THE OHIO JOURNAL OF SCIENCE

VOL. XXXIV NOVEMBER, 1934 No. 6

# DATA ON THE THICKNESS AND CHARACTER OF CERTAIN SEDIMENTARY SERIES IN OHIO

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## INTRODUCTION

The total thickness of the sedimentary rocks in Ohio as measured on the outcrop is a little more than 5,000 feet. As the various series pass under cover away from the outcrop changes in thickness occur which can be determined by a study of data derived from well borings. Based on rather limited data of this type, various estimates have been made from time to time of the thickening of certain sedimentary series to the eastward in Ohio along designated lines.[2] However, as deep well drilling has continued the quantity of available data has increased and a comparative study of some 8,500 well records now on file in the office of the Geological Survey of Ohio has yielded the results set forth in the following pages. Such data lack much that is to be desired in the way of scientific accuracy and detail, but nevertheless the close correspondence in essential fact of data derived from many sources argues for considerable accuracy in its major features. It is believed that the results of such a study will be of interest to geologists and to all who are engaged in the search for oil and gas.

## CLASSIFICATION OF THE SEDIMENTARY ROCKS OF OHIO

The following table gives a brief classification of the sedimentary strata in Ohio and includes the name and character

[1]Published by permission of Mr. Wilber Stout, Director, Geological Survey of Ohio.

[2]Hills, T. M. Some Estimates of the Thickness of the Sedimentary Rocks of Ohio. *Jour. Geol.*, Vol. XXVIII (1920), pp. 84–86. Also various reports of the Geological Survey of Ohio.

of the chief subdivisions, the thickness on the outcrop, and the terms in general use by the well driller. Many of the details of the classification have been omitted. The thickness of the different groups, series, formations, or members appearing in this table have been compiled from various detailed reports. The correlations with surface outcrops of the various strata recognized in drilling are in part the conclusions of the writer, and in part the opinions of others which have appeared in various publications of the Geological Survey of Ohio.

TABLE OF CLASSIFICATION

| System | Group, Series, or Formation | General Character | Thickness on Outcrop (Feet) | Drillers Terms |
|---|---|---|---|---|
| Permian | Greene | Many kinds | 405 | |
| | Washington | Many kinds | 221 | |
| | Monongahela | Many kinds | 144 | |
| | | Sandstone, Sewickley | 20 | Goose Run sand |
| | | Several kinds | 84 | |
| Pennsylvanian | Allegheny | Many kinds | 82 | |
| | | Sandstone, Connellsville | 20 | Mitchell sand |
| | | Several kinds | 7 | |
| | | Sandstone, Morgantown | 0–30 | Wolf Creek or Milner sand |
| | | Many kinds | 100 | |
| | | Sandstone, Cow Run | 30 | Macksburg 140-foot or First Cow Run sand |
| | | Many kinds | 40 | |
| | | Sandstone, Buffalo | 23 | Buell Run sand |
| | | Many kinds | 106 | |
| | | Sandstone, Upper Freeport | 33 | Macksburg 300-foot or Dunkard sand |
| | | Many kinds | 117 | |
| | | Sandstone, Clarion | 10 | Macksburg 500-foot sand |
| | | Many kinds | 34 | |
| | Pottsville | Many kinds | 154 | |
| | | Sandstone, Massillon | 24 | Second Cow Run or Salt sand |
| | | Many kinds | 93 | |
| | | Sandstone, Sharon | 10 | Macksburg 800-foot, Maxton, or Lower Salt sand |

TABLE OF CLASSIFICATION—(*Continued*)

| System | Group Series, or Formation | General Character | Thickness on Outcrop (Feet) | Drillers Terms |
|---|---|---|---|---|
| Mississippian | Maxville | Limestone | 0 to 20 | Big Lime of southeastern Ohio |
| | Logan | Sandstone and shale | 0 to 200 | Keener sand |
| | Cuyahoga | Sandstone, Black Hand | 175 to 600 | Big Injun and Squaw sand |
| | | Shale | | |
| | | Sandstone, Buena Vista | | Hamden, Welsh Stray, or Weir sand |
| | | Shale | | |
| | Sunbury | Shale, black | 5 to 30 | Coffee shale |
| | Berea | Sandstone | 0 to 200 | Berea sand |
| | Bedford | Shale, gray and red | 60 to 90 | |
| | | Sandstone, local | | Second Berea sand |
| Devonian | Ohio | Shale, black, Cleveland | 300 to 700 | Little Cinnamon and Big Cinnamon |
| | | Shale, gray, Chagrin | | |
| | | Shale, black, Huron | | |
| | | Shale, gray, Olentangy | | |
| | Delaware | Limestone | 30 to 70 | |
| | Columbus | Limestone | 60 to 110 | |
| | Detroit River | Dolomite | 0 to 200 | |
| | Sylvania | Sandstone | 0 to 20 | Big Lime (The Oriskany sand, salt beds and Newburg sand occur in this series) |
| Silurian | Bass Island | Dolomite and shale | 0 to 300 | |
| | Niagara | Dolomite | 25 to 300 | |
| | Alger | Shale | 10 to 100 | |
| | Dayton | Limestone | 2 to 12 | Shell or Little Lime |
| | Brassfield | Limestone | 10 to 50 | Shell or Little Lime |
| Ordovician | Richmond | Shale, red and gray | 215 to 265 | |
| | | Sandstone, red and white | | Clinton sand |
| | | Shale, red | | Medina |
| | | Shale, pink and red | | |
| | | Shale, bluish gray, with thin limestone | | |
| | Maysville | Shale and thin limestone | 140 to 240 | |
| | Eden | Shale, blue, with thin limestone | 180 to 250 | |
| | Trenton* | Limestone | 40 to 200 | Trenton |
| | Lexington | Limestone, cherty | 290 to 315 | |
| | Highbridge | Limestone and dolomite with some shale | 250 to 420 | |
| | St. Peter | Sandstone, calcareous | | St. Peter sand. Horizon of Blue Lick Water |

*The series below the Trenton do not outcrop in Ohio.

### THE SEDIMENTARY SERIES BELOW THE ST. PETER SAND

A number of holes have been drilled in the western half of Ohio to varying depths below the St. Peter sand, but only a few have actually reached the underlying crystalline complex. In a test hole which was sunk near Findlay, Hancock County, in 1912 and which reached the granite at a depth of 2,980 feet, 780 feet of sediments were penetrated below the St. Peter sand. A second test near Woodville, Sandusky County, encountered 730 feet of sediments below the St. Peter sand and reached a depth of 2,822 feet. The drill has also reached the crystallines near Tiffin, Seneca County, at a depth of about 2,900 feet, but the details of this record are not available. A number of years ago a deep test was drilled near Waverly, Pike County, in which the St. Peter sand was reached at 2,825 feet and fragments of igneous rock were reported to have been secured at a depth of 3,320 feet.[3]

The deepest test in the western half of Ohio was drilled near South Charleston, Clark County, in 1926–1927. The drill reached a depth of 4,647.5 feet, but it failed to pass through the sedimentaries. The Blue Lick water sand or St. Peter was encountered at a depth of 2,055 feet, and it is therefore underlain at this place by at least 2,592 feet of sediments or over three times the thickness occurring below the St. Peter at Findlay or Woodville.

It is highly probable that the upper surface of the crystalline rocks upon which the sediments were deposited was very irregular and in view of the small number of holes which have been drilled through the entire series in Ohio, any prediction as to its depth outside of the Findlay-Woodville-Tiffin area is somewhat hazardous.

### THE TRENTON-ST. PETER SERIES

The series from the top of the Trenton to the St. Peter sand is composed of limestone and dolomite with some shale in the lower part which is usually of a greenish color. The upper part of this series is exposed along the banks of the Ohio River at Cincinnati, but the lower part consisting of the Lexington and Highbridge series does not outcrop in this state, although it comes to the surface farther south in Kentucky.

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[3]Bassler, R. S. The Stratigraphy of a Deep Well at Waverly, Ohio. *Am. Jour. Science*, 3rd. Ser., Vol. 31 (1911), pp. 19–24.

Below this limestone, dolomite, and shale series is a bed of white calcareous sand or sandy limestone which contains large quantities of strong brine known as the Blue Lick water. This water-bearing sand is the St. Peter sand of Orton[4] and it is generally known among well drillers by that name. The St. Peter sand does not outcrop in Ohio or Kentucky, but it has been reached at a number of places by the drill. At least 80 holes have been sunk to this horizon in Ohio, nearly all of which are located in the western two-thirds of the state and chiefly east of the belt of Trenton production.

By a comparison of well records it has been found that the St. Peter sand occurs at distances below the top of the Trenton, which vary from 435 to 885 feet. The series is thin over an elongated area extending from Columbus southwest to western Pike and eastern Highland counties and also along the western edge of the state in western Butler, Preble, and Darke counties. A second area of reduced thickness extends from Allen County northeast to Erie County. This latter area seems to be continuous with a similar region of thinning extending in a northeastern direction across southwestern Ontario.[5] The series thickens, however, to the northwest in the direction of Michigan and to the southeast in eastern Ohio. The conditions of thickening and thinning of the Trenton-St. Peter series as indicated by well records are shown in Figure 1.

### THE TRENTON-BIG LIME SERIES

The Trenton-Big Lime series outcrops in southwestern Ohio where it forms the surface rocks in Hamilton, Butler, Warren, Clermont, and Brown counties and in portions of adjacent counties to the east and north. Beyond this outcrop area the series extends beneath younger beds throughout eastern and northern Ohio. It has been penetrated by the drill at many places in the western half of the state, but it is probably best known to the driller in the producing fields in the northwestern part where hundreds of wells have been sunk to the Trenton limestone. The thickness of the Trenton-Big Lime series as disclosed by well records varies from 660 to 1,950 feet. The thinnest areas are found in Williams and Defiance counties, from where this series thickens irregularly to the east and

[4]Orton, Edward. *Geol. Survey, Ohio,* Vol. VI (1888), p. 7.

[5]See map of southwestern Ontario by R. B. Harkness, Ontario Gas Commissioner.

southeast, while the greatest thickness is encountered along the eastern line of Trenton holes. Thus, this series measures

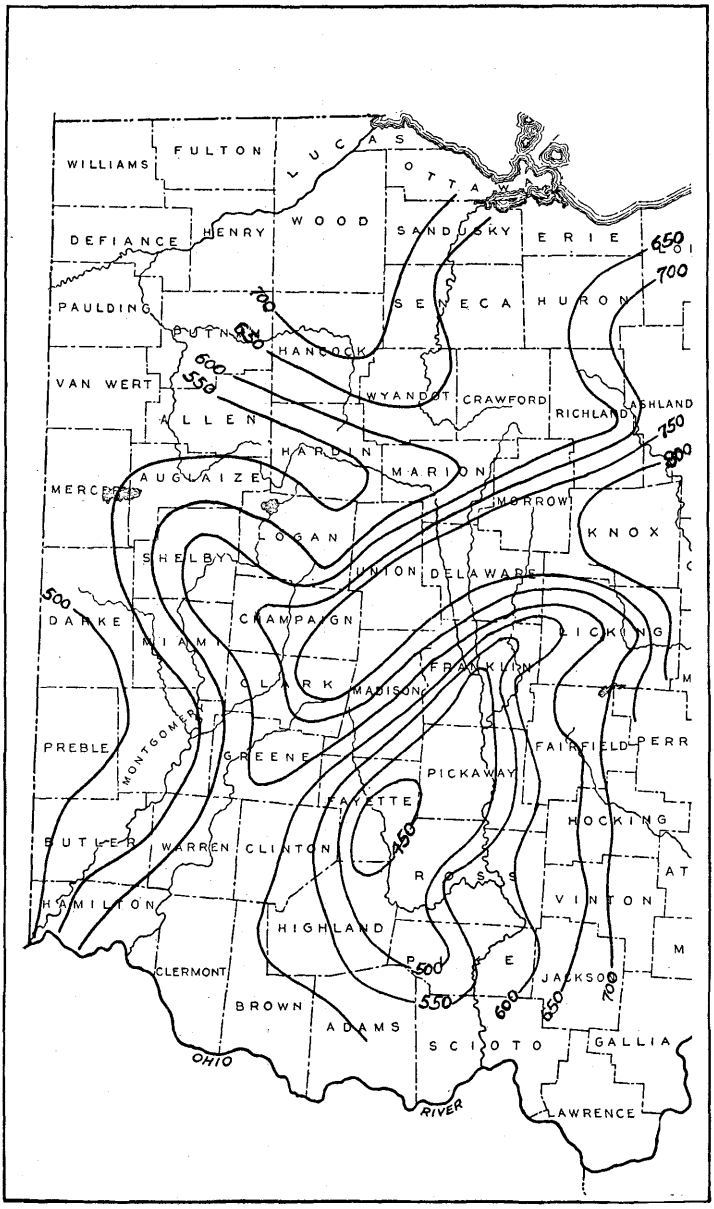


FIG. 1. Map of the western part of Ohio showing isopachs of the series extending from the St. Peter (Blue Lick water) horizon to the top of the Trenton limestone.

1,950 feet in Rome Township, Ashtabula County; 1,700 feet in Brunswick Township, Medina County; 1,360 feet in Jackson Township, Ashland County; 1,560 feet in Hanover Township, Licking County; and 1,400 feet in Jefferson Township, Jackson County. Southeast of this line the drill has not penetrated to a level much below the horizon of the Clinton sand.

The Trenton-Big Lime series consists of shales and thin limestones comprising the Eden, Maysville, Richmond, Brassfield, Dayton, and Alger beds. Throughout all parts of Ohio where this series has been penetrated, a limestone which varies in thickness from 5 to 75 feet and which is known to the driller as the Shell or Little Lime, is present near the top of the series and corresponds in position to the Brassfield and Dayton limestones of surface outcrops. In parts of the belt of Clinton sand production two "shells" are present, separated by a thin bed of shale. The Shell or Little Lime is separated from the base of the Big Lime by a bed of shale which, as pointed out by Orton,[6] is 15 feet or less in thickness in the west-central part of Ohio. This shale increases somewhat in thickness to the east and southeast, however, for in the belt of Clinton sand production it ranges from 75 feet in Lorain County to 250 feet in Lawrence and southern Jackson counties. The material is generally of a greenish gray color, but red shales are common on this horizon in southern Ohio. The Shell is more or less closely underlain with red shale and the red and white Clinton sand.

A second conspicuous feature of the series is a bed of black and brown shale which overlies the Trenton and which often yields small flows of gas. This shale which forms the lower part of the Eden group is known as the Utica shale.[7] It is thin in southwestern Ohio, but it increases in thickness rapidly to the north, northwest, and northeast. The Utica shale has a thickness of about 35 feet in southern Butler County, 200 feet at Dayton in Montgomery County, 300 feet at Urbana in Champaign County, and apparently reaches its maximum thickness of 350 feet in Logan and Hardin counties. It thins slightly to the north, east, and west from Logan and Hardin counties, for it measures 290 feet at Van Wert, 300 feet at Napoleon, 275 feet at Bowling Green, 225 feet in southwestern

[6]Orton, Edward. *Geol. Survey, Ohio*, Vol. VI (1888), p. 13.
[7]Orton, Edward. *Geol. Survey, Ohio*, Vol. VI (1888), p. 8.

Ottawa County, and 285 feet near Tiffin. The Utica shale thickens again in the vicinity of Sandusky, where it measures

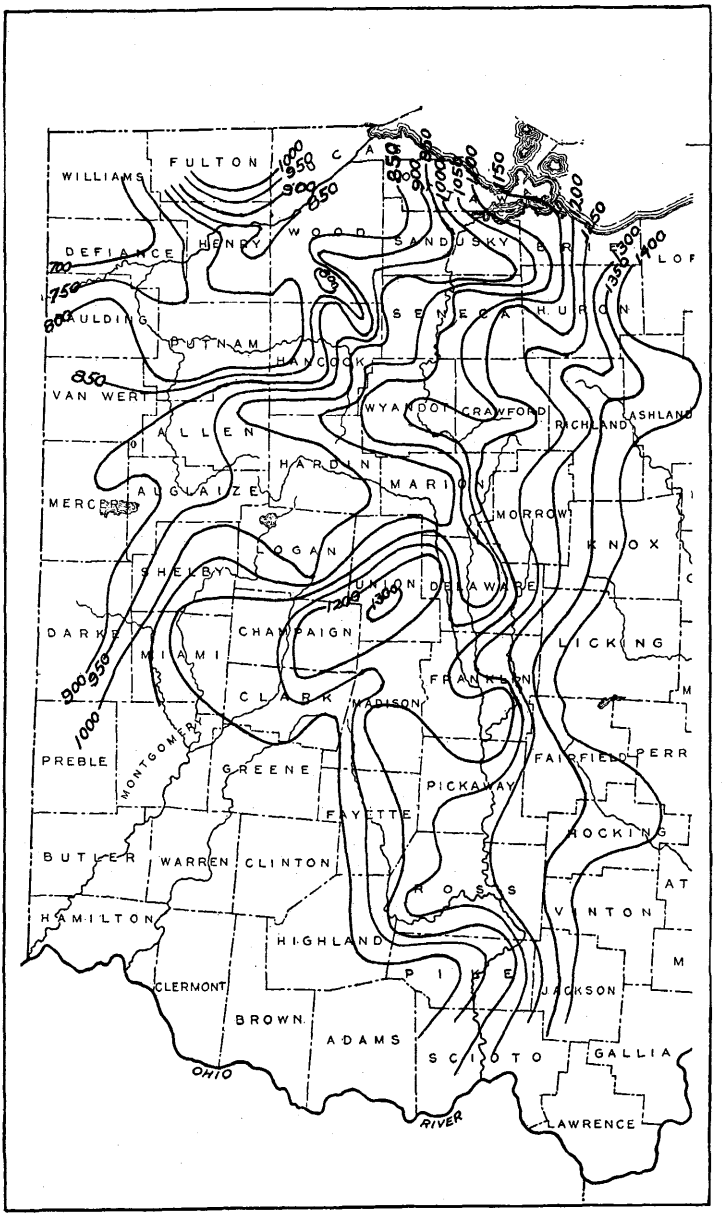


FIG. 2. Map of the western part of Ohio showing isopachs of the series extending from the Trenton Limestone to the base of the Big Lime.

about 335 feet. The thickness of the Trenton-Big Lime series in the western half of Ohio is shown in Fig. 2.

## THE BIG LIME SERIES

The Big Lime series is well known to the driller, as a part or all of this group is penetrated in wells sunk to the Trenton or Clinton sands. This series forms the surface rocks in the Trenton field of northwestern Ohio and the surface exposures extend eastward to a line drawn from Sandusky Bay south through Delaware, Columbus, Greenfield, and Bainbridge and then southward to the Ohio River through eastern Adams County. East of this line the Big Lime dips beneath beds of younger age.

The thinnest part of the Big Lime as recorded in well records is found in Scioto and Pike counties where it measures about 300 feet. It thickens rapidly to the east and northeast, however, for it reaches its maximum development in Ohio along the eastern edge of the state from Columbiana County south to Washington County. From central Columbiana County this series thins again to the north in the direction of Conneaut. The greatest thicknesses yet recorded in this state are 1,987 feet in the Reamer well located in West Township, Columbiana County, and 1,841 feet in the Knowlton well in Independence Township, Washington County.

Stratigraphically the Big Lime includes the limestone and dolomite from the base of the thick Devonian shale to the base of the Niagara dolomite and comprises the Delaware and Columbus limestones, the Detroit River and Bass Island dolomites, and the Niagara dolomites as classified from surface exposures. The increase in thickness of the Big Lime series to the east in Ohio is due in part to the increase in thickness of some of the formations comprising it, and in part to the presence of other formations under cover which pinch out to the west before the outcrops are reached. Thus the Devonian limestones consisting of the Columbus and Delaware formations have a combined thickness on the outcrop of about 130 feet. Under cover the Oriskany sand which lies at the base of the Devonian limestone is found at depths below the top of the Big Lime of 110 to 160 feet in Guernsey County, 200 to 290 feet in Ashtabula County, 235 feet in Island Creek Township, Jefferson County, and 225 feet in Independence Township, Washington County.

In northeastern Ohio beds of rock salt with some shale and

dolomite, all of which probably represent the Salina group, are present in the Big Lime below the Oriskany sand horizon.

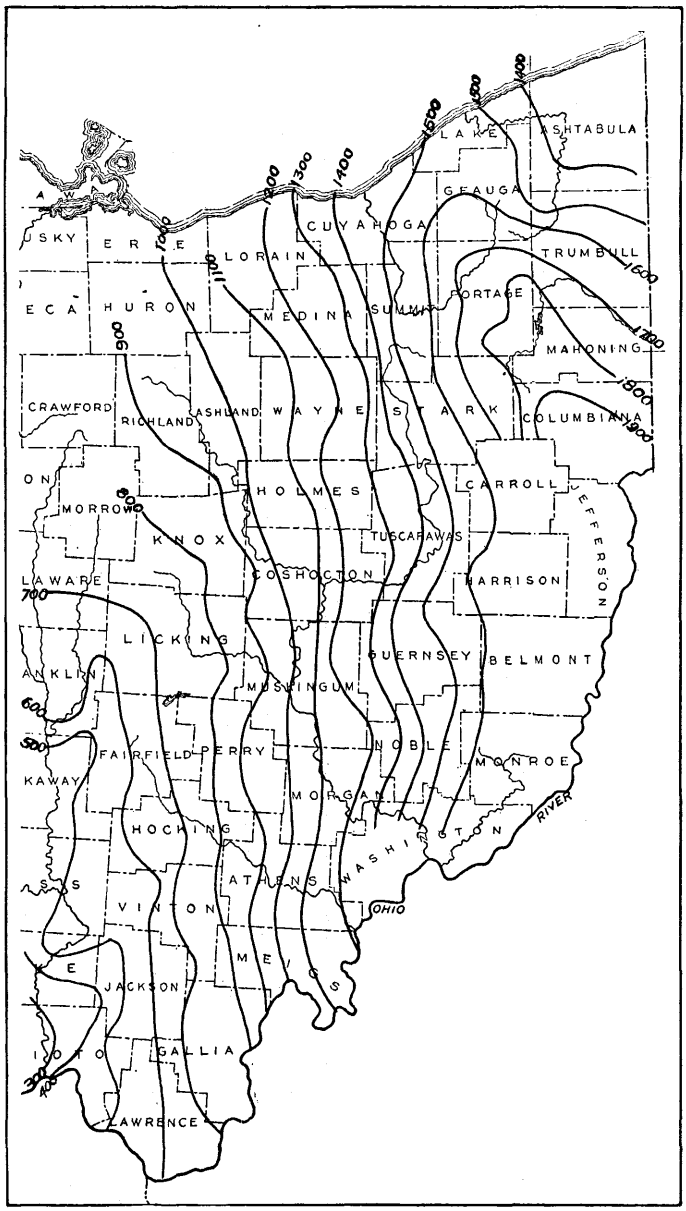


FIG. 3. Map of the eastern part of Ohio showing isopachs of the Big Lime series.

These beds in Ashtabula County approach 600 feet in thickness. This series thins to the west and southwest, however, the salt pinches out, and the dolomite and gypsum are not represented in the outcrops in west-central Ohio and their correlation with exposures in northern Ohio is uncertain.

Dolomite extends from the Salina to the base of the Big Lime. The widespread occurrence of a strong flow of brine about 150 to 300 feet above the base of the Big Lime suggests a persistent horizon of high porosity such as the upper surface of the Niagara dolomite. If this flow of brine comes from a definite stratigraphic horizon, there is little evidence for believing that the part of the Big Lime below it thickens much to the east in Ohio. As indicated from the foregoing discussion, the thickening of the Big Lime to the east is believed to occur chiefly in its middle portion. Greater detail within the Big Lime is impossible without a careful and extended study of drill cuttings. The thickness of the Big Lime series in different parts of the eastern half of Ohio is shown in Fig. 3.

### THE BIG LIME-BEREA SERIES

The interval from the Big Lime to the Berea sand consists for the most part of black, brown, bluish gray, and red shales comprising the Ohio shale and Bedford shale formations. These shales outcrop over a belt of territory varying from two to twenty miles in width, extending from eastern Adams County northward to Erie County and then eastward along the shore of Lake Erie to the Pennsylvania line. The shales have a thickness on the outcrop in Adams County of about 340 feet, but they thicken irregularly to the north along the outcrop, reaching a depth of about 550 feet in Erie County. Eastward from Erie County the expansion is marked for near Cortland, Trumbull County, the thickness is about 2,300 feet.

Under cover the Big Lime-Berea series also shows a great expansion in thickness to the east. Along an east-west line from Pike Township, Knox County, to New Cumberland, Hancock County, West Virginia, the rate of expansion is about 28.9 feet per mile, while along a similar east-west line from Newark, Ohio, to Wheeling, West Virginia, this shale series increases in thickness to the east at the rate of about 33 feet per mile. From western Guernsey County to Wheeling the rate of increase is about 40 feet per mile. The expansion along a third east-west line from western Hocking County to eastern

Washington County is about 34 feet per mile to the east. The two greatest thicknesses yet encountered in tests drilled in

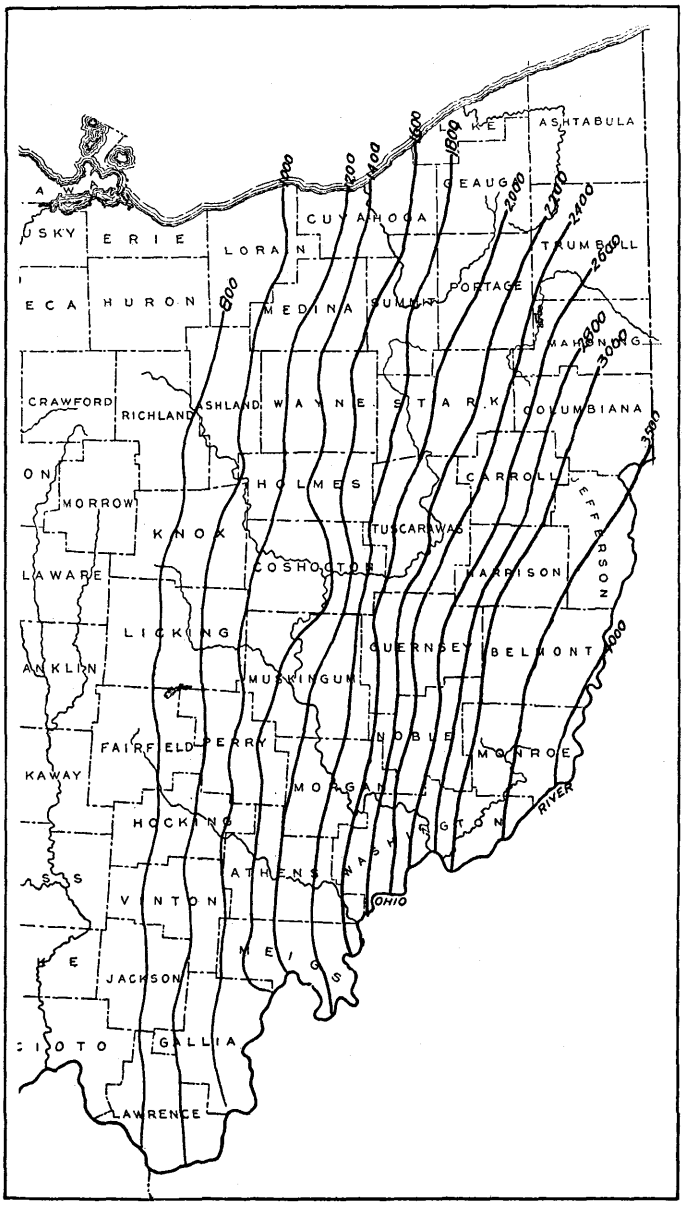


FIG. 4. Map of the eastern part of Ohio showing isopachs of the series extending from the top of the Big Lime to the base of the Berea Sand.

Ohio are 3,427 feet in Section 26, Island Creek Township, Jefferson County, and 3,341 feet in Section 10, Independence Township, Washington County.

The Ohio shale in northern Ohio is generally subdivided into three parts: a basal black shale or Huron, a middle gray shale or Chagrin, and an upper black shale or Cleveland member. This three-fold subdivision is not generally applied to the outcrops in central and southern Ohio although bluish-gray shale somewhat similar lithologically to the Chagrin is present in the middle portion in both regions and gives a three-phase character to the formation. Beneath the lower black shale of the Ohio formation and extending to the top of the Big Lime, there is another bed of blue shale which is persistent on the outcrop in central Ohio and which is found at many places in southern Ohio. This is the Olentangy formation of various reports on the geology of Ohio, but it is considered by the writer to be a phase of the Ohio formation.[8]

East of the belt of outcrops, black, brown and blue shales are encountered by the drill in all wells which have penetrated far below the Berea sand. West of a line from central Stark to central Lawrence counties the Big Lime is immediately overlain by material which is variously described as white or gray shale. This light material has a thickness of about 300 feet in western Stark County, 175 feet in western Muskingum County, and about 110 feet in western Lawrence County. It thins to the west and northwest of this line and at places it can be traced close to the outcrop. The stratigraphic position of this light shale suggests that it represents the eastern continuation of the so-called Olentangy shale of surface outcrops. This bed increases in thickness east of the line from central Stark to central Lawrence counties, but it is separated from the Big Lime by a wedge of black or brown shale which thickens to the east. In the deep well drilled on the Jones farm in Warren Township, Belmont County, the Big Lime is immediately overlain by 200 feet of black shale representing this wedge, above which occurs the gray shale; while in the test drilled in Island Creek Township, Jefferson County, the Big Lime is overlain by 400 feet of black shale with 775 feet of light shale above it.

Overlying the light shale which in the western part of the

[8]Lamborn, R. E. The Olentangy Shale of Southern Ohio. *Jour. Geol.*, Vol. XXXV (1927), pp. 708–722.

field forms the base of the Ohio shale there is a bed of black or brown shale which is generally known to the driller as the Cinnamon. Over large areas in eastern Ohio the Cinnamon is divided into two parts by a thin bed of blue or gray shale. The upper and thinner portion is called the Little Cinnamon, while the lower and thicker portion is known among the drillers as the Big Cinnamon. Showings of gas are of widespread occurrence in both of the cinnamon shales and the commercial production of shale gas in Lawrence County is apparently derived from these beds. The thickness of the Cinnamon shale along the first line of Clinton production from Jackson County to Lorain County varies irregularly from 300 to 400 feet. It increases in thickness somewhat to the southeast, however, for in general it measures 450 to 550 feet along a zone from western Noble County to western Columbiana County. The black Ohio shale of outcrops in central and southern Ohio is believed to represent the western continuation of the Cinnamon shale of the driller.

The shale from the Cinnamon to the base of the Berea sand is the most variable element in the Big Lime-Berea series, as it expands rapidly to the east in Ohio and as it is composed of a wide variety of materials. Along a north-south line from central Vinton County to central Ashland County this shale varies from 350 to 450 feet in thickness. It expands rapidly to the east, however, for it attains a thickness of 780 feet in northeastern Gallia County, 800 feet or more in central Athens County, 1,150 feet in central Guernsey County, and 1,400 feet or more in eastern Tuscarawas, western Carroll, and western Columbiana counties. In the deep test drilled in Island Creek Township, Jefferson County, in 1931 the shale between the Cinnamon and the Berea sand was found to have a thickness of 1,667 feet.

Red shale and thin sandstone are conspicuous elements in the shale series between the Cinnamon and the Berea. The red shale which for the most part is found less than 75 feet below the Berea sand is correlative with the red shale of the Bedford formation of surface outcrops. Sandstone is present close below the red shale and 20 to 60 feet below the Berea sand at some localities in western Medina and eastern Lorain counties. The position of this sandstone suggests that it represents the Euclid member of the Bedford formation. Sandstone occupying a similar position with respect to the

Berea is likewise found at many localities in southern Ohio. Through eastern Gallia, Meigs, Athens, eastern Morgan, and southern Muskingum counties a productive sandstone known as the Second Berea sand is present 15 to 75 feet below the Berea, from which it is separated at many places by red shale. This sandstone is likewise believed to be Bedford in age. Little detail can be derived from the series extending from the position of the Second Berea sand to the Cinnamon shale. Gray shale predominates in this interval, although red and pink shales are reported in the northeastern part of the state. The great array of productive sands below the Berea in West Virginia and western Pennsylvania belong in this series, but they either pinch out to the west or become so thin in eastern Ohio that they are generally described by the driller as "shells" and can not be correlated with accuracy. A notable exception, however, occurs in the presence of a thin sand of rather wide distribution which is found some 300 to 400 feet below the Berea sand.

### THE MISSISSIPPIAN SERIES ABOVE THE BEREA SANDSTONE

The Mississippian series above the Berea sandstone outcrops over a broad belt extending from Scioto and eastern Adams counties on the south to Medina, Lorain, and southeastern Erie counties on the north and then eastward over a somewhat narrower belt embracing portions of Summit, Cuyahoga, Geauga, Trumbull, and southern Ashtabula counties. From the region of outcrop the series slopes to the southeast beneath the Pennsylvanian and Permian strata which constitute the surface beds in the southeastern third of the state. The most conspicuous formation above the Berea sand which can be followed under cover by well records is the Maxville limestone, the youngest formation of the Mississippian system in Ohio. The Maxville limestone apparently remains as an unbroken sheet over Monroe, southern Belmont, and eastern Noble counties where it varies from 25 to 200 feet in thickness. North, west and southwest of this area the limestone is patchy in distribution, for at many places it has been entirely removed by erosion occurring at the end of the Mississippian period and preceding the deposition of the Pennsylvanian sediments. Enough limestone remnants remain, however, to mark the contact of the systems over large areas and to permit the

determination of the thickness of the Mississippian strata above the Berea with some degree of accuracy.

Where the Maxville limestone has been removed other criteria for determining the position of the contact must be applied. White sands are relatively rare in the outcrops of Mississippian rocks but are of common occurrence in the lower part of the Pennsylvanian. White sands, therefore, found close above the Berea sand and accompanied by reduced intervals from the Berea to known horizons in the Pennsylvanian are considered as representing the basal portion of the Pennsylvanian.

The thickness of the Mississippian strata above the Berea is apparently greatest along the western outcrop from southern Hocking County northward to Ashland and Wayne counties. In Hocking County the thickness of this series varies from 750 to 850 feet; in southern Licking and southeastern Ashland counties it is about 700 feet; and in Wayne County the maximum thickness measures 870 feet.[9] From east-central Ohio the series thins somewhat to the southeast, but the most notable reduction in thickness is from the south and west toward eastern Stark, northern Columbiana, and southern Mahoning counties, where the basal beds of the Pennsylvanian lie less than 100 feet above the Berea. The range in thickness of the Mississippian series above the Berea in many counties in southeastern Ohio as determined from well records is as follows:

| | |
|---|---|
| Athens County | 550 to 650 feet |
| Belmont County | 550 to 760 feet |
| Columbiana County (southern) | 200 to 250 feet |
| Coshocton County | 500 to 560 feet |
| Guernsey County | 500 to 700 feet |
| Jefferson County (southern) | 525 to 730 feet |
| Meigs County | 450 to 600 feet |
| Monroe County | 575 to 700 feet |
| Muskingum County | 650 to 700 feet |
| Noble County | 550 to 600 feet |
| Stark County (central) | 300 to 350 feet |
| Vinton County | 550 to 600 feet |
| Washington County | 500 to 640 feet |

The Maxville limestone is not known from well records north of an east-west line along the northern boundary of Harrison County and it has apparently been removed by erosion over large areas south of this line. It is also generally wanting on the outcrop except for small scattered exposures

[9]Conrey, G. W. *Geol. Survey Ohio*, Fourth Series, Bull. 24 (1921), pp. 49–50.

extending from western Muskingum County to northern Jackson County. The figures given above for the thickness of the series along the outcrop and in the northeastern part of the state apply to the clastic portion only, while in southeastern Ohio these figures include the remnants of the Maxville limestone.

The lower 300 to 400 feet of the Mississippian series above the Berea sand consists for the most part of bluish-gray and black shales, while sandstone is a conspicuous element in the upper half. Immediately overlying the Berea sand there is a thin bed of black shale known as "coffee" shale among the drillers, which represents the continuation under cover of the Sunbury shale. This black shale, which is very persistent, varies from 14 to 60 feet. The changes in thickness, however, are local in nature as no directional expansion is evident from a comparison of well records.

At many places in eastern and southeastern Ohio a sandy zone or "shell" is found from 65 to 100 feet above the Berea sand. This "shell" becomes a well developed sand in parts of Monroe County where it reaches a thickness of 175 feet and is called the Welsh Stray or Weir Sand. A thin sand at the same horizon is present in Jackson County where it is called the Hamden sand, and in Columbiana County where it is known as the Stray sand. The stratigraphic position of this sand suggests that it is correlative with the Buena Vista member of the Cuyahoga formation of surface outcrops.

Over much of southeastern Ohio sandstones form an important element in the 200 to 300 feet of strata immediately underlying the horizon of the Maxville limestone. These sandstones which are correlative with the Black Hand and Logan sandstones of surface outcrops, comprise the Squaw, Big Injun, and Keener sands of the driller. The Squaw sand, which lies at the base of this series, is relatively unimportant as it is thin and irregular in its occurrence. The top of this sandstone series is represented by the Keener sand, which rarely exceeds 60 feet in thickness, where it is best represented in Monroe and Belmont counties. The Big Injun sand, which lies between the Keener and Squaw sands, is the thickest and best known. From a comparative study of well records it appears that the Big Injun sand is well developed over two areas which are separated by a region of thin sandstone and shale. The first area of good sandstone development extends from southern Vinton County to southern Richland and

Ashland counties and lies west of a line passing through southeastern Vinton, eastern Athens, southeastern Perry, western Muskingum, western Coshocton, and western Holmes counties. In this area the sand is quite variable in thickness, but it shows no common directional expansion. Thicknesses of 300 feet or more occur in eastern Knox, western Muskingum, central Hocking, and eastern Vinton counties. The second area lies east of a line extending from central Meigs County through eastern Muskingum and eastern Wayne counties and includes eastern Meigs, Washington, Monroe, eastern Noble, Belmont, Guernsey, southern Jefferson, Harrison, western Carroll, Tuscarawas, western Stark, and eastern Wayne counties. In this portion of the field the Big Injun likewise shows great variation in thickness over small areas, but apparently reaches its best development over Monroe, Belmont, and southern Jefferson counties, where it measures as much as 300 feet.

Separating the two regions where the Big Injun sand is well expressed there is an elongated area including western Wayne, central Holmes, central Coshocton, east central Muskingum, Morgan, and eastern Athens counties in which the Big Injun sand is either wanting or is less than 50 feet in thickness. Apparently the thick sandstones found both to the east and west give way over this elongated area to thin sandstones and shales.

### THE BEREA-PITTSBURGH COAL SERIES

In both the Permian and Pennsylvanian systems the horizons which can be correlated over large areas are generally wanting as most of the beds either lack continuity, want definite determinable characteristics, or are too thin to be recognized by the driller. The Pittsburgh coal is a notable exception. In southeastern Gallia County the Berea sand lies about 1,800 to 1,900 feet below this coal; in eastern Athens County the interval is 1,380 to 1,480 feet; while in eastern Muskingum County the distance is 1,480 to 1,520 feet. The Pittsburgh coal occurs 1,600 to 1,660 feet above the Berea sand in eastern Noble, southern Monroe, and southeastern Belmont counties. The interval decreases to the north along the Ohio River valley, however, for in central Jefferson County is measures 1,400 to 1,460 feet. When the horizon of the Pittsburgh coal is projected north and northwest beyond its outcrop into Columbiana County, the interval to the Berea is

found to be about 1,170 feet in Knox Township, about 1,200 feet in southern Madison Township near Wellsville, and about 1,240 feet near East Palestine in Unity Township. The decrease in this interval to the north, which is most rapid in northern Jefferson and Columbiana counties, is due to the removal by erosion of many feet of Mississippian sediments before the deposition of the Pennsylvanian beds.

## SUMMARY AND CONCLUSIONS

From the foregoing discussion it is apparent that the St. Peter-Trenton series, the Trenton-Big Lime series, the Big Lime series, and the Big Lime-Berea series increase in thickness to the eastward in Ohio. This eastward expansion is due in part to the thickening of outcropping formations and in part to the presence under cover of certain beds which according to correlations based on a study of well records are not represented on the outcrop. Notable examples occur in the Clinton sand and overlying red and gray shales which have not been recognized on the outcrop. Either these beds never extended into the region of outcrop or they were removed by erosion before the deposition of the Brassfield (Shell) limestone. In the Big Lime series the salt beds with the associated gypsum and shale are not found to be represented in the outcrops in northern Ohio. A similar condition is present in the Big Lime-Berea series where beds of shale are present under cover both at the bottom and in the upper part of the series, neither of which are represented in surface outcrops of central and southern Ohio.

Of the various series above the St. Peter sand which have been described, the greatest thickening to the eastward occurs in the Big Lime and the overlying shales below the Berea sand. These series have their maximum combined thickness of about 5,900 feet in eastern Monroe and southern Belmont counties where the greatest depth of Permian is found. Adding 1,650 feet, the interval from the Berea sand to the Pittsburgh coal, and 870 feet, the combined thickness of the Monongahela and Permian strata, it is apparent that the series above the base of the Big Lime has a maximum thickness of about 8,420 feet. The series from the St. Peter sand to the base of the Big Lime likewise thickens to the eastward, but so many local variations occur in the western half of Ohio that the projection of any rate of increase eastward is somewhat hazardous. We believe

it safe to conclude, however, that the series above the St. Peter sand in eastern Monroe County has a thickness of 12,000 to 13,000 feet. Insufficient data prevents any conclusion as to the thickness of the sedimentary series below the St. Peter sand in eastern Ohio.