during the first eleven hours after the oil was struck, 10,000 barrels. The Huffaker was first a salt water well. Finally, however, the salt water gave way to oil and for a time it produced the latter at the rate of fifty barrels per day. Ten thousand barrels of oil were pumped from this well prior to 1872. Most of the oil was barged in the crude state down the Cumberland River, but the product of the Gabbert well was prepared for market in a refinery erected in the neighborhood. The oil horizon appears to have been in the Cincinnatian in all these wells.

Allen County Field.—The discovery of oil in Allen County appears to have been the result of the presence of an oil spring on Trammel Creek. It is reported that these first wells were from seventy-five to 600 feet deep. The most productive was the Porter, drilled in 1866 or '67 at the forks of Bays Creek, northwest of Scottsville. It is said to have yielded from 100 to 500 barrels per day of a highly sulphurous oil. The product was wagoned to the railroad and shipped to Louisville to be refined. The wells started in the lower Waverly, and the most of them appear to have obtained their oil from the formation next below the Ohio black shale, which in the nearest outcrops on Long Creek is the Devonian limestone (Onondaga?).

Barren County Pool.—The wells which struck oil in this county at this time were on Boyd Creek. The most celebrated of these was the Kinslow, drilled in 1865. It gushed at first at the rate of 150 barrels per day, and later sunk to a pumping well. Between 1872 and 1888 it yielded 43,000 barrels. Even now it is said to be capable of yielding two barrels of oil per day, being the oldest producing well in the State. During this period the product of the wells was shipped to Louisville to be refined. The wells had an average depth of 120 feet. They started in the lower Waverly and, according to Mr. J. B. Hoeing, derived their oil from Niagara limestone.

Meade County Oil Exploration.—In Meade County during the period from 1863 to '65 some twenty or thirty wells were drilled near the site of an oil spring on Doe Run. No considerable amounts of oil were developed, but salt water and gas were struck. Later (in 1872) Mr. Moorman, the owner of several of these wells, utilized the combined product in building up there a flourishing salt industry. The gas was the fuel used in evaporating the salt water. It was also used as fuel in running a flour mill. This is the earliest instance in Kentucky of natural gas being used as a fuel for either commercial or domestic heating. The horizon from which this gas came is somewhere in the Mississippian.

GAS EXPLORATION OF THE EIGHTIES

The next period of activity in well drilling in Kentucky was the result of the discovery in the eighties of gas in the Trenton limestone under cover in Northern Ohio and Northeastern Indiana. Western Kentucky responded mostly to this stimulus, the object being to discover gas which might be used for domestic heating, and wells, some of them from 1,500 to 1,900 feet deep, were put down at or near Louisville, LaGrange, Brandenburg, Cloverport, Hawesville, Henderson, Livingston, Paducah, Hopkinsville, Bowling Green, Glasgow, and a number of other towns. The result was that in Barren County some wells were drilled which developed as high as 87,000 cubic feet of gas per day, and a new locality for oil in the county was discovered. These oil wells, which were located near Oil City, west of Glasgow, derived their oil from the same sand as the old Boyd Creek wells. Also in Meade and Breckinridge Counties gas was found—in the former in the Ohio black shale and in the later in the Warsaw.

Meade County Gas Field.—It was undoubtedly the partial success of the drilling on Doe Run in the sixties and seventies which led to this redrilling in the eighties. It was Louisville enterprise, with Colonel Castleman a leading spirit, which was responsible for this attempt to obtain a supply of gas that would warrant its being piped to the city. Major W. T. Davis, of Louisville, was employed as geologist to undertake a study of the rock structure and to make well locations. The first location of Major Davis resulted in the striking in the Ohio black shale at a depth of 375 feet a flow of gas which, when measured, showed it was capable of yielding 805,000 cubic feet per day. This location by Major Davis was made on the basis of the anticlinal theory of the occurrence of oil and gas, and his anticipations, including the depth at which the gas horizon (Ohio black shale) would be struck, were perfectly realized. This is the first and only instance of high pressure gas having been struck in the Ohio shale. It is also the first instance of the utilization in Kentucky of the services of a geologist for the location of the presence of a petroleum product in commercial quantities beneath a definite spot on the surface of the earth.

Between 1887 and 1889 there were put down in this field some eighteen wells, which at the close of the time had a potential production of 11,000,000 cubic feet per day. This supply was piped to Louisville and has been used for domestic heating there ever since, though at the present time (1918) the flow is quite weak and it has become necessary for the gas company supplying Louisville to rely mainly on natural gas piped from the West Virginia Field.

Even before this Meade County gas had been piped to Louisville, Cloverport enterprise had established the presence in the Warsaw underlying Breckinridge County a gas horizon capable of yielding per well as much as the average of those in Meade County. This gas was used in the town of Cloverport for domestic heating as early as 1889. Unless it be true that gas was piped to Catlettsburg and Ashland from the Warfield well on the Tug Fork previous to that time, Cloverport enjoys the distinction of being the first town in the State to have used natural gas as a domestic fuel. This supply of natural gas, along with the salt water which some of the wells produced, was used in the maintenance of a flourishing salt manufacturing industry in the town, and in addition the gas was used as fuel in a brick plant.

For Western Kentucky, this development in Meade and Breckinridge Counties constituted the culmination in the gas excitement which began in the middle eighties. By the nineties it had spent itself.

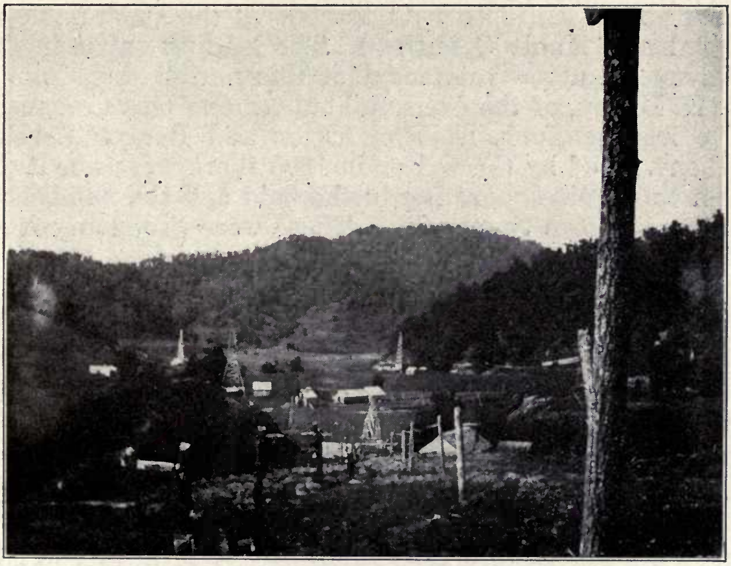
GAS AND OIL IN EASTERN KENTUCKY IN THE EIGHTIES AND NINETIES

Gas in Johnson and Martin Counties.—In Northeastern Kentucky more or less desultory drilling had been going on since the seventies—or even since the sixties. In 1879 Charles Dulin, Sr., put down a well on Granny's Branch near Paintsville, which struck a show of oil in the Berea. He followed this up with a well on the Tug Fork near Warfield, Martin County. This was a big gasser—the famous Warfield Well—which blew off for so long a time under high pressure before it was finally harnessed and its product utilized. Its location was determined by the presence of gas emanations in the bottom of the Tug Fork in the vicinity. These had been noted and commented upon since the earliest settlement of the country. Subsequent geological investigation by Professor I. C. White of West Virginia, showed that the well was located on the crest of an arch—the Warfield Anticline. Since then many more large gas wells have been drilled on this structure both in Martin County, Kentucky, and in Mingo and Wayne Counties, West Virginia, developing the Warfield-Kermit-Tug Fork Gas Field, from which towns in Northern Kentucky are mostly supplied with natural gas.

The gas comes from the "Big Injun" sand and the "Big Lime" just above, at depths in the neighborhood of 1,300 feet. As early as 1889 the gas from the Warfield well had been piped for domestic use for towns along the Ohio River, and had also been used in the manufacture of "carbon black."

Oil in Lawrence County.—The first successful oil wells in Northeastern Kentucky appear to have been drilled in the nineties. These were located in the valley of Big Blaine Creek and the oil came from the Berea.

Oil in Floyd and Knott Counties.—The most promis-



97. OIL WELLS BEAVER CREEK, FLOYD COUNTY
Summer of 1902. Photograph by A. M. Miller.

ing pool in Northeastern Kentucky was developed on the Right Fork of Beaver, mostly between 1890 and 1902. The New Domain Oil and Gas Company and the Guffy and

Galey Company did most of the drilling in this field. The producing sands in this region are in the lower Coal Measures. Named in descending order these are the Beaver, Horton, Pike and Salt. The wells had an average depth of 1,000 feet. When the writer visited the field in 1902 the New Domain Company had down eighteen wells producing an aggregate of sixty barrels daily, and the Guffy and Galey Company had down three wells. The first well in this field was drilled on the Howard Purchase, in 1892, by Louis H. Gormley, of Prestonburg. It flowed moderately and still yields a small production. Its maximum yearly production was 1,513 barrels in 1901. It is the oldest producing well in Eastern Kentucky.

Oil in Wayne County.—It was during the eighties and nineties that there was renascence of oil interest in Wayne County. It began with the Fairchild Well drilled in 1886 to a depth of 1,100 feet. The two common producing horizons in this county were found to be the Beaver just above the Ohio black shale and another sand within a short distance below the same black shale. (The Beaver must not be confused with the one of the same name in Floyd and Knott Counties.) The leading spirit in the Wayne County development of this period was Colonel A. H. Hovey, of the Consolidated Oil and Gas Company. The leading pools were on Otter and Beaver Creeks. When visited by the writer in 1895 there were about fifteen companies operating in the field and the number of wells put down twenty-five. These were producing from five to fifty barrels each per day.

OIL AND GAS DEVELOPMENT IN FIRST DECADE OF 1900

Ragland Pool.—Beginning in the early part of 1900 another wave of oil excitement swept over the State—the greatest since the one affecting the whole Eastern United States in the sixties of the previous century. It may be said to have begun with the discovery of oil on the old Uncle Tommy Ragland farm, in the valley of the Licking River about seven miles southeast of Salt Lick, Bath County.

Two wells had just been put down by the Mt. Sterling Oil and Gas Company when visited by the president of the company and the writer, in February, 1901. These wells, which were pure "wildcat," were found to have been located by chance on the southeastern flank of a steeply dipping monocline. They were about 340 feet deep. They began in the Lower Waverly and derived their oil—a heavy black variety—from the Onondaga limestone (so-called "Corniferous").

A number of companies soon entered the Ragland Field, and a great many wells were put down, the original exploring company mentioned above, Mr. S. M. Robinson, president, alone putting down 137. The product was piped to Salt Lick and shipped out from there in tank cars. Also for a time it had connection with the Cumberland Pipe Line to the southeast. Drilling in the field practically ceased in 1903. The production gradually declined until today the output is very small.

Redrilling of the Cumberland River Field.—The strike in Bath County resulted in an increased activity in the Cumberland River Field. In Wayne County this resulted in the discovery of a new and deeper oil horizon —the Trenton. This rock had been reached and in some cases penetrated by deep drilling in various parts of the State, but up to this time had never proved productive.

The discovery in Wayne County of oil in the Trenton was made by Captain Geary at Sunnybrook in May, 1901. The Bertram Number 2, which, beginning near the top of the Waverly, here struck the Trenton at 870 feet, yielded at eight feet in the "sand" a flow of 350 barrels of oil per day. As in the case of all other pools struck since in the Trenton in this State the supply of oil was soon exhausted.

The years 1901 to 1904 witnessed a pretty thorough redrilling of the Wayne-Cumberland-Clinton-Russell County Field, and the extension of operations into surrounding counties. Some of these in Wayne County were drilled to a considerable depth, one, a dry hole, reaching the top of the Calciferous at 2,435 feet. The Lowry Well, at Cloyd's Landing on the Cumberland River below Burkesville, came in as a gusher about July 23, 1902. It ignited from the fire under the boiler and burned furiously for ten days before the fire was extinguished and the well brought under control. It yielded after this only a few hundred barrels before it became exhausted. The well started in the upper Cincinnatian, and got its oil in the Trenton at 570 feet. A number of other wells were put down in the immediate vicinity which struck oil in varying quantities at depths ranging from 400 to 825 feet. In addition to these, some thirty-five or forty wells were drilled by the New Domain Oil and Gas Company in other parts of Cumberland County, eighteen of these yielding enough oil to be pumped. They mostly began in the Cincinnatian and reached into the Trenton. Some went below, but found no oil. The deepest of these, of which we have a complete record, was one drilled by the New Domain Company, 1,680 feet, ending in the Knox dolomite, which here, as in Tennessee, intervenes between the Camp Nelson and the Calciferous.

A well drilled on Clear Fork of Caney Fork of Wolf Creek in Russell County during this period struck gas under such pressure that it quickly ignited from the fire under the boiler and burned up the derrick. The driller scarcely escaped being incinerated.

Discovery of Oil in Knox County.—Further up towards the Head of the Cumberland River oil was discovered in 1901 on Little Richland Creek north of Barbourville in Knox County. The productive sands, which belong in the Pottsville conglomerate measures, were found to be three in number. Named in descending order with their approximate intervals these are as follows:

60 to 300 feet

Wages

Interval 100 to 135 feet

Jones

Interval 200 feet

Epperson

Most of these wells were moderate producers only. They began in the Pottsville above the Conglomerate Series.

The deepest well—a dry hole—drilled in the district was at Grays, a station on the Louisville and Nashville Railroad. It penetrated to the Cincinnatian at a depth of 1,974 feet. Several wells deep enough to strike the "Big Injun" developed considerable flows of gas in it. Barbourville has been supplied with gas from these wells.

Menefee-Powell Gas Field.—In the northern part of Eastern Kentucky the extension of drilling operations outward from Bath County resulted in the discovery of gas in Menefee County and the adjacent portion of Powell. A later study of this field by Mr. M. J. Munn showed it to be trapped under a dome. Probably the first productive gas well in this field was drilled on Adams Branch in 1901 for Dr. Northcutt. The gas sand here was found to be the same as the Ragland (Onondaga). The wells, beginning in the Waverly, reached the sand at from 480 to 750 feet. Most of them were put down by the New Domain Oil and Gas Company. Individual wells were found capable of yielding upwards of 1,000,000 cubic feet of gas per day. When visited by the writer in 1907, soon after the field was purchased by the Central Kentucky Natural Gas Company for the purpose of piping the product to Central Kentucky towns, there were forty producing wells here. By 1914 the supply of gas in this field had so far failed that the company was confronted with the alternative either of giving up the attempt to furnish gas to its customers, or going to the Warfield-Kermit-Tug Fork Field for an additional supply. It chose the latter.

Scattered wells—all of them dry—were put down in other portions of Menefee County during this period. One of them, drilled to 3,131 feet, was up to that time (1907) the deepest well in the State. It started at about the top of the Conglomerate and ended in the Calciferous, which it struck at 3,125 feet.

Oil Exploration on the Caney Anticline, Morgan County.—A pronounced anticline, with an axis extending southwest to northeast in the vicinity of Caney, Morgan County, had been known to Kentucky geologists for a number of years. It was natural, therefore, that attention should be directed to this locality as a favorable place to explore for oil. Mr. J. B. Hoeing, afterwards State Geologist, and the writer, each made a special examination of this anticline in 1901 with a view to determining its oil possibilities. Two companies were organized to test the structure as the result of our investigations. Both of these companies—the Hoeing and the Eastern Kentucky—tested the north flank of this anticline with two wells each without success. One of these, drilled by the former company, reached a depth of 2,021 feet, penetrating the Cincinnatian 500 feet. As we shall see, eleven years later the Kentucky Block Cannel Coal Company tested the south side of the anticline with marked success.

Campton Pool, Wolfe County.—Guided by the alignment of the Ragland Pool with the Kentucky River Fault —which has been referred to previously as a continuous break extending from near Burdett's Knob in Garrard County to near Ruckersville in Clark, and thence by the Jackson Ferry fault as an offset to near Camargo in Montgomery County—the writer anticipated that another pool should lie just south of an eastern extension of the Glencairn fault—a break which at the time had been traced from near Irvine in Estill County to Glencairn on the Lexington and Eastern Railroad at the Powell-Wolfe line. With the assistance of Mr. A. R. Marshall tracing this break further to the northeast, the writer selected the region about Campton as bearing some such relation to the Glencairn fault as the Ragland District did to the Kentucky River fault. Development here fulfilled the anticipation. In 1903 the Becket-Iseman Company, closely followed by the Eastern Kentucky, sank several successful wells here which proved the existence on this structure of a productive oil pool. Between 1903 and 1909, when drilling this region ceased, about 300 wells were put down on this pool. The average depth was 1,250 feet, and the average yield at the start was about fifty barrels per day. The wells began near the top of the Pottsville conglomerate and the oil horizon struck was the Onondaga.

The discovery of the Campton Pool was the first instance in Kentucky of the successful requisition of the services of a geologist in oil exploration.

Wells in Other Portions of Wolfe County.—Other wells were drilled in other portions of Wolfe County. The most of these were dry. Some, however, obtained a show of oil and others a small pay. Six of these were near Zachariah. They ranged in depth from 1,000 to 1,250 feet. Another pool was discovered further east at Stillwater on the same structure as the Campton. Also northeast of Hazel Green several gas wells were struck. One of these, until recently, furnished the town with an abundant supply of gas.

First Irvine Pool, Estill County.—Following the discovery of oil in the Campton Pool, some shallow wells —seventy-five to 111 feet deep—were put down by Haselrig and Chenault in the valley of the Kentucky River at the mouth of Cow Creek, one mile east of Irvine. These developed a considerable amount of oil, which was pumped until a few years ago, when the supply became exhausted. The yards and shops at Ravenna belonging to the Louisville and Atlantic Division of the Louisville and Nashville Railroad are now located on the site of these wells. The noteworthy fact in regard to this pool was that it was located close by the outcrop of the sand (the Onondaga). This trapping of the oil so near the outcrop seems to be due to a fault—the Sweet Lick, which passes through the town of Irvine. This is a fault secondary to a larger fault which crosses the Kentucky River at the western side of Sweet Lick Knob, and passing through the Estill Springs grounds, splits the divide between White Oak Creek and its tributary, Sweet Lick. This appears to be the main Irvine-Glencairn-Campton-Daysboro-Lewis Station fault which is continuous across Northeastern Kentucky as far as the Big Sandy, and bounds the northern limit of oil production on this important Irvine-Cannel City-Paintsville oil and gas structure.

THE OIL AND GAS DEVELOPMENT IN THE PRESENT DECADE

Later Exploration of the Caney Anticline in Morgan County.—As referred to before, the first successful well drilled on this Caney Anticline was at Cannel City in 1912. It came in as a flowing well yielding 320 barrels per day. It increased and then dropped to a pumping well. When at its maximum it produced 12,000 barrels per month. In all about sixty-five wells have been put down on this pool on the headwaters of Caney Creek since the first ones were drilled there in 1901. Of these, fifty-eight are on the Cannel City Pool proper. Two of these were gas wells and two were dry. Their depths vary from 1,567 to 1,818 feet. The depths of the top of the sand, which is the Onondaga, are from 651 to 706 feet below sea level. The average interval between the top of the sand and the Cannel City Cannel coal is 1,612 feet. The interval between it and the Fire Clay coal (Number 4), as measured on the Susan B. Lykens Farm northeast of Cannel City, is 1,726 feet.

Elk Fork Gas Field of Morgan County.—During this period drilling operations in the northern part of Morgan County disclosed the presence of considerable gas in the Onondaga. The successful wells were put down by Dr. Collier of West Liberty on Elk Fork northeast of the town. In all there are about six wells here which supply the town with gas. They range in depth from 1,430 to 1,750 feet to the sand, which here lies approximately at 690 feet below sea level. One well reached the Cincinnatian at 1,505 feet.

Burning Fork Gas Wells of Magoffin County.—About this time three wells were drilled at J. T. Patrick's Store on Burning Fork, southeast of Salyersville. At shallow depths in the lower Coal Measures these wells developed enough gas to supply the town of Salyersville, to which it has been piped for a number of years.

Fallsburg and Busseyville Pools, Lawrence County.—While much and deep drilling has been done in Lawrence County prior to 1912, it was not until that year that oil exploration here was attended with any measure of success. The horizon found to be productive is the Berea. The wells are not heavy producers, but they are very persistent. Starting off at eight to ten barrels per day at the end of the first month, they drop to about four to five barrels, and at the end of six months to about three, at which rate they have continued to produce to date with little perceptible decline.

Discovery and Development of the Present Irvine Oil Pool.—The present period of oil development in the State may be said to have started with the drilling for Mr. Charles Dulin, Jr., of a successful well on the Dan Rollings Farm on Tick Fork of Cow Creek, about three miles northeast of Irvine. This was in 1915. The well was only 200 feet deep. Starting in the Waverly it penetrated the Ohio shale, here about 110 feet thick, and struck the oil immediately below in the Onondaga limestone. This horizon has since become generally known as the "Irvine sand." This well started an oil excitement which has far surpassed all others which have ever agitated the State.

The Irvine Pool proper, on which this well was located, has been found to extend from southwest to northeast for a distance of nine miles. Its southwestern end is about two miles from Irvine and its northeastern end is about one mile northeast of the old Estill Furnace. Its width ranges from one to two miles. On this pool have been sunk to date about 2,000 wells ranging in depth from 200 to 800 feet. The more shallow of these begin in the lower Waverly and the deeper near the base of the lower

Conglomerate Series of the Pottsville. The initial production of each varies from five to 200 barrels per day.

Further Development Northeastward Along the Irvine-Caney Anticlinal Structure.—During the years 1916, '17 and '18 oil production was traced further eastward and northeastward along the anticlinal and fault

98. A PUMPING OIL WELL
Furnace District, Irvine Field, Estill-Powell County. Photograph by A. M. Miller

structure which is now known to be continuous from Irvine to Paintsville.

The first pool found to succeed the Irvine was the Pilot, lying under the celebrated Ashley lease, over the line in Powell County, which is valued higher probably than any other oil lease in Kentucky, its present owners having refused, so it is reported, $2,500,000 therefor. This tract previous to the discovery of oil on it was just a poor broken mountain farm of about 300 acres, not worth over $4 per acre. Soon after the discovery of oil on his farm Mr. Ashley—the mountaineer owner—cashed in one-half of his royalty at $65,000, and bought with it a fine bluegrass farm near Winchester, where he is now living. During this period the section about Torrent was reprospected, and the old Campton and Stillwater pools were redrilled. A few scattered producers were found about Torrent, no wells of note in the Campton district, while the Stillwater was extended further northeastward in a narrow belt. Also a few additional wells were put down on the Cannel City Pool with moderate results. The most important development in 1918 was the discovery of the Big Sinking Creek Pool in northern Lee County. Recent wells have been struck in this region reported at 300 barrels per day. One is said to have flowed at the rate of 1,000 barrels per day. In September, 1918, the production from this pool amounted to 31,434 barrels per week and it bids fair to exceed in productiveness the Irvine Pool. It is the farthest south of any pool on the main Irvine-Campton-Stillwater-Caney-Paintsville structure. The total number of producing wells drilled to December, 1918, in the Estill-Powell-Lee field was estimated at 3,500. These had at that time a pipe line production of 88,000 barrels per week.

Station Camp and Ross Creek Pools.—South of the Kentucky River a small oil pool was discovered on Station Camp Creek where it is joined by Middle Fork. This is in Estill County. Also later than this the Ross Creek Pool on the borders of Estill and Lee Counties was discovered. Both pools appear to be on a minor structure which farther west in Madison County is marked by the Joe Lick fault.

Oil Exploration Elsewhere in Kentucky from 1915 to 1918 Inclusive.—Following the discovery of oil in the Irvine Pool, oil prospectors and geologists flocked to Kentucky from all parts of the country. Virtually all of Eastern and Southern Kentucky has been leased and everything which could be construed as structure—whether "anticline," "terrace" or "dome"—has been delineated upon a map. All the old pools were reprospected and drilled. Sporadic strikes were made in various portions of the State and some good gas wells obtained—as at Mize and on the Reed farm in Morgan County, on Mine Fork in Johnson County, on Sexton Creek, and on Bullskin in Clay County, and on Frozen Creek in Breathitt County—but no new oil territory has been developed outside of the Estill-Powell-Lee County Pools, and no new oil horizons discovered. Some additional pools have been discovered in Allen County, the most important being the Johnson, near Gainesville in the northern part of the county. Here a flowing well was struck which was reported at 500 barrels per day. The other pools in this county now being developed are south of Scottsville. They are the North Petroleum, Rodemer, Wildwood, Hinton, Miller, Fisher and Scottsville. The wells in all of these are shallow and small producers. A pipe line recently laid from Bowling Green into this county has led to a considerable increase in its oil output, reaching in October and November, 1918, 30,370 barrels.

The older fields in Floyd, Wayne and Bath Counties still have small production; the Beaver Creek, Floyd County, with fifteen wells producing 190 to 200 barrels per week; the 600 to 800 wells in Wayne out of a total of about 4,000 drilled since oil was first discovered there producing from 2,500 to 3,000 barrels per week; and the eighty-eight wells on the Ragland Pool out of a total of several hundred drilled since the discovery of the pool; producing about 375 barrels per week.

BITUMINOUS SHALE

Oil Shale as a Source of Petroleum and Gas.—Reference has already been made (on page 288) to oil distilling plants erected at Vanceburg in the late fifties of the previous century. These seem to have used mainly the Sunbury shale, a formation about ten feet thick, which there lies about 100 feet above the Ohio shale. South of the latitude of Irvine, whether on the east or west side of the Cincinnati Anticline, these two shales come together as the result of the thinning and disappearance of the sandstone and shale interval which separates them further north.

Tests made upon samples of this combined Ohio-Sunbury shale show it is capable of yielding from seven to twelve gallons of oil per ton, with 2,000 cubic feet of gas and one-third of a pound of ammonia per ton as by-products. The aggregate thickness of these two shales varies from about 250 feet in the northern part of its outcrop to twenty-five feet in the southern. Whenever the price of oil and the perfection of the process of distillation of it from shale justifies this method of obtaining oil and its by-products, there will be available in the State a practically inexhaustible supply of bituminous shale for this purpose.

BITUMINOUS SANDSTONE

Bituminous sandstone, or as it is commonly called, "asphalt rock," has been found chiefly in certain of the sandstones forming a border around the Western Coal Field. One deposit is known in Northeastern Kentucky.

NATURE OF THE PRODUCT AND USE TO WHICH IT CAN BE PUT.—So-called "Kentucky asphalt rock" is simply a sandstone impregnated with a thick tarry oil. Where found it is always above drainage, and appears to have been originally an oil sand. The thickening of its oil content is due to the evaporation of its more volatile constituents and the oxidation of the residue by reason of its being brought near the surface through the carrying away of the overlying strata during the process of erosion. It is an excellent material for the surfacing of streets and roads, needing little treatment other than crushing before it is spread over the surface of the roadway and then rolled. Heating to 400 degree Fahrenheit immediately before spreading and rolling is recommended for street surfacing. Some of the best streets in Buffalo were surfaced with this rock more than twenty years ago, and it has stood the test well. It has been used also for sidewalks in Pittsburg.

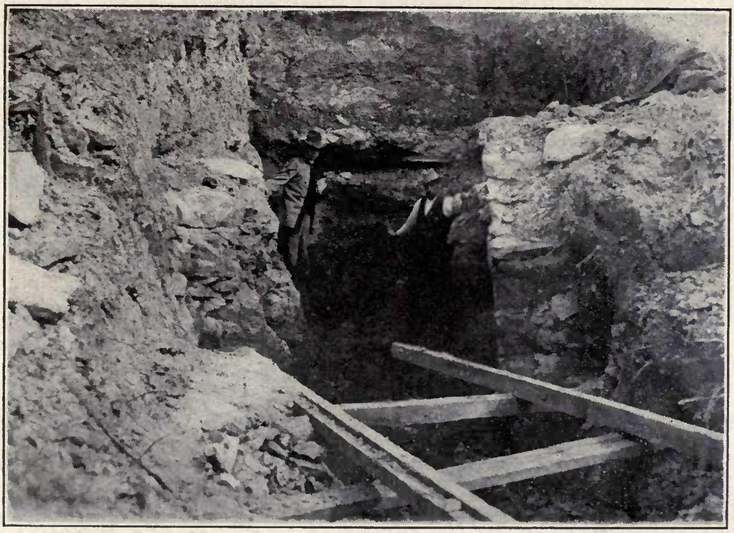
99. QUARRY IN BITUMINOUS SANDSTONE
Five miles northeast of Russellville, Logan County. Photograph by S. D. Averitt

WESTERN KENTUCKY ASPHALT ROCK DEPOSITS.—The deposits in Western Kentucky are about nine in number. They are in the counties of Breckinridge, Grayson, Edmonson, Warren and Logan.

The *Breckinridge County* deposit is two and one-half miles south of Garfield. It shows up there fifteen feet thick, richer towards the bottom than the top. It is worked as an open-face quarry. It is in the Cypress sandstone. (Mr. S. D. Averitt would place it in what he calls the "Leitchfield flag"—Hardinsburg sandstone).

The *Grayson County* deposits are three in number. Two of these—the Breyfogle and the Schillinger—are in the northeastern portion of the county. The former is in the Cypress and the latter according to Mr. Averitt, is in the "Leitchfield flag." The remaining deposit is four miles west of Leitchfield. It is in the Bee Spring sandstone of the lower Conglomerate Coal Measures.

The *Edmonson County* deposits are mainly in the Bee Spring sandstone. The best prospects are the one two miles northeast and the one one and one-half miles south of Bee Spring. Much of the product from this county has



100. OPENING ON BITUMINOUS SANDSTONE, SOLDIER, CARTER COUNTY
Photograph by A. M. Miller

been used recently by the Federal Government at Camp Knox.

The *Warren County* deposit is near Young's Ferry on the Green River. It is in the Bee Spring sandstone. It is fifteen feet thick.

There are three deposits in *Logan County*. These are rather centrally located, and are all found in the Cypress sandstone. The one which proved most profitable to work was a deposit eighteen to twenty feet thick, located five miles northeast of Russellville. It has now been worked out.

NORTHEASTERN KENTUCKY ASPHALT ROCK DEPOSITS.—There is a deposit of asphalt rock near Soldier in Carter County which has attracted some attention, but on account of its heavy overburden, preventing its being worked by stripping, has never been exploited. It is six feet thick. The lower four feet of this is saturated with the bitumen. It underlies several hundred acres. There is some doubt as to the geological horizon of this deposit. It was first thought to be in a basal sandstone of the Coal Measures at about the horizon of the Carter County fire clay. The recent determination of this fire clay to be of Chester age renders it probable that this bituminous sandstone deposit also belongs in the Chester.

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CHAPTER XIV

IRON ORE

At present no iron ore is mined and little is smelted in Kentucky, though it was a pioneer State in its production—the old Slate Creek Furnace erected near Owensville in 1790 being the first constructed west of the Alleghenies—and as late as the sixties of the last century it was the fourth State in the Union in the production of the metal.

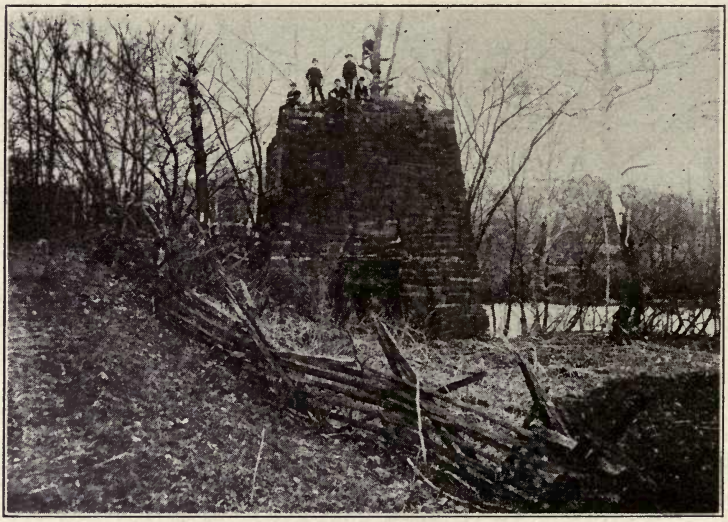
The geological horizons of the various beds of ore range from the Silurian to the Tertiary, inclusive. A tabular presentation of these horizons follows:

System	*Series*	*Iron Ores*
Cenozoic	Tertiary	Limonite ore at disconformity between the Mississippian and Tertiary: Lower Tennessee and Cumberland River deposits of Trigg, Lyon and Livingston Counties.
Paleozoic	Allegheny	Siderite and its weathered product, limonite: Red kidney ore between the Lower Freeport and Middle Kittanning (Numbers 8 and 7) coals.
		Siderite and its weathered product, limonite: Yellow kidney ore between the Middle Kittanning and Lower Kittanning (Numbers 7 and 6) coals.
		Siderite and its weathered product, limonite: Vanport (ferriferous limestone) ore between the Lower Kittanning and Brookville (Numbers 6 and 5) coals.
	Pottsville	Siderite and its weathered product, limonite: Main upper block ore between the Upper and Lower Mercer (Numbers 4 and 3) coals.
		Siderite and its weathered product, limonite: Block ore between Lower Mercer and Quakertown (Numbers 3 and 2) coals.
		Siderite and its weathered product, limonite: Block ore between Quakertown and Sharon (Jackson Shaft) (Numbers 2 and 1) coals.
	Mississippian	Siderite and its weathered product, limonite: Mammoth Cave limestone ore at disconformity between Mississippian and Pennsylvanian.
		Siderite and its weathered product, limonite: Concretionary ore of the Lower Waverly, Bullitt and Bath Counties.
	Devonian	Siderite and its weathered product, limonite: Oolitic limestone ore, Preston Ore Banks, Bath County.
	Silurian	Hematite and its weathered product, limonite: Clinton flaxseed (Brassfield) ore, Rose Run Mines, Bath County.

THE BATH COUNTY IRON ORES

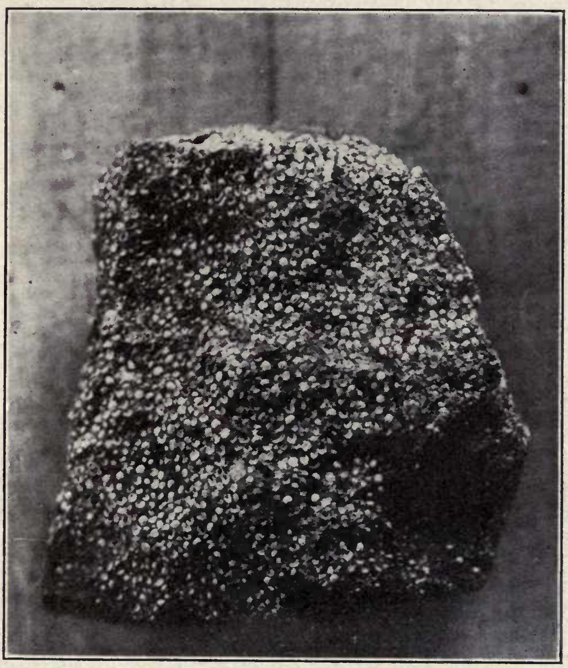
THE PRESTON ORE BANKS

Early Development of These Banks.—First of all iron ore deposits to be worked in the State were those on Slate Creek, southeast of where Owingsville, the county seat of Bath County, now stands. The first furnace for the smelting of this ore was erected in 1790 or 1791 by Thomas D. Owings, who came out from Baltimore for that purpose. The "palace in the wilderness," which he erected on the present site of Owingsville, and which still stands, was finished inside largely of material brought out on pack animals from the East. The beautiful spiral stairway is an object of special architectural interest. The ruins of the old furnace—the "Slate Creek Furnace"



101. OLD SLATE CREEK, IRON FURNACE
Bank of Slate Creek, near Owensville, Bath County. Photograph by A. M. Miller

—with a good-sized tree growing out of the top, stands on the bank of Slate Creek by the side of the road leading from Preston Station to Owingsville. It went out of operation in 1838. The iron ore smelted here was an oölitic carbonate or siderite in the unweathered condition. It occupies the place of the Onondaga limestone on the ridge to the east of the creek and Preston Station road, and is undoubtedly a chemical replacement of this limestone. It was only the limonite, a superficial weathered product of the carbonate, which was at first mined and smelted. A forge was erected on the creek further down toward the Licking River, and the iron smelted at the furnace was here worked into stoves and other utensils.

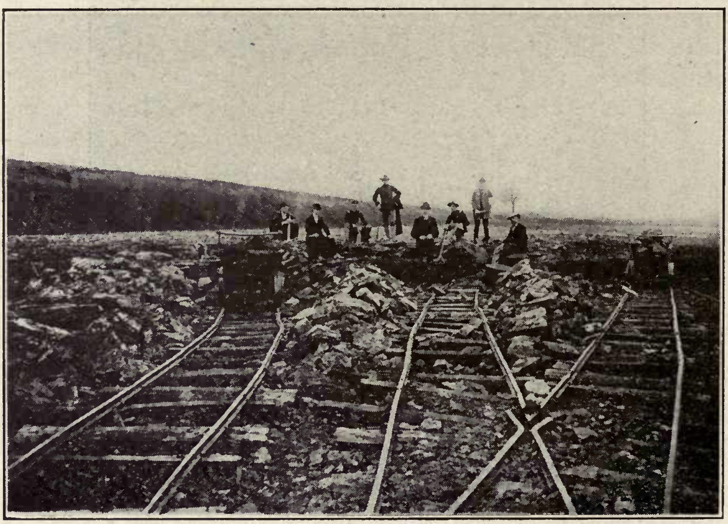


102. ONONDAGA OOLITIC SIDERITE
Preston Ore Banks, Bath County

During the second war with England cannon balls weighing about four pounds each were cast here and in 1814 were wagoned to the Licking River and thence shipped by flatboat via the Licking, Ohio and Mississippi Rivers to New Orleans for use of General Jackson in his battle there against the British. The writer has in his possession one of the cannon balls made in this lot.

Later Development and Exhaustion of These Banks.—Following the early development these banks were worked from time to time until they came into possession of General William Preston. Under his ownership the land on which the deposit was located was leased to a company organized by Professor N. S. Shaler and largely financed by New England capital. This company worked the deposit continuously from about 1880 to 1894, at the end of which period the ore was practically exhausted. The company mined both the carbonate and the oxide, roasting the former and washing the latter before it was shipped to Ashland, where it was smelted.

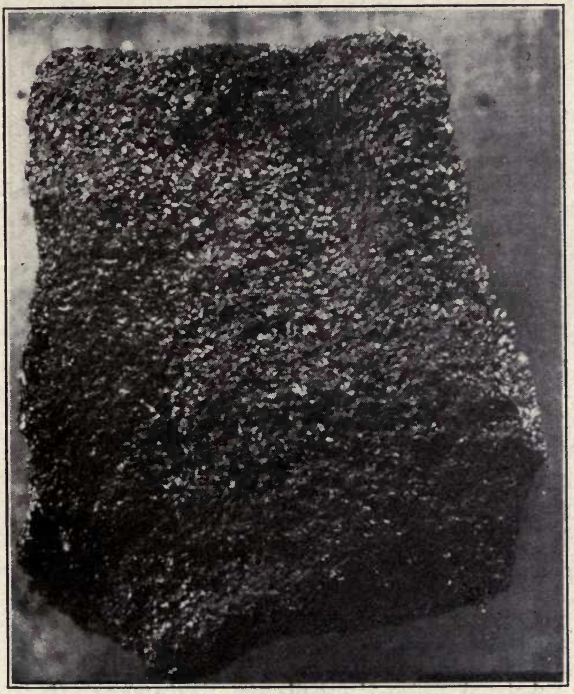
THE ROSE RUN IRON MINES.—After the exhaustion of the Preston Ore Banks the mining of iron ore in Bath County was transferred to Rose Run, about five miles northeast of Olympia on the Chesapeake and Ohio Railroad, from which a spur of track was laid to the mines. The mining of this ore, which is the Clinton, was con-



103. BRASSFIELD (CLINTON) IRON ORE BED
Rose Run Iron Mines, Bath County. Photograph by A. M. Miller

tinued down to two years ago, at which time labor strikes, accompanied by violence, caused the company to shut down for an indefinite period. The ore has the same chemical and physical characteristics here that it has at Rochester, New York; near Hillsboro, Ohio; LaFollette, Tennessee; and Birmingham, Alabama. It is an oolitic hematite, the flattened constitutent granules of which have caused it to be called "flaxseed ore." It is also known as the "dye-stone ore" because used as a red coloring matter. Still another name for it is the "fossil ore," because it contains abundant traces of fossils. The original carbonate of lime in the shells of these fossils has been replaced by hematite (iron oxide). It is a unique deposit. No other iron ore in this country has the same physical structure and appearance.

The average thickness of the bed in the Rose Run



104. BRASSFIELD (KENTUCKY CLINTON) OOLITIC HEMATITE
Rose Run Iron Mines, Bath County

region is about three feet. It occurs nowhere else in the Clinton outcrop of Kentucky in workable thickness. The best portion of this ore runs from forty-six to fifty-seven per cent. ferric oxide, which would yield in metallic iron from thirty-three to forty per cent. A considerable amount of lime carbonate accompanies the ore, so that it will frequently run as low in iron as twenty per cent. When the writer came to Kentucky in 1892 this ore was being mined and shipped to Ashland to be mixed in smelting with that from the Superior region. For this purpose the large amount of lime carbonate present was not objectionable, as it helped to flux the combined charge in the furnaces, and thus rendered unnecessary the addition of so much limestone.

Iron Ores Formerly Mined in the County.—Southeast of Salt Lick in the southeastern portion of the county a nodular iron ore from the Lower Waverly was formerly mined and smelted at the old Caney Furnace. This furnace was built in 1838. Also south of Salt Lick an ore in the same situation as the one next to be described—the one lying on top of the Mammoth Cave limestone—was mined and smelted at the old Bath Furnace.

THE RED RIVER IRON ORE DEPOSITS

Nature of These Deposits and History of Their Development.—Another very important deposit of iron ore, which early attracted attention in the State, was the limonite which so frequently occurs in pockets in erosion hollows on top of the Mammoth Cave limestone where it is covered by the conglomerate of the Pottsville Coal Measures. Before weathering it was probably a carbonate ore formed by replacement of the limestone. This ore is abundant along the western margin of the Eastern Coal Field north of the Kentucky River, and especially in the ridge forming the divide between the Kentucky and its tributary, the Red. On the latter river as early as 1806 or 1808 there was erected at the present site of Clay City by William Smith a furnace and a forge for the smelting of this ore. On account of its distance from the ore the furnace was torn down about 1830 or 1831 and the Estill Furnace was built on top of the divide at what is now Furnace Post Office. The stack of this Estill Furnace is still standing in a good state of preservation. In 1837 a rolling mill was erected at the Red River site where Clay City now stands. The ore smelted at the Estill Furnace, and later at the Cottage Furnace situated on the same ridge with it, was wagoned to the forge and rolling mill. Here it was converted first into blooms and then into bar iron and into nails. These products were then wagoned to the various Bluegrass towns and to Louisville. Traces of this old route are still preserved locally in such names as "Ironworks Road" and "Ironworks Pike"—as in Fayette County.

In 1869 a much larger furnace—the Fitchburg—was built on Furnace Fork of Miller's Creek. Including the cost of homes for the laborers, $1,000,000 was put into this enterprise. This furnace, like all the others of this and previous times in Kentucky, used charcoal for fuel. It had a capacity of fifteen tons of iron per day. Sixty dollars per ton was at first received for this iron. It was trammed down Furnace Fork and Miller's Creek to Scott's Landing on the Kentucky River and thence barged to a railroad. The iron was of such high quality as to be in great demand for manufacture of car wheels. Roughly estimated it took three tons of ore to make one of iron, and the charcoal required per ton of iron was about 179 bushels. This demanded for the wood used in the manufacture of the charcoal the clearing of about eight-tenths of an acre of land for every ton of iron smelted. It can be seen from this how rapidly the region about was denuded of forest during the time the furnace operated.

However, the industry, after the building of the Fitchburg Furnace, was short lived. The revolution in the manufacture of iron wrought by the introduction of coke for fuel and the opening up of the great iron mines of the Upper Great Lakes so cheapened the metal that this Kentucky enterprise soon went out of existence. The old Fitchburg Furnace, in excellent state of preservation, still stands, but of the town of some two thousand inhabitants at the height of its prosperity not a vestige remains.

OTHER IRON ORE DEPOSITS AT THE BASE OF THE COAL MEASURES

Those Along the Northwestern Margin of the Eastern Coal Field.—The same kind of ore as in the Red-Kentucky River region occurs northeastward along the margin of the Coal Field in exactly the same geological position; and smelting furnaces of the cold blast-charcoal-fuel type were built during this period in the neighborhood of its outcrop. The ruins of most of these still stand. One of them is the Beaver Furnace in northeastern Menefee County, built in 1819 by J. T. Mason and others. Another is the old Bath Furnace already referred to. Those still further to the northeast in Greenup County, which also used ores from higher geological horizons, were operated till a later period, and will be noted later in an account of the iron industry of Boyd, Carter and Greenup Counties.

Marginal Iron Ore Deposits of the Western Coal Field.—Around the margin of the Western Coal Field pockets of iron ore are also found in erosion hollows in

Mississippian limestone where this formed the floor on which the basal members of the Coal Measures were laid down. The same ore is found underneath the outlier of the basal Coal Measures in Green, Larue and Taylor Counties. There was erected in western Green County in the early day a furnace for the smelting of this ore. No trace now exists of this furnace but the slag which was run from it. There can still be found in the region an occasional tea kettle which was made from the iron.

IRON ORES OF BOYD, CARTER AND GREENUP COUNTIES

The Boyd, Carter and Greenup County iron ore district is continuous with that of the Hanging Rock District of Ohio. Indeed, the first mining and smelting of iron ore in this region began in Kentucky and spread to Ohio. It was in Greenup County in 1822 that the first furnaces of the district—the Argillite and the Pactolus—were built.

When Mr. P. N. Moore made his report for the Shaler Survey in 1884 there were thirteen of these furnaces in operation in Kentucky. Eleven of these used charcoal and two coal as fuel. The ore smelted was of three types —*limestone, block* and *kidney*. These ranged geologically from the top of the Mammoth Cave limestone to the interval between the Middle Kittanning and Upper Freeport coals of the Allegheny series.

The Limestone Ore.—The erosion hollows at the top of the Mammoth Cave limestone in this region carry an iron ore which is identical with the ore of the Red River region. It has been mined in the western part of Greenup County—almost exclusively in that portion lying west of Tygert Creek. It is not found in a region north of an east and west line through Bennett's Mills on this creek. Along with the block ores next to be described, it was smelted at the Kenton, Boone, Iron Hills, Raccoon, Laurel and New Hampshire Furnaces, which are situated in this portion of the district.

The Block Ores.—There are two horizons at which lower block ores occur in this region, one between the Sharon (Jackson Shaft) and the Quakertown coals, and the other between the Quakertown and Lower Mercer coals. They are carbonates which on exposure have weathered to limonites. They are called block ores on account of their cubical cleavage. Their range in thickness is from three or four to fifteen inches. The area of these lower block ores is that of the limestone ore previously described and they also extend eastward to the Little Sandy River.

A third block ore—the main upper seam—occurs between the Upper and Lower Mercer coals. Its distance from the base of the Coal Measures is from 300 to 350 feet. Its maximum thickness is approximately that of the other two beds, and its area overlaps them on the west. Towards the east the area extends as far as the outcrop of the Vanport (ferriferous) limestone next to be described. It lies, therefore, mainly in the Little Sandy drainage. The Raccoon, Buffalo and Laurel Furnaces drew their supplies largely from this ore.

FERRIFEROUS LIMESTONE ORE.—The Vanport limestone of Pennsylvania, in extending southwestward into Southeastern Ohio and Northeastern Kentucky, becomes largely replaced by a carbonate of iron deposit. This weathers to a limonite, furnishing the ferriferous limestone ore of this celebrated Hanging Rock iron manufacturing region. Its geological position is between the Brookville and Lower Kittanning (Numbers 5 and 6) coals. Its area of outcrop is in eastern Greenup and Carter Counties, east of the Little Sandy River, extending from opposite Ironton on the Ohio River to the Elliott-Lawrence County line south of Willard. Beginning at the Ohio River a line of furnaces—Amanda, Bellefont, Caroline, Old Steam, Pennsylvania, Buena Vista, Hunnewell, Star and Mt. Savage, at which it and the kidney ores were largely smelted, serves to indicate approximately its outcrop. Throughout this area its thickness varies from four to twenty inches, and the limestone on which it lies, or which it wholly or partly replaces, ranges from nothing to about five feet in thickness.

KIDNEY ORES.—These ores—the lower of which, the yellow kidney, lies between the Lower and Middle Kittanning coals, and the upper of which, the red kidney, lies between the Middle Kittanning and the Lower Freeport—are nodular segregation deposits often found in shales. Originally formed as a carbonate (siderite), they are now weathered to hydrated oxide (limonite).

The outcrop of these kidney ores lies farther east than the Vanport limestone ore just described. They are found mainly in Boyd County and in the extreme southeastern portion of Carter. In the former county they occur in the hills back of Catlettsburg and Ashland and in the drainage of Shopes Creek and East Fork of the Little Sandy; and in the latter county in the drainage of Lost Creek east of Willard. They were largely smelted in the same furnaces that used the ferriferous limestone ore.

Culmination and Decline of the Iron Industry in This Region.—The iron industry of Boyd, Carter and Greenup Counties appears to have reached its maximum development about 1884, since when it declined rapidly. At the time the writer came to Kentucky twenty-six years ago no furnaces were in operation in this district except those at Ashland, and these were largely occupied with the smelting of lake ores.

LOWER CUMBERLAND AND TENNESSEE RIVER IRON ORES

The iron ore of the district between the lower Cumberland and Tennessee Rivers is limonite. This lies on the Mammoth Cave limestone where it is overlaid disconformably by the Tertiary.

Extent of the District and the Furnaces Erected Therein.—The ore occupies for the most part the area lying between the two rivers. Furnaces were erected for the smelting of it as early as 1830. One of the earliest of these was the "Jim and I" in Lyon County. It operated until 1843 or '45. Other furnaces in this county with the dates of their erection were the Empire (1844), Suwanee (1844), and the Fulton (1844 or '45). In Livingston County there were two furnaces—the White, built in 1833 or '34, and the Hopewell, built in 1847. Crittenden County had one furnace—the Cobb, built in 1847. The furnaces built in Trigg County, with the dates of their erection, were the Laura (1852), Great Western (1852), Line Island (1852), and Trigg (1872). Also the Holman Rolling Mills were built in this county in 1844. As in the case of the other furnaces of this period in Kentucky, charcoal was the fuel used. Accordingly, with the introduction in the iron industry of coke for fuel and the discovery of the rich hematite ores of the Lake Superior region, these furnaces were soon forced to shut down. It was at one of these furnaces (probably the Suwanee of Lyon County) that William Kelly in 1851 discovered the process of making steel by blowing air into the iron to burn out the carbon. This process was afterwards credited to Bessemer, though he first performed the experiment four years later than Kelly. The priority of Kelly's claim was officially recognized in 1871, when, at the expiration of the Bessemer patent, the United States Commissioner of Patents extended the Kelly patent seven years longer. Kelly was the first person to import Chinese labor into this country, which labor he used at his furnaces. Sugar kettles for the Southern planters were extensively manufactured by him.

The Coalings.—During the time the furnaces operated in this region a considerable amount of iron was produced, causing nearly all the forest area between the two rivers to be cut over to supply wood for the charcoal. This region has been reforested by second-growth timber constituting a wilderness. On a visit to the region in the summer of 1896, the writer found that a few deer and wild turkeys still remained there. However, all game disappeared at least twenty years ago. In 1919 Mr. J. Quincy Ward, Fish and Game Commissioner of the State, stocked this area with deer brought originally from Michigan. The species is the common white-tailed deer (*Cariacus virginianus*). Owing to the sparse population of the region, and its protective river barriers, this is expected to become one of the finest deer ranges in the country.

MUHLENBERG COUNTY IRON ORE

Nature of the Ore and History of the Attempt to Develop It.—The ore is a siderite (carbonate) of the variety known as black band. It forms the roof of the Number 12 coals found in that region. It was first smelted in a furnace built in 1837 by Aylette H. Buckner, the father of General Simon Boliver Buckner. The remains of this structure, known as the "Stack," still stands at the junction of Pond and Salt Lick Creeks, five miles south of Greenville. A more ambitious structure was the Airdrie Furnace, built in 1857, on the banks of Green River near the village of Paradise. This was a Scotch enterprise, the funds being supplied for it by a rich iron manufacturer—a "laird," Sir Robert S. C. A. Alexander, who though born in this country (at Frankfort, Kentucky) had gone to Scotland on invitation of his titled bachelor uncle and there at death of the latter had succeeded to his title, estate and business. Induced by the exhaustion of the ore he was working in Scotland to look elsewhere for a similar variety (black band) he sent his geologists—the Hendries, father and son—to Kentucky to locate if possible such an ore there. They selected this Muhlenberg deposit as the most suitable, and "Lord Alexander," as he was called in Kentucky, bought up the large tract of land under which the deposit was known to occur and transported thither virtually his whole iron-working force. Unfortunately the ore was not quite the same as the black band ore this force had been working in Scotland, and the Number 12 coal of the Western Coal Field was not quite the same as the coal they had used in Scotland as fuel for the furnace. After spending in two years the sum of $350,000 without being able to produce one pound of saleable iron, Alexander gave up the attempt in disgust and retired to a large Bluegrass estate he had purchased in Woodford County. This is Woodburn—the famous Alexander estate—which at Sir Robert's death became the property of his brother.

There is little doubt, if Sir Robert in his iron making enterprise in Kentucky, had not surrounded himself so exclusively with his fellow-countrymen, but had taken some advice from successful iron men in this country, and especially from those who had had some practical experience in the iron business in Kentucky, that he would have succeeded, for a time at least, in manufacturing iron with profit from this deposit.

The Airdrie property afterwards passed by purchase into the hands of General Don Carlos Buell, who, while campaigning in Kentucky during the Civil War, became, like so many Northern soldiers, impressed with its industrial possibilities—especially those of oil, and returned after the cessation of hostilities to develop them. It was with this end in view--the development of oil—that General Buell purchased the property. Failing in this he settled on the estate and turned his attention to coal mining. It was in this he was engaged at the time of his death.

BULLITT-NELSON COUNTY DEPOSITS

The iron ore of Bullitt and Nelson Counties consists of carbonate of iron concretions and their weathered hydroxide derivative—limonite. These concretions occur in the Lower Waverly (Cuyahoga) of the region. Little has been written of the exploitation of these deposits. We only know that during the main iron manufacturing period in Kentucky there was erected for the smelting of this ore at least one furnace—the Bellemont—in Bullitt County; and one—the Nelsonville—in Nelson County.

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CHAPTER XV

FLUORSPAR, HEAVYSPAR, CALCSPAR AND LEAD AND ZINC ORES

FLUORSPAR

Nature and Mode of Occurrence.—Fluorspar, commonly known among miners of it as "spar," is the mineral *fluorite* (fluoride of calcium). It is translucent to transparent, variously tinted (white and purple colors

105. FLUORITE BANDED WITH GALENITE, FROM CRITTENDEN COUNTY

being the most prevalent) and when crystallized is in cubical forms. It is found in fissure veins and in replacement and brecciated deposits, the vein type of deposit being the most common. It occurs extensively in Southwestern Kentucky—chiefly in the counties of Crittenden, Livingston, Caldwell, Lyon, Christian and Trigg, and slightly in the Bluegrass Region. In Crittenden and Livingston Counties the veins, which traverse Upper Mississippian limestone, are intimately associated with a system of normal faults. These faults have two prevailing directions of strike—a northeast-southwest and a northwest-southeast. There are also in this region dikes of mica-peridotite, which have the same prevailing directions of strike. The best veins of fluorspar usually have the northeast-southwest strike. These veins also sometimes carry small amounts of lead and zinc sulphide (galenite and sphalerite) intimately mixed with the fluorspar as the gangue (veinstone) mineral.

It is thought by some economic geologists that the fluorspar and disseminated galenite and sphalerite were deposited by ascending heated waters which carried them, or at least the fluorine of the fluorspar, from igneous rocks below. The presence of peridotite dikes cutting the country rock in the region would lend support to this view.

The faults with the accompanying veins and dikes have blocked the district out in checkerboard fashion. This is especially true of Crittenden County, where most of the faults and veins occur.

The fluorspar vein deposits of Western Kentucky are of two types—the *solid* and the *gravel.* The latter type is produced by long continued weathering of the former. The solid veins vary in width from a few feet up to fifteen, and extend down to unknown depths. The gravel type vein has been known to show a width of thirty-six feet. The linear outcrop of the vein generally extends for miles.

The deposits of the Bluegrass Region are of the solid vein type. They traverse Highbridge limestone. Only two of these are known to have much extent in outcrop, depth and width. These are the Smitha vein on Boone's Creek and the Faircloth vein on the north side of the Kentucky River at Mundy's Landing.

MINING.—At the time (1907) when Julius Fohs issued his report on Fuorspar Deposits of Kentucky there were known to be 223 mines and prospects of that mineral in Western Kentucky. These were distributed by counties as follows: Crittenden, 127; Livingston, 50; Caldwell, 19;

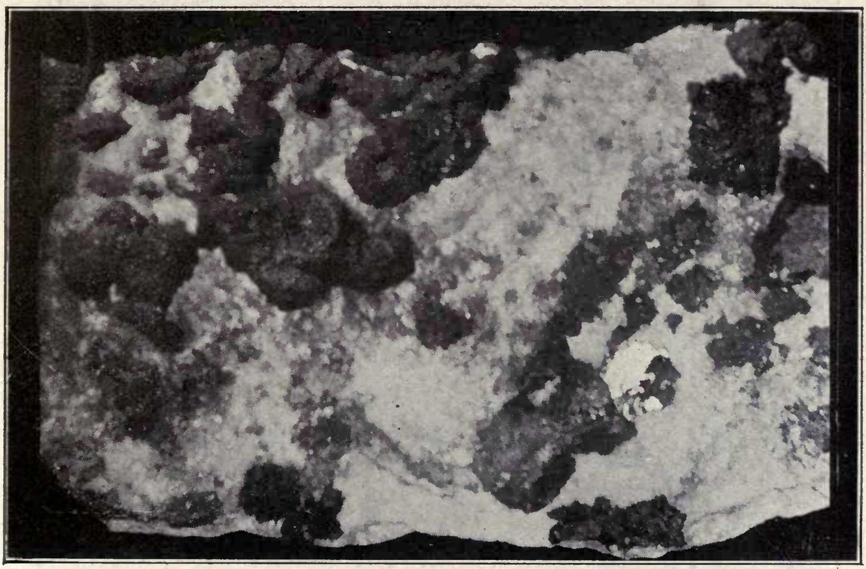
Christian, 8; Lyon, 6; and Trigg, 11. From the extent of the deposits indicated by these developments Mr. Fohs estimated that the total supply of the mineral there would approximate 200,000,000 tons--enough to meet the demands for its chief use, fluxing iron, for the next six to twelve centuries.

In 1906 the price paid for crude lump fluorspar varied at the mines from $3.85 to $8.70. At present (1918), owing to the stimulation of the iron industry by the Great War, the price paid is $40 to $50 per ton. In consequence of this there is great activity in the mining of fluorspar in the Western Kentucky District—making it the greatest fluorspar producing region in the world.

Uses.—Besides its chief use in iron smelting, common fluorspar is used as a flux in extracting certain other metals from their ores, for instance, aluminum; as one of the ingredients in the manufacture of glass, especially the opalescent variety; as a flux in producing glazes and enamels in pottery and fireproof crucibles; as a source of fluorine in the production of hydrofluoric acid (whose chief industrial use is cleaning iron castings); and as an ingredient to give high luminosity to the carbon electrodes in the flaming arc light. Besides these more purely industrial uses fluorspar ministers to the aesthetic taste by supplying in some of its rarer varieties a material which can be cut into ornamental objects, and even gems; though it is rather soft for the latter purpose. In its variety known as "optical fluorspar" it also supplies a very necessary transparent medium for correcting an optical defect in glass when the latter is ground into lenses for microscope objectives. In order to make a microscope objective "apochromatic" a small lens of transparent fluorspar must be inserted between the pair of small glass lenses in it. Only the clearest material devoid of flaws can be used for this purpose. This variety is so rare as to command a price "above rubies." Fohs discovered that some of the Western Kentucky product is optical, and it has been determined recently that the Bluegrass product has a higher ratio of specimens with this property than the fluorspar found elsewhere in the section. For lack of recognition by the workmen in the mining of fluorspar it is doubtless true that much of the precious variety has been in the past shoveled into cars along with the common grade and sold at five dollars or less per ton, when it was worth that much or more per pound.

HEAVY SPAR

NATURE AND MODE OF OCCURRENCE.—Heavyspar, barytes or barite is sulphate of barium. It is a white, usually non-crystalline, mineral occurring in veins and cavities in limestone. Its common name, "heavyspar," and its mineralogical name, "barite"—the latter from the Greek



106. BARYTES AND ZINC BLENDE AND CAVITIES FROM WHICH ZINC BLENDE HAS BEEN LEACHED
Mosby Prospect, Woodford County

baros, weight—indicate its weighty character. Its specific gravity is about four and one-half.

Its commercial occurrence in the State is virtually confined to the Inner Bluegrass Region, where it is found as the main filling of fissure veins traversing Lexington (Trenton) limestone. These veins range in thickness from a few inches up to twenty feet. One to three feet may be taken as a fair average of the thickness. In strike outcrop the veins frequently extend for several miles. In depth the barytes content of the veins usually terminates in passing from the Lexington into the underlying Highbridge limestone. The fissures extend below, but the filling usually changes to calcite, or in some cases to fluorite.

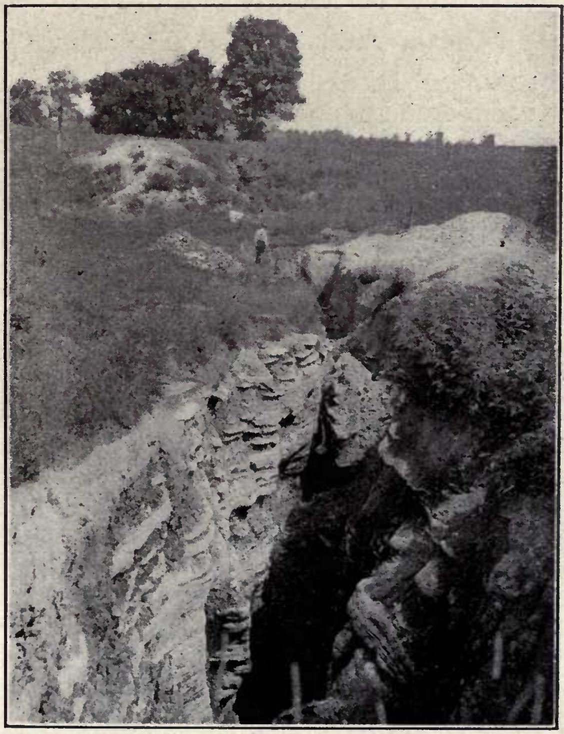
The prevailing strike of the veins is north and south. Disseminated in the gangue of these veins—whether it is barite, calcite or fluorite—galenite and sphalerite are apt to occur. These ores of lead and zinc, however, bear in the aggregate a very small ratio to the amount of the gangue.

107. BARYTES ENCRUSTED WITH STRONTIANITE
Johnson Mine, Scott County

MINING.—Fayette County leads in the number of veins that have been worked. The other counties where veins have been opened are Jessamine, Garrard, Woodford, Clark, Bourbon, Scott, Franklin and Owen. Mining is primitive, consisting of open trench excavation by which only the superficial portion of the mineral is removed. Most of this is shipped to Nicholasville, where it is prepared for use by the Central Pigment Company, being ground to a fine powder in a mill. The price paid for crude barites at the mill was formerly (1909) $4.50 per ton, but the present war price now is $9 to $10 per ton. The bleached ground or floated barytes sold in 1909 for

$17 to $22 per ton. The price of *blanc fixé* in the same year was $40 to $55 per ton.

Uses.—The chief use of ground barytes is in the manufacture of paint, either mixed with white lead, or as the sole ingredient. Very fine grinding adds to its value for this purpose. The best form of the mineral for paint, however, is the chemically precipitated barium sulphate, or *blanc fixé*. Other uses for ground barytes are, as a filler for leather belting to give this greater gripping



108. A WORKED VEIN OF BARITE NEAR KEEN, JESSAMINE COUNTY
Photograph by H. Ries

power; as a filler for canvas fabric for the sacking of hams, making this impervious and incidentally adding considerably to the weight; as an ingredient in rubber for automobile tires; as an enamel for pottery, and under the name "lithopone" (a compound of barytes and zinc sulphide) as an enamel for iron; in the form of the sulphide as a depilatory; and finally as an ingredient in lithographic ink. Until outlawed by pure food legislation and inspection it was also used in the United States as an adulterant for food, especially flour. This adulterated product is still shipped abroad, particularly to the West Indies and Latin-American countries, where pure food laws do not obtain. However heavy the bread made from this flour may lie on the stomachs of the consumers, it would seem that this meanest of commercial frauds rests lightly on the consciences of the food profiteers.

CALCSPAR OR CALCITE

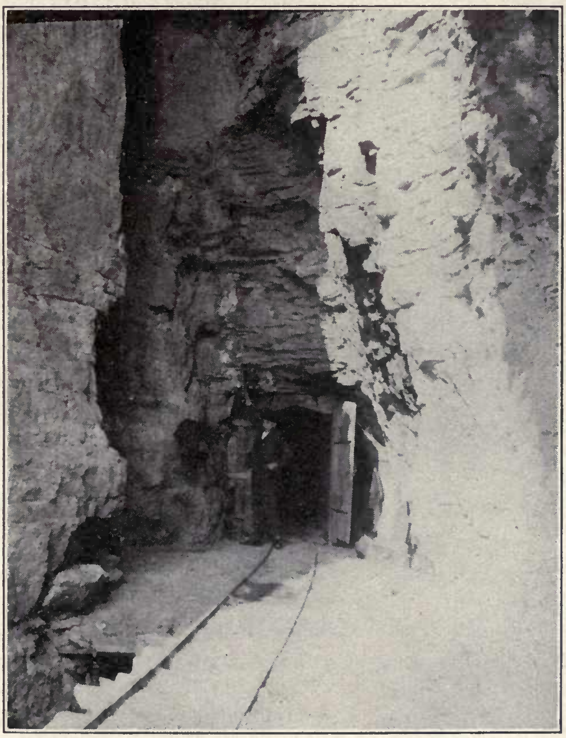
Calcspar, calcite, or crystallized calcium carbonate is a white soft mineral breaking with a rhomboidal fracture. Only one commercial deposit of this is at present worked in the State—that belonging to Colonel Jack Chinn on the Mercer County side of the Kentucky at the mouth of Shawnee Run near Mundy's Landing. It is a nearly vertical fissure vein from six to sixteen feet wide, exposed in the steep face of Highbridge limestone and traceable back from the river cliff to the south for at least a mile. On the north side of the river the content of the fissure changes to fluorite, constituting the Faircloth vein mentioned in the account given previously under the head, Fluorspar. The calcite is ground to a fine flour by the Chinn Mining Company in a mill located on the river at the mouth of the mine. The mill has a capacity of sixty tons of ground calcite per day of twenty-four hours. The product, which is barged to Highbridge and shipped out thence by rail, commands, loaded on the cars, $20 per ton.

Recently a vein of calcite has been uncovered on the Crutcher Farm near Camp Nelson, which promises to yield the mineral in good quantity. It is remarkably pure and exhibits to a marked degree the rhombohedral cleavage of the mineral. Some specimens are so transparent as to entitle it to the name "Iceland Spar."

Uses.—Pulverized calcite, known as "Spanish white," is used as one of the constituents in the manufacture of putty, paint, automobile tires and optical glass. The growth of the moving picture industry has contributed much to the use of calcite for the last named purpose, as the lenses in the projection apparatus must be made from glass which has been made "optical" by the addition of this substance.

LEAD AND ZINC ORES

In association with the fluorite, barite and calcite deposits just described, there occur in the mineral veins of the State galenite (lead sulphide), sphalerite (zinc sulphide) and smithsonite (zinc carbonate). Attempts to mine these deposits for the lead and zinc content date back to pioneer days. They were not attended with much success, though a Pennsylvania company in recent years did operate for some time a mine on the Kentucky River near Gratz in Owen County, and for about the same period a lead and barytes works operated at Kissinger on the Georgetown and Frankfort Railroad near the Scott-



109. ENTRY ON LEAD VEIN, GRATZ, OWEN COUNTY
Photograph by A. M. Miller

Franklin County line. Galena concentrate was made at the former place and shipped to St. Louis. The Kissinger works produced lead fume in addition to barytes products. Also from about 1906 to 1909 galena concentrate and zinc sulphide and zinc carbonate—chiefly the latter—were shipped from one or two mines in Crittenden County. The greatest amount of lead ore (galena) shipped from these Crittenden County mines in any one year during this period was 107 tons, and the greatest amount of zinc ore (sphalerite and smithsonite) shipped from the same mines in any one year was 1210 tons.

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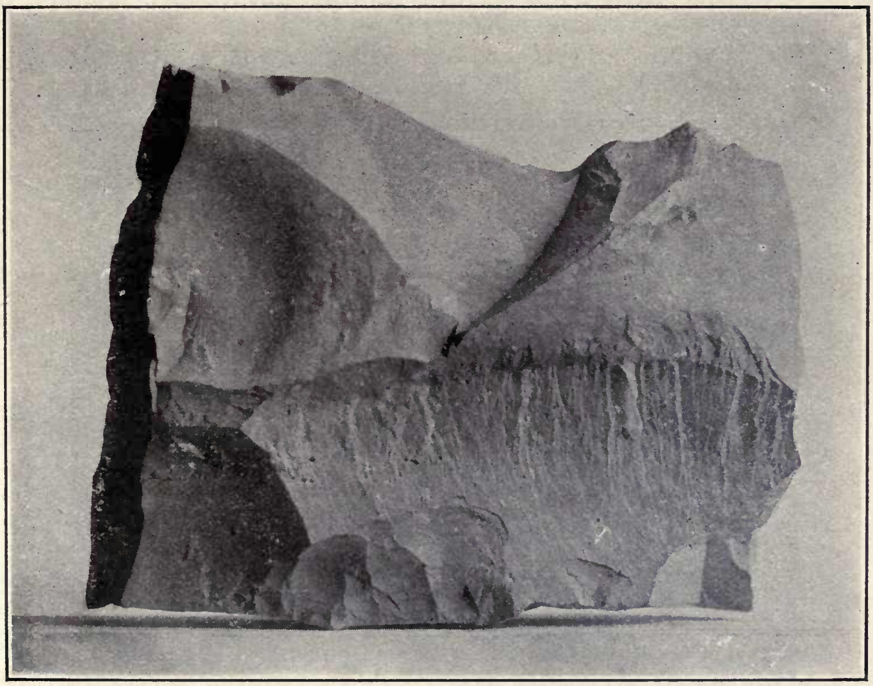
CHAPTER XVI

CLAY AND STONE

Clay.—Clay, which is a soft rock composed largely of kaolin (hydrated silicate of alumina) is widely distributed in Kentucky. This clay is either residual (formed in place by the decay of the rock in that locality) or transported (brought into its present position by the action of water). There is hardly any section of the State which is not supplied with clays (usually residual) pure enough to be burned into ordinary building brick and tile. Less



110. OLIVE HILL FLINT CLAY, SHOWING CONCHOIDAL FRACTURE

frequent in occurrence are clays of a higher degree of purity suitable for the cheaper grades of stoneware and crockery. Rare, but existent in commercial quantities in the State, are those clays of such high degree of purity and of such physical constitution that they can be used to make fine pottery, or have such a heat resistence that they can be employed in the manufacture of fire brick.

The clays of the State may be grouped under the heads: *fire clay, pottery clay* and *brick clay.*

FIRE CLAY.—This is a clay so free from such fusible substances, as the compounds of iron potassium and sodium, that it will stand a high degree of heat (not less than 3,000 degrees Fahr.) without melting. Such clays are termed "refractory" and can be used in the manufacture of fire brick for the lining of furnaces used in the smelting of ores, for the construction of fire boxes in locomotives, and for the making of crucibles, glass pots and gas retorts.

Highly satisfactory clays of this nature are found chiefly in Northeastern Kentucky—in the counties of Carter, Greenup and Boyd, and in adjacent portions of Rowan and Morgan. The most important deposit here

111. FLINT FIRE CLAY INTERBEDDED WITH CHESTER
The light colored band is the fire clay. Cut of Morehead and North Fork Railroad, Blairs Mill, Morgan County, Photograph by A. M. Miller

is the clay usually found on top of the Mammoth Cave limestone, or in its absence on top of the Waverly formation. This consists largely of the flint or non-plastic variety, in which the kaolin has undergone secondary recrystallization, though some plastic clay is found at the same horizon. Occurring as it does at the top of the Mississippian Series, and closely overlaid disconformably by the Lower Pottsville Coal Measures, it has been held to be a residual deposit from the limestone, which had been decomposed by atmospheric decay and whose soluble parts had been removed by erosion before the deposition of the Coal Measures. However, the discovery by the writer that a deposit of this clay, near Blair's Mill Station on the Morehead and North Fork Railroad in northern Morgan County, was interbedded with Chester strata establishes its Chester age, and its undoubted stratified structure indicates that it must have been transported by water to its present position. Occasionally in the same region pockets of fire clay—probably transported—are found above the Conglomerate bed. The Chester fire clay, in the district referred to, ranges in thickness from nothing to twenty-seven feet. Six feet is considered a good workable thickness. The clay is known to occupy a large area stretching in a belt approximately thirteen to eighteen miles wide from Scioto County, Ohio (Sciotoville fire clay) to and beyond the Licking River in Morgan County, Kentucky, a distance of fifty-five miles.

This belt is transected nearly midway by the Ashland-Louisville Branch of the Chesapeake and Ohio Railroad, along which it is extensively mined and manufactured into fire brick and refractory ware. Olive Hill constitutes the center of this district. Here it is that there is a deposit of flint fire clay twenty-seven feet thick, and here it was in 1895 that Eifort, Grahn and Staughton erected the first fire brick plant built in the State. The erection of other plants followed; in 1900 that of the Ashland Fire Company at Hayward, nine miles west of Olive Hill; in 1903 that of the Kentucky Fire Brick Company at Haldeman in Rowan County; in 1910 that of the Olive Hill Calcine Company at Olive Hill; and recently that of the Louisville Fire Brick Works at Grahn, five miles east of Olive Hill. In addition to what is worked up at the above mentioned plants a considerable amount of clay is shipped to Ashland from these mines and there manufactured into fire brick by the Ashland Fire Brick Company. Near the northern end of the Kentucky portion of the district, which is divided into nearly equal east and west portions by the northward flowing Tygert's Creek, there is a plant owned by the Charles Taylor Sons located at Call at the mouth of Tygert's Creek. This station is on the Ashland-Cincinnati Branch of the Chesapeake and Ohio Railroad.

To the eastward in this same Northeastern Kentucky region, fire clay occurs at higher geological horizons than this Olive Hill fire clay. The only one of these, which up to the present has been profitably worked, is the deposit lying on top of the Vanport, or "ferriferous" limestone. (See an account of the areal distribution of this limestone in Kentucky in Chapter XIV on Iron Ore). This is a plastic fire clay, reaching in some places a thickness of five feet. The belt in which it is found varies from about two miles wide in the southern part near Willard, to about fourteen miles wide near the Ohio River. The largest fire brick plant in Kentucky, and probably in the world, has been built at Hitchins, at the crossing of the Eastern Kentucky and the Chesapeake and Ohio Railroad, for the utilization mainly of this clay. The maximum daily capacity of this plant, which belongs to the Olive Hill Fire Brick Company, is 100,000 bricks.

A very characteristic flint fire clay, usually full of plant remains, has been referred to in the account given of the Eastern Kentucky coals as almost constantly associated with the Upper Mercer, or the Number 4 coal. It is widely known as the "Fire Clay coal" for this reason. The clay, however, never occurs thicker than a few inches and hence has never been commercially utilized.

There is a deposit of fire clay in the neighborhood of Smithland, Livingston County, in the western part of the State, which from 1899 to 1902 was mined and shipped by the Western Clay and Mining Company to the Western Tube Company at Kewanee, Illinois. It was there used in the making of fire brick of a reputed excellent quality. This deposit rests on the Upper Mississippian limestone, where it is here overlaid disconformably by the Lafayette sands and gravels, and may be either a residual product from the decay of the limestone, or a transported product laid down during the Lafayette sub-stage of the Tertiary. If a residual product of the limestone it must have formed during the erosion interval in this region represented by the disconformity between the Mississippian and the Tertiary.

Fire clay of Tertiary age is known to occur in the Purchase Region, but it has not been exploited to any extent for the making of refractory products.

Pottery Clay.—A pottery clay is a plastic variety comparatively free from ingredients which will cause discoloration when calcined. Of these iron oxide is the most objectionable.

The only clay occurring in Kentucky which satisfactorily complies with these conditions is one found in the LaGrange Formation of the Purchase Region. Graves County leads in the production of this clay; the deposits near Boas, Pryorsburg and Wingo being especially worthy of mention. Clay from these deposits tested at the Rookwood Pottery in Cincinnati proved to be very satisfactory for the manufacture of chinaware. In the Purchase Region, however, it has been manufactured in the local potteries only into the more common grades of earthen and stoneware—such as jugs, mugs, churns, flower pots, cuspidors, filters, coolers, flue thimbles and into brick and tile. Exceptionally pure grades of this clay can also be used as one of the ingredients in the manufacture of fine grades of paper.

The following is a list of the potteries in operation in this district in 1905:

McCracken County—J. P. Bauer's, Paducah.
Calloway County—W. K. Russell's, Pottertown.
Graves County—W. B. Howard & Sons, Bell City.
" " —Water Valley Pottery Company, Water Valley.
" " —Mayfield Pottery, Mayfield.
Hickman County—Schenk & Rocker, Columbus.
Ballard County—Wickliffe Pottery, Wickliffe.

Brick and Tile Clay.—In the Purchase Region common brick and drain tile is made from the brown loam of the Pleistocene. A partial list of the brick, or brick and tile, plants in the district is as follows:

McCracken County—Hill & Karnes, Katterjohn & Sons and Chamberlain and Murray—all three at Paducah.
Calloway County—Hazel Brick & Tile Company, Hazel.
Graves County—McDonald Bros., and Mayfield Brick Company, both of Mayfield.
Carlisle County—Bardwell Brick and Tile Company, Bardwell.
Fulton County—G. H. Bransford & Sons, Fulton.

Throughout the rest of the State, as indicated at the beginning of the chapter, there is not a county which does not possess deposits of clay of sufficient purity for at least brick and tile, and in some instances for the commoner grades of pottery, such as jugs, crocks and stoneware jars. Most of these clays are residual, but some are transported—as for instance those in the bottom lands. In one instance—near Waco, Madison County—a deposit, laid down by the Kentucky River during a past cycle of erosion, is used in the manufacture of earthenware pottery, drain tile and roofing tile. This deposit belongs to the Irvine Formation of Pliocene or Pleistocene age.

There is only one instance in Kentucky of clay being used to supply one of the two ingredients used in the manufacture of Portland cement. This is an alluvial deposit near Kosmosdale in Jefferson County.

Building Stone.—Stone suitable for structural uses occurs at many different geological horizons in the State. Treated in the order of their geological succession these beds are as follows:

The so-called "Kentucky River marble"—a magnesian limestone often presenting a mottled appearance—is in the Highbridge Series. It is the Oregon Bed, which outcrops along the Kentucky River from Boonesboro to Camp Nelson when the river is on the northwest side of the Kentucky River Fault, and below Camp Nelson all along the river until the formation sinks below drainage at Clifton. Important quarries of this bed were formerly located in Fayette County near Grimes Mill on Boone's Creek, and near Clay's Ferry on the Kentucky River. Boone's monument and the columns of the old State House at Frankfort and the shaft of Clay's monument at Lexington are built of this stone.

Immediately overlying the Oregon is the Tyrone. This compact, light-colored or dove-colored limestone, breaking with a conchoidal fracture and exhibiting on its fractured surfaces facets of calcite which have given to the rock the name "birdseye," is a very durable stone. It whitens on exposure and gives a pleasing effect in foundations and building walls. It has been much used along the Kentucky River in the same stretch as that described for the Oregon bed, and in addition extends down below Frankfort as far as the mouth of Steele Branch. It appears in many of the more substantial buildings and finer residences in Frankfort, as the old Capital Hotel, gutted by fire in recent years, the old State House, the Penitentiary walls, and a number of attractive homes in South Frankfort. From it also were built many of the distilleries and mills along the river, some of the older of which have been abandoned and now form picturesque ruins.

Next above the Tyrone is the grayish, crystalline Lexington, or Trenton, limestone, much used for foundations and occasionally for walls of buildings in Lexington and other central Bluegrass towns near outcrops of this formation.

Northeastward from the central Bluegrass area, the next overlying formation—the Cynthiana—exhibits thick enough layers to be quarried for structural uses. This is particularly so on the Ohio River above Cincinnati; as at Moscow Station on the Chesapeake and Ohio Railroad.

Above this last mentioned horizon no other stone of marked suitability for building purposes occurs until the Niagara is reached. It is from the Louisville limestone member of this that much of the material for foundations in Louisville is obtained. It is a magnesian limestone and quite durable.

The next building stone above the Niagara is the Berea in the Lower Waverly. It affords a highly desirable sandstone for structural uses, and is much quarried along the Ohio River in the neighborhood of Vanceburg. Further southward it thins, and south of the Ashland-Louisville branch of the Chesapeake and Ohio Railroad is hardly recognizable as a distinct horizon. However, in these more southerly situations its place is taken by sandstone layers in the Cuyahoga. These are very even courses interstratified with shale. There are extensive quarries of this stone at Farmers on the Licking River in Rowan County. The trade name for it is "Rowan County stone."

Still further south in Kentucky the Upper Waverly furnishes a valuable building stone. This is in Rockcastle County, where at Orlando and neighboring stations on the Louisville and Nashville Railroad it is quarried and marketed under the name of "Rockcastle freestone." This is at the horizon of the "Big Injun" oil and gas sand of West Virginia and Eastern Kentucky.

In the Mississippian above the Waverly most of the limestones are at least suitable for foundations and are in local demand for that purpose. At two horizons—the Fredonia and the Gasper—the texture of the stone is oolite, similar to that of the celebrated Bedford stone of Indiana from a lower horizon than either. Both are fully the equal of the Bedford stone for building purposes, and the Gasper especially, under the name "Bowling Green stone," has an established reputation among builders which makes it a rival of the Indiana variety.

The sandstones both of the Chester and of the Coal

Measures are scarcely even-bedded enough to be very suitable for building purposes. However, there are certain beds in each which have a local reputation for chimneys, fireplace backs, well curbs, and even tombstones, and there are not wanting in certain localities workmen who have achieved considerable skill in dressing and building these sandstones into substantial and even ornamental structures.

Lithographic Stone.—Stone capable of being used in lithography has been yielded by certain beds of the St. Louis limestone—particularly in Estill County, and near Brandenburg in Meade County. It, however, does not equal in quality the celebrated Bavarian lithographic stone from Solenhofen.

Road Macadam.—In the Bluegrass Region almost any of the limestones can be used for road-making purposes. However, where the old method of spreading the rock on loose and allowing traffic to smooth it still prevails, the softer gray limestone of the Trenton and blue limestone of the Cincinnatian are preferable to the harder limestones of the Highbridge Series, though if a roller is used to smooth the surface, the latter will be found more satisfactory.

In the Lower Carboniferous Plateau Region of the State the various limestone beds of the Mississippian are suitable for road macadam and are used for that purpose wherever the people are alive to the advantages of having good roads. For the most part, however, this abundant material is little used for that purpose.

Railroad Ballast.—The best rock for this purpose comes from the Highbridge Series and from various harder beds of the Mississippian.

Lime.—The Tyrone limestone from the Highbridge Series and the purer layers of the Mississippian—in particular the oolitic limestone of the Fredonia and the Gasper—will burn into a good quality of lime.

Cement Rock.—Natural cement is manufactured at but one locality in the State—Louisville. It is here made from the Silver Creek member of the Sellersburg limestone.

Portland Cement.—The most suitable sources for the lime in the manufacture of Portland cement are the various purer limestones of the Mississippian—especially the Fredonia and Gasper oolitic beds. It is Mississippian limestone which is used in the Portland Cement Works at Kosmosdale in Jefferson County.

Agricultural Lime.—Satisfactory ground limestone for liming land may be obtained from any of the limestones of the State.

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For an account of the Technology of Kentucky Clays, see H. D. Easton's Report, pages 713-888, Series IV, Vol. 1, Part 2, Geological Survey of Kentucky, 1913.

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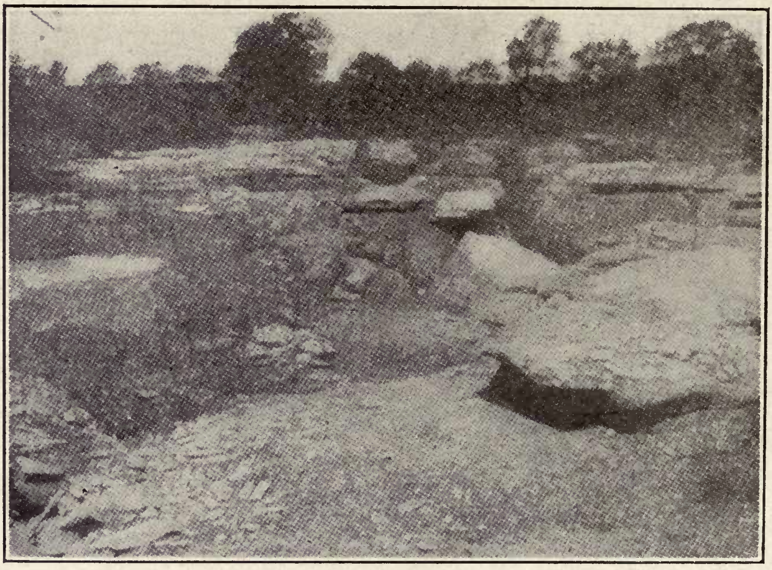
CHAPTER XVII

MISCELLANEOUS ECONOMIC PRODUCTS

Phosphate Rock.—Phosphatic limestone occurs in the Trenton of the Inner Bluegrass Region. Its presence was first detected by Dr. Robert Peter, who announced his discovery as early as 1846. He noted that the thin layers of this rock which occurred near the top of the Trenton, contained tricalcium phosphate, and that its presence was in association with a minute fossil gastropod. Investigations later by his son, Dr. Alfred M. Peter, and by the writer proved that the phosphate in the unleached rock was in the form of the casts of the shells of this small gastropod—*Cyclora minuta*. Dr. Robert Peter connected the exceptional fertility of the soils of the Inner Bluegrass



112. OLD PHOSPHATE WORKINGS SHOWING "CUTTERS" AND LIMESTONE "HORSES"
Near Wallace, Ky. Photograph by W. C. Phalen

Region with the presence of the phosphate in the rock from which the soils had been formed. Professor N. S. Shaler, also, in his monograph on soils in illustrating "soil inheritance" referred to the richer soils of the Inner Bluegrass Region as being immediately below the horizon of the phosphatic layers. In 1904 the writer discovered two miles east of Wallace in Woodfard County deposits of leached or altered phosphate rock which ran as high in tricalcium phosphate as seventy-two per cent., and he called attention to the commercial possibilities of this occurrence. In 1915 the discovery by a negro in digging post holes on the farm of H. L. Martin near Wallace of deposits of the same character as those found by the writer eleven years before led to an investigation by the owner which resulted in the formation of Central Kentucky Phosphate Company to exploit the product.

This company, now merged into the United Phosphate and Chemical Company, erected a grinding plant near Wallace, which with little interruption has been mining and utilizing the rock for fertilizer ever since. At first the company disposed of the product in the pulverized condition as crude phosphate rock. It is now made into "commercial fertilizer" by treatment with sulphuric acid.

Investigations first by the writer, later by August Foerste and finally by W. C. Phalen, determined the vertical and horizontal distribution of these phosphate deposits. They occur in the Woodburn member of the Upper Trenton, and in the top of the Benson bed which lies next below the Woodburn. The source of the material in the unleached condition is in the Woodburn. This has been converted into commercial deposits by reconcentration as the result of leaching out of the phosphate in the overlying and precipitating it in the underlying beds by replacement (main mode of occurrence as advocated by the writer), or as the result of leaching out of the carbonate of lime from the overlying rock and thus leaving it as a residual product at a lower horizon (main mode of concentration as advocated by Dr. Alfred M. Peter and W. C. Phalen).

While at present mining of the phosphate is carried on only near Wallace, the investigations of the foregoing named four persons indicate that it is present in quantity outside of this immediate area and may be looked for wherever the Woodburn Bed outcrops under conditions which have led to its extensive weathering in rather broad upland stretches. Such areas exist in the following counties: Northern Woodford, south Franklin, southern Scott, northern Jessamine, western Fayette and central Bourbon.

Gravel and Sand.—Residual and transported deposits of gravel and sand are found in various portions of the State.

Under the name "Paducah gravels" deposits of Lafayette age are much used in Southwestern Kentucky for the surfacing of roads. Their ferruginous character gives them bonding qualities not possessed by recent stream gravels.

In districts traversed by streams which have their upper courses in the Waverly formation, as for instance, those lying in the Dix River drainage and that of the upper Green River, a siliceous gravel detritus from this formation furnishes a cheap and satisfactory material for surfacing roads.

Residual gravel from the Pottsville Conglomerate occurs in some localities to a considerable thickness—as for instance, near Livingston in Rockcastle County—and has been used as one of the ingredients in the manufacture of concrete grouting. Quartz sand suitable for mixing with lime in the making of mortar and with cement in the making of concrete is obtained from the rivers of Kentucky, usually by dredging.

Foundry Sand.—The best material for foundry use in the making of molds is loess, and in particular the upland loess of the Wisconsin Glacial Epoch. Such loess is found not far from the Ohio River below Cincinnati as far south as Trimble County.

Mineral Waters.—Water containing carbonate of iron (iron or chalybeate water) sulphate or iron (alum water), hydrogen sulphide and sulphates of sodium and calcium (sulphur water), chloride of sodium (saline water), or sulphate and chloride of magnesia (cathartic water), whether these occur singly or in combination, has a different taste from ordinary water and hence a reputed medicinal value. All these ingredients occur in appreciable quantities in the water from certain springs and wells of the State. Also carbonate of lithium occurs in certain spring or well water in quantities not to exceed several grains to a gallon (about the amount of lithium a lithia tablet would add to a glass of water).

Usually there is a relation between the mineral ingredient or ingredients in spring and shallow well water and the minerals contained in the surface formation from which the water is obtained. For instance, the Ohio black shale contains many nodules of pyrite (iron sulphide).

The springs which issue from this formation are quite commonly charged with sulphur and iron compounds formed by the decomposition of the pyrite. Hence the line of mineral springs (sulphur, alum and iron) which follow the outcrop of this Ohio shale belt. This outcrop may be pretty well traced by naming in order the more or less celebrated health resorts located at certain of these springs: Esculapia in Lewis County; Fox in Fleming; Olympia in Bath; Estill in Estill, and site of old Linietta Springs in Boyle County.

The springs and wells at Crab Orchard, in Lincoln County, derive their mineral ingredients from gypsum (sulphate of lime) and the sulphates of magnesia which are disseminated through the Osgood formation at this locality.

The celebrated saline springs at Big Bone Lick in Boone County and at the Blue Licks, Upper and Lower, in Nicholas County, appear to have some deep-seated source, probably the deep underlying "Calciferous" formation from which the water rises through fissures in the intervening strata. An account of these springs, with a discussion of the drying up of the one at the Lower Blue Licks, is given on page 220.

Salt-sulphur water has been struck in artesian wells at a number of places in the State—notably at Louisville, at Sander's Station in Carroll County, at Frankfort and at the Old Crow Distillery, near the Kentucky River, four miles above Frankfort. These all appear to derive their supply from the same deep-seated geological horizon—the "Calciferous."

Even very slight amounts of mineral matter in spring and stream water may affect its use in certain industries. The distilling business illustrates this. It has long been known that the flavor and aroma of whiskey made in certain sections of the State are distinctive. Even a private connoisseur can readily tell the difference between liquor made on the Green River from that made on the Kentucky, while a professional whiskey tester, such as Pat Lamphear, who was known as the "man with the golden nose," because he earned his livlihood by passing expert opinion on aromas of whiskies, could detect by its aroma not only whether or not a whiskey had been made on the Kentucky River, but if made on the Kentucky, whether the distillery was on the right or left bank.

The explanation of this detectable aromatic difference in whiskey is primarily a chemical problem, but ultimately a geological one. Even very minute amounts of certain mineral matter dissolved in the water used in making the grain mash affect the chemical reactions, which during fermentation cause certain flavoring ethers to develop. Most of the distilleries along the Kentucky are between Camp Nelson and Frankfort located at points where there are "big springs," the water of which is used in making the grain mash.

In most of this stretch the Kentucky River marks a geological boundary. The water issuing from the springs on the right are exits of underground channels draining Highbridge and Trenton limestone, those on the left derive their supply from water which has percolated down through Cincinnatian strata; hence the mineral ingredients in the water issuing from these two sets of springs are different; hence the difference in the developed ethers; hence the difference in the whiskey flavors.

Salt.—In pioneer days salt was obtained from a number of saline springs in various portions of the State. In addition to the Upper and Lower Blue Licks and Big Bone Lick, already mentioned, there were the "Licks" of Bullitt County to which the early settlers resorted. In later times wells were drilled for the salt water, which was evaporated to obtain the salt; as in Clay, Wayne and Allen Counties, and more recently in Meade. In the latter county the wells were first drilled for gas, but on striking salt water in some of them, the product was used in the manufacture of salt. This was in 1872. An account of this enterprise is given on page 290.

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CHAPTER XVIII

MINERALOGY

A mineral may be defined as an inorganic substance possessing a definite chemical composition and exhibiting usually a regular crystalline form. It may consist of an element or a combination of elements.

Sixty-one minerals have been identified as native to the State. This may be considered as a fairly liberal allowance when the fact is taken into consideration that minerals exist in greatest variety and abundance in the crystalline rocks (igneous and metamorphic), and Kentucky has little else within her borders but stratified rocks.

These sixty-one minerals with their composition, leading characteristics and some facts in regard to their mode of occurrence and importance or use are as follows:

Almandite, $FeAl_2(SiO_4)_3$—iron-aluminum silicate—common garnet. A hard mineral crystallizing in rhombic dodecahedrons. Found in small crystals in Elliott County peridotite.

Alunogen, $Al_2(SO_4)_3$, $18H_2O$—hydrous sulphate of aluminum. A soft mineral with massive or fibrous structure found as an efflorescence on shales, where it has been formed by the action of sulphuric acid set free by the decomposition of sulphides—especially iron pyrite.

Ankerite, $CaSO_3(MgFeMn)CO_3$ — calcium-magnesium-iron carbonate. Allied to dolomite and siderite, which see. It is found in the Western Kentucky fluorite-lead-zinc district.

Aragonite, $CaCO_3$—calcium carbonate. The same in composition as calcite, but different in crystalline form and more soluble. Found in cave deposits.

Augite, one form of which is $CaMg(SiO_3)_2$—calcium-magnesium silicate. A variety of pyroxene, which is a dark green to black mineral, usually hard to very hard and crystallizing in the monoclinic-system. Found in Crittenden County peridotite.

Barite, $BaSO_4$—barium sulphate, "heavy spar." A white mineral of relatively high specific gravity (4.5). Found in veins and cavities in limestone, particularly those of the Inner Bluegrass Region. Chief use is as an ingredient in the manufacture of paint. See "Barite," page 323,

Biotite, $HK(MgFe)_3Al_2(SiO_4)_3$—a complex silicate of potassium magnesium, iron and aluminum. Black in color and splitting into thin elastic sheets. Found in Elliott County peridotite. A rock-forming mineral.

Calamine, $H_2Zn_2SiO_5$—basic zinc silicate. A soft, transparent to opaque white mineral (sometimes tinted) with a vitreous luster. It crystallizes in the monoclinic system, with the crystals arranged in divergent groups forming masses with cox-comb or mammillary surfaces; also stalactitic. Formed as an oxidation product from sphalerite and found in the Western Kentucky fluorite-lead-zinc district.

Calcite, $CaCO_3$—the common form of calcium carbonate. Crystallizes in rhombohedral forms and exhibits perfect rhombohedral cleavage. Translucent to transparent. Double refracting to light. It is the chief constituent of limestone, in veins and cavities of which it is apt to occur in its purer and more transparent crystalline form as a secondary mineral. In a pulverized condition it is used as a paint ingredient substitute and as a clearing agent in the manufacture of optical glass. See "Calcite, page 326.

Celestite, $SrSO_4$—strontium sulphate. A soft mineral usually faint blue in color (hence the name). Crystallizes in tabular crystals of the orthorhombic system. It commonly occurs lining geoditic or vugue cavities in limestone. Used in a powdered condition to give the red color to flame in pyrotechnics.

Cerussite, $PbCO_3$—lead carbonate. A colorless, white or gray mineral crystallizing in the orthorhombic system. It is rather soft, but possesses an adamantine luster. Specific gravity high (6.55). It is found in the Western Kentucky fluorite-lead-zinc district, where it has been formed as an alteration product of galenite.

Chalcopyrite, $CuFeS_2$—copper-iron sulphate. A brassy yellow mineral with metallic luster. It is not very hard and crystallizes in the tetragonal system. The crystals are usually wedge-shaped (sphenoids). Found in small amounts in the Western Kentucky fluorite-lead-zinc district. It does not occur in sufficient quantities there to be a commercial ore of copper.

Chlorite, a group of minerals consisting of the silicates of aluminum with magnesium, ferrous iron and hydroxil. The chlorites are greenish in color and somewhat micaceous in structure, with the laminae tough and inelastic. Found as a secondary mineral in Crittenden County peridotite.

Chrysolite, $(MgFe)_2SiO_4$—silicate of iron and magnesium. A granular greenish mineral. It occurs as one of the constituents of the Elliott County peridotite. A rock-forming mineral in highly basic igneous rocks.

Copper, Cu—native copper. This metal when crystalline shows the faces of the tetrahexahedron, cube and dodecahedron. It usually occurs, however, massive in irregular shapes. Found sparingly in small disseminated grains in veins traversing the Highbridge series—particularly in the one struck in the Russell Cave Shaft, Fayette County.

Diamond, C—pure crystallized carbon. Crystals octahedral. Very hard (the hardest of minerals). Transparent with internal reflections, giving it its brillian luster. Only one specimen has been found in the State. This was on a farm, then belonging to Henry Burris, in Russell County near Montpelier Postoffice in Adair County. It was reported to have been picked up by a farm hand—Mr. Oliver Helm—from a path through a cornfield. He left it with the postmaster, Mr. Williams, at Montpelier, who sent it to Louisville for identification. It was finally purchased by the late Dr. L. T. Chamberlain, who presented it to the National Museum at Washington, where it is on exhibit. It weighs .75 carats.

There is nothing in the formations in the vicinity of Montpelier to explain the diamond's occurrence, as there are no igneous or metamorphic rocks within 150 or 200 miles of the place. The surface formation where this diamond was found is Upper Waverly, which in that region is especially full of quartz geodes (hollow spherical nodules lined with quartz crystals). The surface of the ground thereabouts is strewn with these geodes, and the quartz crystals from the broken and decomposed ones are seen glistening from every bare surface. Not only can no satisfactory explanation be offered for the occurrence of a diamond in this locality, but even more difficult to explain is how anyone at the distance of the eye from the ground should have had his attention arrested by the difference in gleam between a quartz crystal and a diamond in the rough; and so be led to stoop down and pick the latter up. For possibility of diamond occurrence in Elliott and Crittenden Counties, see account of dikes in Chapter VIII, page 245.

Dolomite, $CaMg(CO_3)_2$—calcium-magnesium carbonate. The crystallized form exhibits cox-comb crystals. It behaves similar to calcite on treatment with acids, but effervesces less freely. A constituent of certain limestones and may form the whole of it. Such magnesian limestones calcine to a more slowly slacking lime than does ordinary calcitic limestone.

Enstatite, $MgSiO_3$—magnesium metasilicate. A rock-forming mineral in igneous and metamorphic rocks. It is found in Elliott County peridotite.

Epsomite, $MgSO_47H_2O$—hydrous magnesium sulphate. Found as a whitish efflorescence on shales and in well and spring water traversing and issuing from shale impregnated with this salt.

Fluorite, CaF_2—calcium fluoride. Called also "fluorspar." A white, rose-colored, purple or amber-colored mineral crystallizing in cubes. It is slightly harder than calcite, which it is apt to accompany in veins and cavities in limestone, or it may be found as the exclusive vein material. It is most abundant in Crittenden and Livingston Counties, where it is extensively mined for use as a flux in iron manufacture, and for other purposes. See "Fluorspar," pages 320-323.

Galenite, PbS—lead sulphide. A gray metallic lustered mineral crystallizing in cubes and quite heavy, having a specific gravity of 7.5. It is found in veins in limestone — especially those of the fluorspar district of Western Kentucky. Found also in the veins of the Bluegrass Region. The gangue (veinstone) accompanying it in the former region is fluorite and in the latter calcite or barite. The chief ore of lead, for which it has been mined, but not very successfully in Kentucky. See "Lead and Zinc Ores," pages 327, 328.

Glauconite—iron and potash silicate. Not a pure mineral—indeed, rather a rock than a mineral. Often called "greensand." A greenish granular deposit when in purest form. Also found as a constituent of clays, particularly those of the Cretaceous formation of the Jackson Purchase Region.

Greenockite, CdS—cadmium sulphide. A soft pulverent or incrusting mineral of a yellow color. Crystals small and rare. Found in the Western Kentucky fluorspar, lead and zinc district as an orange-yellow coating on the walls of veins and in cracks of the walls, also on the surface of smithsonite. It is a product of weathering.

Gypsum, $CaSO_42HO$—hydrated calcium sulphate. A white or transparent, very soft mineral, occurring in monoclinic crystals or massive. It is found on the ceilings and walls of certain caves and in the shales of the Niagara formation. Where, as in certain other states, it forms a bedded deposit of considerable thickness, it can be used in a pulverized raw condition as a fertilizer under the name "land plaster." Calcined and pulverized it constitutes "plaster-of-paris." It does not occur in commercial quantities in Kentucky.

Halite, $NaCl$—sodium chloride or common salt. It crystallizes in cubes and is very soft and soluble—dissolving in water. Obtained in Kentucky by the evaporation of brines from wells. It was formerly obtained in the State in this way from saline waters of springs and licks. See "Salt," page 342.

Halloysite, a variety of kaolinite, which see.

Hematite, Fe_2O_3—ferric oxide. A red mineral found massive or crystalline. As it occurs in Kentucky it is oolitic in structure, with the constituent grains of the oolite flattened like flaxseed—hence name "flaxseed" ore. Until quite recently it was mined from the Clinton formation of Bath County. See "Iron Ore," pages 310, 311.

Hydrozincite, $ZnCO_32Zn(OH)_2$—basic zinc carbonate. An alteration product of smithsonite, which it resembles. It is found in association with the zinc deposits of the fluorite-lead-zinc district of Western Kentucky.

Ilmenite, $(TiFe)2O_3$—but variable in ratio of Ti to Fe —iron-titanium oxide. Crystallization similar to that of hematite. A hard black mineral with sub-metallic luster and a specific gravity of about 4.5. Found in Elliott County peridotite.

Kaolinite, $H_4Al_2Si_2O_9$—hydrated aluminum silicate. A soft friable mineral which is the main constituent of clay. It is found in purest condition in the Jackson Purchase.

Limonite, $2Fe_2O_33H_2O$—hydrated iron oxide. A yellow to redish-brown mineral, usually massive. It is the cause of the reddish and yellowish colors in rocks and soils, and when concentrated in beds of considerable size is a valuable ore of iron. It is the chief ore of iron in Kentucky. See "Iron Ore," pages 307, 319.

Magnetite, Fe_3O_4—magnetic iron oxide. A dark mineral crystallizing in octahedrons. Black streak. It is attracted by the magnet. Found in Kentucky only in Elliott County peridotite. Not in quantity there sufficient to make it an ore of iron.

Malachite, $CuCo_3Cu(OH_2)$—basic copper carbonate. A soft greenish mineral commonly occurring in botryoidal, mammilary or stalactitic masses. When crystallized, the crystals, which belong to the monoclinic system, are small and slender and rarely distinct. Found in the Western Kentucky fluorspar, lead and zinc district, where it occurs as an alteration product of chalcopyrite.

Marcasite, FeS_2—orthorhombic iron sulphide, white pyrites. A hard metallic lustered mineral, not commonly distinguished from pyrite with which it is identical in composition. It is lighter in color than pyrite and more decomposable. Distribution same as pyrite, which see.

Melanterite, $FeSO_4$—ferrous sulphate. Found as a whitish efflorescence on rocks—chiefly shales—where it has been formed by the oxydation of pyrite, or marcasite. It is also found dissolved in spring and well water which has traversed these shales. It is this chiefly which gives the alum taste to water.

Mellite, $Al_2C_{12}O_{12}18aq.$—When typical it is a honey-yellow mineral ("honigstein" of the Germans), crystallizing in octahedrons. Not a common mineral.

Niter, KNO_3—potassium nitrate, salt peter. Found as a constituent of many cave earths. It has in the past been used in Kentucky in the manufacture of gun powder and might be used as a fertilizer. See "Cave Deposits," on page 208.

Nitro-calcite, $Ca(NO_3)(H_2O)$.—A mineral found in cave earth, where it has been formed by the action of nitric acid on calcium. The nitric acid is supposed to be a product of the activities of certain bacteria, known as "nitrifying organisms."

Opal, SiO_2H_2O—hydrated silicon oxide, variety silicified wood. This mineral is a replacement of wood tissue by hydrous silica, and exhibits the banding and often the microscopic cell structure of the original wood. It is found in the Ohio black shale—especially of Taylor and Marion Counties, where the wood silicified may be identified as belonging to the Devonian genus Dadoxylon.

Perovskite, $CaTiO_3$—calcium titanium oxide. A rare form of titanium mineral crystallizing in the isometric system. Found in Crittenden County peridotite.

Phosphorite, impure apatite. The formula for pure apatite is $Ca_4(CaF)(PO_4)_3$. This mineral is chiefly found in the Inner Bluegrass Region as an amorphous porous deposit called "phosphate rock." It is also found at the base of the Cuyahoga shale as concretions, many of them as spherical as marbles. The limestone phosphate is used as a source of phosphorus in the manufacture of commercial fertilizers. See "Phosphate Rock," on pages 338, 339.

Psilomelane, of uncertain composition, chiefly MnO_2 H_2O—hydrated oxide of manganese. A black amorphous mineral found in massive botryoidal or stalactitic form in certain soils.

Pyrite, FeS_2—iron sulphide, "fool's gold." A hard mineral with a brassy yellow color, and a tendency to crystallize in cubes or pentagonal dodecahedrons (pyritohedrons). It is frequently mistaken for gold, hence a common synonym for it given above. Its superior hardness makes it possible to strike fire from steel with it, hence the name pyrite—"fireite." This quality also readily distinguishes it from gold which is one of the softest of metals. Another distinguishing character is its shade of yellow, being a brassy yellow, whereas gold is a pure yellow. It is widely distributed in all kinds of rocks in Kentucky and is particularly common in the Ohio black shale. It is, however, not abundant enough to permit its use as a source of sulphur in the manufacture of sulphuric acid.

Pyrolusite, MnO_2—manganese dioxide. A black, amorphous, soft mineral found in sedimentary rocks in fibrous, stalactitic and dendritic forms. It is apt to occur in soils formed from the decay of certain limestones.

Pyromorphite, $Pb_4(PbCl)(PO_4)_3$—a lead phosphate and chloride. A soft mineral, usually yellowish or brownish in color and with a resinous luster. Crystals hexagonal; crystalline aggregates globular, reniform, fibrous, or granular. It is found in the Western Kentucky fluorspar, lead and zinc district, where it is an alteration product of galena. Rare.

Pyrope, $Mg_3Al_2(SiO_4)_3$—magnesium-aluminum silicate, magnesia garnet. This variety, or red garnet, is often mistaken for ruby. Garnet is a hard mineral crystallizing in forms with 12 faces, each of which is a rhomb, hence the name for the form, rhombic dodecahedron. The variety pyrope is found in Elliott County peridotite.

Quartz, SiO_2—silicon oxide. A very hard, vitreous lustered mineral, found massive or crystallized. When in crystals these are hexagonal prisms terminated with hexagonal pyramids. It has fracture but not cleavage, and is brittle and relatively insoluble and infusible. Specific gravity between 2.3 and 2.6. The mineral is widely distributed in nature and exists in great variety. The forms most common in Kentucky are as follows:

Rock Crystal—(Transparent crystallized quartz.) Found especially lining the cavities of geodes in the Waverly formation.

Smoky Quartz—Same in form and hardness as the foregoing, but with a non-essential color, brown or black, due to the presence through it of some impurity—especially iron oxide.

Amethyst—(Amethystine quartz.) Same as the foregoing but purple from the presence of manganese dioxide in minute quantities. Found in Waverly geodes.

Chalcedony—A non-crystalline waxy lustered mineral with botryoidal or mammillary surfaces. Found in Waverly geodes.

Flint—A non-crystalline quartz breaking with curved surfaces (conchoidal fracture). Found as bands and nodules in limestones and in soil formed from the decay of these rocks. A great deal of this flint is impure and then called "chert."

Rutile, TiO_2—titanium oxide, variety octahedrite. This mineral, crystallizing in octahedrons, is an accessory mineral in metamorphic and igneous rocks. It occurs in the Elliott County peridotite.

Serpentine, $HMg_3Si_2O_9$—hydrated magnesium silicate. A secondary mineral formed by the alteration of highly basic igneous rocks, and as a product of metamorphism in the metamorphic rocks. It is greenish in color and soft. Sometimes it is fibrous in texture, constituting the variety known as "chrysotile." The Kentucky variety is massive, and was formed by the alteration of the Crittenden County peridotite.

Siderite, $FeCO_3$—iron carbonate, an iron ore. It occurs massive or crystalline. In Kentucky it is found in the unweathered massive condition as a limestone ore (sometimes oolitic, as in the case of the deposits near Preston Station), as black-band ore, and in the concretionary form, as kidney ore. See "Iron Ore," on pages 308, 312, 314-317.

Silver. This metal has been reported as present in some of the galena of the West Kentucky fluorspar, lead and zinc district. Its presence there, even in minute quantities, is exceedingly problematic.

Smithsonite, $ZnCO_3$—zinc carbonate. A massive amorphous mineral in irregular shaped or concretionary masses formed by the weathering of sphalerite. It commonly exhibits mammilated surfaces. Found in Crittenden County, where certain deposits of it were for a time mined for zinc. See "Zinc Ore," on pages 327, 328.

Sphalerite, ZnS—zinc sulphide. This mineral is sometimes dark colored and then called "black jack" (form of the ore in north-central portion of the State), or it is yellowish and with a resinous luster and then called "rosin ore," as in the Western Kentucky fluorspar, lead and zinc district. It is the most important ore of zinc. See "Zinc Ore," on pages 327, 328.

Spinel, $MgAl_2O_4$—magnesium-aluminium oxide. A hard mineral crystallizing in octahedrons. Colors various, the red variety, known as ruby spinel, being the most common variety. Doubtfully present in Elliott County peridotite.

Strontianite, $SrCO_3$—strontium carbonate. In Kentucky this mineral occurs as incrustations on barite, the small bladed crystals being closely packed together with their long axes at right angles to mammilated surfaces. It is known from one locality only—the Clark barite vein in Franklin County. When in sufficient quantity strontianite may be used in sugar refining and in pyrotechny, where it produces "red fire." [See Plate 107, page 324.]

Sulphur, S—one of the non-metallic chemical elements. It is soft, yellow, readily burning with a blue flame. Found rarely in the Western Kentucky fluorite, lead and zinc district, where it is one of the products of the weathering of galena.

Titanite, $CaTiSiO_5$—calcium-titanium silicate. A hard mineral usually dark in color and crystallizing in wedge forms, belonging to the monoclinic system. On account of the wedge shape to its crystals it has received the name "sphene." Found in Crittenden County peridotite.

Turgite, $2Fe_2O_3 1(H_2O)$—hydro-hematite. This mineral is similar to limonite. It is found in the Cumberland River iron ore deposits of Lyon and adjacent counties.

Vivianite, $Fe_3P_2O_8 8(H_2O)$—hydrated phosphate of iron. A bluish-green mineral in acicular crystals, or a blue powder. It is found replacing woody stems and roots, especially in the Jackson Purchase Region. Not commercially valuable.

Wad, impure hydrated manganese oxide. One of the commonest impurities in it is iron oxide. It is found in a nodular or pisolitic form in wet soils, where it has probably been derived from the decay of limestones. Not in sufficient quantity in Kentucky to be used as a source of manganese.

Wavellite, $(AlOH)_3(PO_4)_3 5H_2O$—a hydrous aluminium phosphate. It usually occurs in radiating crystals forming globular aggregates. The individual crystals are needle-like and orthorhombic. A soft mineral of low specific gravity. Found in Western Kentucky halloysite.

METEORITES

While not minerals in the strict scientific sense, it seems best to give in this part devoted to minerals an account of those stony and metallic bodies of celestial origin which have been found in various parts of Kentucky.

They have been found at fourteen distinct localities in the State, and doubtless belong to as many distinct falls, though only in three instances have they been observed to descend. These three—the Cynthiana, Bath Furnace, and Cumberland Falls—are *aerolites* or stony meteorites; that is, stony masses with finely disseminated nickel-iron. Two—Eagle Station and Mt. Vernon—are *siderolites,* meteorites with larger connected masses of nickel-iron and having the stony matrix chondritic; that is, exhibiting a spherulitic structure. The remaining nine are *siderites*—nickel-irons.

In its predominance of its iron over its stony meteorites, Kentucky is in harmony with the rest of the world. Though rarely seen to fall, irons are by far the most numerous in collections of meteorites. Being composed chiefly of nickel-iron—a very durable compound—they tend to remain for ages in the soil without undergoing much alteration. They also more readily attract attention than the stony variety when struck with the plow or hoe, and hence have the best chance of being discovered, with the result that ultimately they find their way into the meteorite collections of the various museums.

Kentucky lies in a belt of the United States—one extending from Kansas to North Carolina—where per unit area the number of meteorites found is unusually large. This is probably because it is in a belt constituting an exceptionally old land surface—one unaffected with accumulation of deposits other than those of a residual character. Lying between the glacial drift area of the north and the coastal plain area of the south with its marine and estuarine Cretaceous and Tertiary deposits, it has been a land surface on which meteorites have been dropping since the close of Pennsylvanian time—certainly a period measured in millions of years.

It was the writer's good fortune to witness the fall of one of the latest of these meteorites and to be instrumental in securing for science three of the pieces. This was the Bath Furnace Meteor, which in its fall on November 15, 1902, at 6:45 p. m., Standard Central time, was seen by a large number of people in a north and south belt extending from middle Ohio to the Gulf of Mexico. It came to earth in the knobs of southern Bath County, five miles south of Salt Lick and fifty-one miles east of Lexington. The first piece found was a mass weighing thirteen pounds which struck in the road in front of the cabin of Mr. Buford Staton. The second piece, weighing four ounces, was picked up a few days later from a field nearby. The third, which turned out to be the main mass, weighing 180 pounds, was not found till the following spring. It was located by a Mr. Pergrem, who, while squirrel hunting, noted where the top of a white oak sapling had been clipped off. Looking further he found a skinned place on the side of a tree. Lining up these two points he de-

113. BATH FURNACE METEORITE NUMBER 3
Photograph by A. M. Miller

termined the trajectory of the falling body, which he rightfully inferred must have been part of the fall which, accompanied by the blinding light and deafening detonations, had so startled and alarmed the community on the evening of the 15th of November preceding. Digging at the base of a tulip poplar tree as the point indicated where the projectile should have buried itself, he there found the mass imbedded, and with the aid of a horse and bobsled, removed it in triumph. His joy, however, was short lived. The Ewing heirs, owners of the land on which it fell, brought suit for possession. The case was finally compromised out of court, the finder being compensated for his services.

Mr. Henry Ward, who when he died, had the largest collection of meteorites in existence, secured by purchase this main mass as well as the first piece found, and it may be seen today in the meteorite collection of the Field Columbian Museum, Chicago.

On April 9, 1919, a meteor fell at midday in a northwesterly direction across northeastern Tennessee, which observers declared exceeded the sun in brightness. Passing over Southeastern Kentucky, where the sky was obscured by clouds, the meteor made its presence known by loud detonations, accompanied by the spalling off of fragments. So violent were the concussions that buildings were rocked and the impression conveyed to the inhabitants that the region was being visited by an earthquake. The first fragments fell near Sawyer P. O., McCreary County, near the Falls-of-the-Cumberland. The writer, through use of the local papers and by correspondence with railroad telegraph operators (who put the celestial visitor on a schedule) determined the path of the meteor and secured most of the fragments. At present writing (May 27, 1919) seven pieces ranging in weight from thirteen ounces to five and one-fourth pounds have been found that by their covering of glaze indicate that they split off a considerable distance from the ground. In addition to these, forty-five pieces, weighing from less than an ounce up to four pounds, have been picked up as fragments of a portion weighing originally about twenty-five or thirty pounds, which was shattered by falling on the top of the conglomerate cliff forming the wall of the Cumberland River gorge below the Falls. All of the fragments which retain any of the original outer surface have the characteristic pittings of meteorites. They are light gray in color, and present on the outside a brecciated appearance. The interior much resembles granite. Chemical analysis shows that they are composed mainly of the mineral enstatite (silicate of magnesium), through which is distributed generally nickel-iron in amounts not exceeding two-tenths of one per cent. Occasionally, however, masses of this alloy are found which are as large as walnuts. The presence of sulphur, sodium, calcium, chromium, potassium, phosphorus, and carbon has been detected. The latter element is in the form of graphite, forming in places thin coatings of the enstatite. Structure and content thus classify the meteorite as a chondritic serolite. The central nuclear mass of this meteorite has not yet been discovered.

The following is a complete list of Kentucky meteorites with the years in which they were found or seen to fall:

Smithland, Livingston County—Siderite. Found 1839.
Salt River, Bullitt County—Siderite. Found 1850.
Nelson County—Siderite. Found 1860.
LaGrange, Oldham County—Siderite. Found 1860.
Marshall County—Siderite. Found 1860.
Frankfort (eight miles south of)—Siderite. Found 1866.
Scottsville, Allen County—Siderite. Found 1867.
Mt. Vernon, Christian County—Siderolite. Found 1868.
Cynthiana (nine miles from)—Aerolite. Fell 1877.
Eagle Station, Carroll County—Siderolite. Found 1880.
Kenton County (eight miles south of Independence)—Siderite. Found 1889.
Bath Furnace, Bath County—Aerolite. Fell 1902.
Williamstown, Grant County—Siderite. Found 1908.
Cumberland Falls, McCreary-Whitley Counties—Aerolite. Fell 1919.

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PART FIVE

Geological Bibliography of Kentucky

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