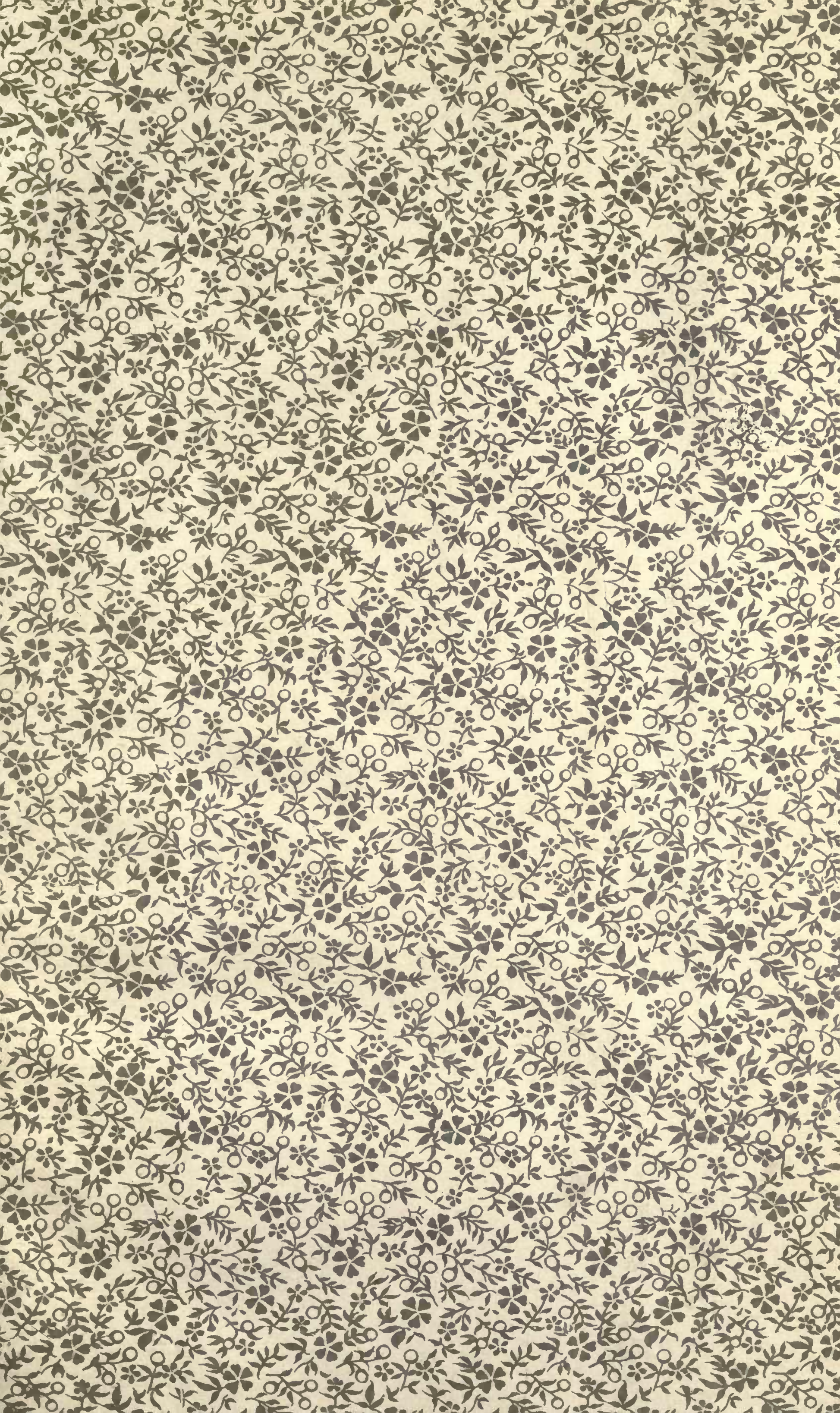
GEOLOGY OF THE GOLCONDA QUADRANGLE

STUART WELLER



The

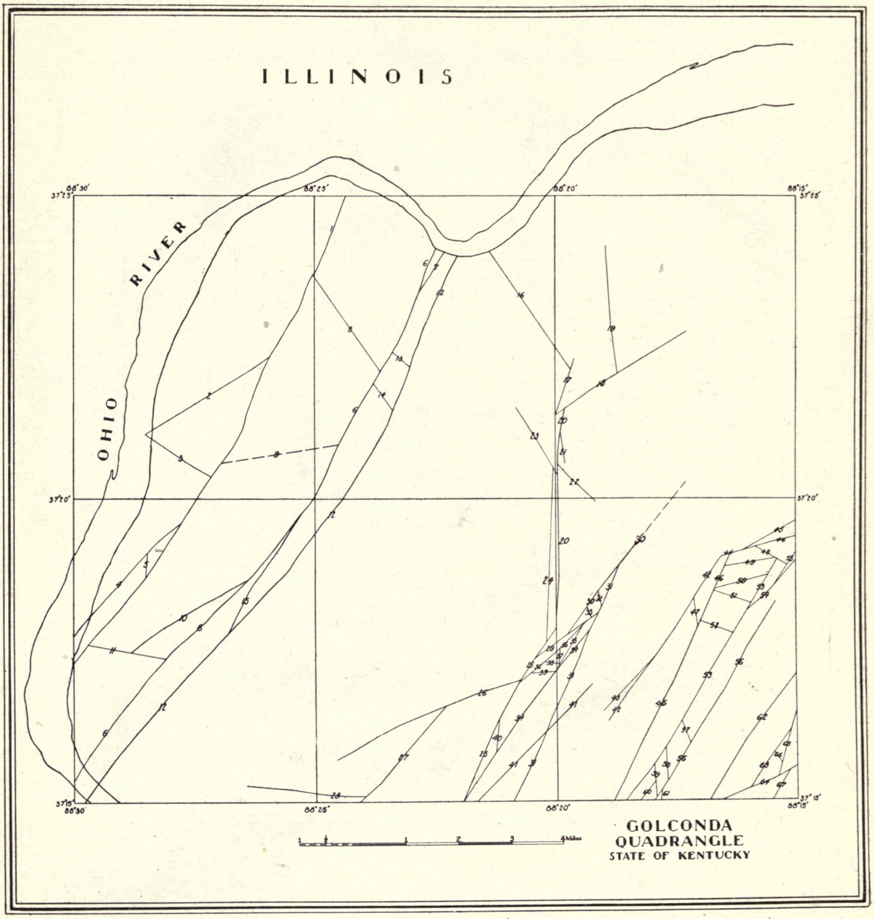
Kentucky Geological Survey

WILLARD ROUSE JILLSON
DIRECTOR AND STATE GEOLOGIST

SERIES SIX
VOLUME FOUR

Geology of the Golconda Quadrangle

1921



SKETCH MAP SHOWING FAULTS OF THE GOLCONDA QUADRANGLE IN THE STATE OF KENTUCKY.

The irregular lines which are numbered to correspond to the text represent the surface extension of the faults. These lines will be easily distinguished from the North-South and East-West lines of longitude and latitude. This outline map is a reduced reproduction of the New Standard U. S. G. S. quadrangle (Golconda), scale 1-62,500, on which the areal and structural geology of this region has been plotted by the author.

GEOLOGY OF THE GOLCONDA QUADRANGLE

A Detailed Report on the Stratigraphy and Structure of That Portion of the Golconda Quadrangle Lying in Kentucky

BY

STUART WELLER

ASSISTANT GEOLOGIST

Author of

THE GEOLOGY OF HARDIN COUNTY (Illinois.)
MISSISSIPPIAN BRACHIOPODA OF THE MISSISSIPPI VALLEY BASIN.
THE CHESTER SERIES IN ILLINOIS.

First Edition

500

THE KENTUCKY GEOLOGICAL SURVEY

FRANKFORT, KY.

1921

THE STATE JOURNAL COMPANY
Printer to the Commonwealth
Frankfort, Ky.

LETTER OF TRANSMISSION

CHICAGO, ILLINOIS, June 6th, 1921.

DR. W. R. JILLSON,
Director and State Geologist,
The Kentucky Geological Survey,
Frankfort, Ky.

Dear Sir:

I am transmitting herewith the manuscript of a report on the Stratigraphic and Structural Geology of that portion of the Golconda Quadrangle of the United States Geological Survey topographic atlas which lies on the Kentucky side of the Ohio River.

The field work upon which the report has been based was carried on during the Summer of 1920. The region is of especial interest because it covers a portion of the fluorspar producing area of western Kentucky. The deposits of this mineral are closely associated with the faults which cross the area in great numbers, and it is hoped that the detailed mapping of these faults will be of service in directing intelligent prospecting.

Respectfully submitted,

STUART WELLER.
Assistant Geologist.

PREFACE

The area described in this report is a part of a region of remarkably complex geology in southern Illinois and western Kentucky. It is characterized by a most extraordinary series of faults. During a period of several years the author, Dr. Stuart Weller, Professor of invertebrate Paleontology in the University of Chicago, has been engaged in the detailed mapping of that portion of the area which is situated in Missouri and Illinois. In order to elucidate the structure it has been necessary to devote a long time to establishing the stratigraphic succession of the Chester Series of rocks, a series which is wonderfully complex in detail, but is comparatively simple in its larger features, now that they have come to be understood. Without an accurate knowledge of the Chester succession it would have been impossible to establish the exact position and the direction and amount of throw of the fault dislocations.

The investigations upon the Chester Series throughout this broad area have been carried on by Dr. Weller personally, and by competent assistants under his immediate direction. Detailed mapping has been done in St. Clair, Monroe, Randolph and Jackson Counties, east of the Mississippi River in Illinois; in Ste. Genevieve and Perry Counties, in Missouri, west of the Mississippi River; and across southern Illinois in Union, Johnson, Pope and Hardin Counties. These wide Chester studies, projected in great detail, have given a substantial basis for the interpretation of the Chester Series.

The extension of these studies into Kentucky is a part of an informal plan of cooperation between the Geological Surveys of Illinois, Missouri and Kentucky, for the purpose of covering the entire area in detail, occupied by the Chester Series and by the numerous and economically important faults.

In bringing the experience gained in Illinois and Missouri into the Kentucky work, it has been possible to coordinate this part of the region with the wider area, to prosecute the detailed mapping much more thoroughly, with greater dispatch, and a much lessened cost to the State of Kentucky, than would otherwise have been possible. In carrying on this work in the Golconda Quadrangle, Dr. Weller has been efficiently assisted by Mr. Richard A. Jones of Chicago.

This report has been carefully prepared for the use of all who may be interested in the geology of this part of Livingston and Crittenden Counties, Kentucky. Discussions have been freed from technical terms insofar as possible, and it is felt that a thoughtful and intelligent review of this work and the geologic map accompanying it will materially assist operators of fluorspar properties and students of the stratigraphic and structural geology of this region generally.

W. R. Jillson

Director and State Geologist.

Old Capitol,
Frankfort, Ky.
November, 1, 1921.

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CHAPTER I

INTRODUCTION.

Location. The Golconda sheet of the United States Geological Survey atlas is a fifteen minute quadrangle lying between north latitude 37° 15′ and 37° 30′, and west longitude 88° 15′ and 88° 30′. It is situated in the states of Illinois and Kentucky, being crossed by the Ohio river whose direction in this part of its course is in general from the northeast to the southwest. The areal extent of the quadrangle is approximately 250 square miles. About 70 square miles of the entire area lie in Illinois, the remaining portion being in Kentucky. The present report will deal only with that portion of the quadrangle which lies in Kentucky, the Illinois portion having been described and mapped in the report on Hardin County of that state.[1] The greater part of the Golconda Quadrangle in Kentucky lies in the northern part of Livingston County, but a small portion of Crittenden County, lying east of Deer Creek is also included in it.

Importance of the area. The importance of this area geologically is due to the fact that it lies within the most remarkably faulted area of the whole interior region of the United States, and associated with these fault structures are the rich fluorspar deposits of the Kentucky-Illinois field. The town of Rosiclare, Illinois, where are located the two most fully developed mines of the entire district, is situated within the Golconda quadrangle, although the greater part of the spar production in Kentucky is from mines in Crittenden County, in the area lying just east of the Golconda quadrangle here described. The only mine within the Kentucky portion of the quadrangle producing at the time the field work for this report was in progress, was the Bonanza Mine, one and one-half miles

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[1] Illinois State Geological Survey, Bulletin No. 41 (1921).

southwest of Lola. The possibilities for mineral development within the area are considerable, however, and the determination of the faults, as shown upon the accompanying map, may assist in directing future prospecting.

Culture. Within the area here described the population is altogether rural, and the occupation almost wholly agricultural, although some of the citizens spend a portion of their time in prospecting for mineral or in working in some of the producing mines. From Carrsville a considerable number of men cross the river daily to work in the mines at Rosiclare, Illinois. The villages of Carrsville, Hampton, Lola and Joy are situated within the area, but the largest of these places does not exceed 300 in number of population, and the smallest is less than 100. No railroad enters the region. The town of Carrsville, situated on the Ohio river, is served chiefly by the river boats, but the interior villages are served only by team and motor transport, which is greatly handicapped by the lack of improved roads.

Topography. The topography of the area has reached the stage of maturity. Apart from the river bottoms and the valleys of some of the larger streams towards their junction with the Ohio, there is very little level land. The highest point in the area is about one and one-half miles west of Joy and just rises beyond 700 feet above sea-level, although there are a number of other points within the district that rise to 680 feet. The elevation of the bank of the Ohio river at the southwestern corner of the quadrangle is essentially 320 feet, so that the total relief is about 380 feet. The character of the underlying rock formations has exercised a great influence upon the topographic features. The resistant sandstone formations in many places form more or less abrupt bluffs or escarpments, while the limestone formations underlie most of the lower and more lever ground. Good examples of the more level, limestone topography occur in the region about Lola, and to some extent also west and northwest of Salem, a village just outside the southeastern corner of the quadrangle.

Among the most notable topographic features of the area are several more or less continuous bluffs or escarpments which cross the quadrangle in a general north-south or northeast-southwest direction. The most conspicuous of these may be called the Carrsville escarpment, it continues from the bank of the Ohio river just west of Carrsville, in a southwesterly direction to the point where the valley of Bayou Creek joins the valley of the Ohio. For a short distance just west of Joy, between the heads of two ravines extending in opposite directions, the Carrsville escarpment is partially interrupted, but aside from this it is a nearly straight, continuous bluff of resistant Pottsville sandstone and conglomerate, underlain by the higher beds of the Chester Series. The southern portion of this escarpment is known locally as Newman's Bluff.

A second escarpment may be named from the village of Joy which is situated near its northern extremity. This escarpment is not so straight as the Carrsville, being convexly curved to the east between Joy and Hampton. West of Hampton it is transected by one of the branches of Bayou Creek, both the north and south walls of this valley being continuations of the Joy escarpment. South of this valley the direction of the escarpment is almost north and south and extends nearly to the southern boundary of the Golconda quadrangle. This escarpment is formed by the resistant Hardinsburg sandstone, underlain by the more or less shaly Golconda limestone of the Middle Chester. Both of these formations have a gentle dip to the west throughout most of their extent in this portion of the area, and northwest from the crest of the escarpment is a rather broad cuesta slope underlain by the Hardinsburg sandstone.

Between the Joy and Carrsville escarpment there is a much less conspicuous topographic feature of similar character, formed by the Tar Springs sandstone underlain by the Glen Dean limestone, but the fault block whose eastern face is formed by this escarpment is so narrow that the Tar Springs cuesta slope is inconspicuous.

The Bethel Hill escarpment is so-called from Bethel hill about two miles north of Lola on the road to Joy. This escarpment is at least partially determined by a series of faults which lie along its eastern front. It extends in an easterly direction from the mouth of Buck Creek just outside of Carrsville, for a distance of nearly two miles, throughout most of which distance it rises abruptly from the channel of Deer Creek. Beyond this point it turns to the south and continues to a point three miles southwest of Lola where it is lost. Throughout most of its extent the summit of this escarpment is the Bethel sandstone, the lower slope being underlain by the Renault limestone, but for a portion of the distance where its direction is east and west, the determining sandstone is the Cypress, which is underlain by the Paint Creek shales.

A more or less continuous escarpment extending in a northeast-southwest direction, crosses the southeastern corner of the Golconda quadrangle about two miles northwest of Salem. This is determined by the Pottsville sandstone and conglomerate, and continues to the southwest from the conspicuous Hardin Knob in Crittenden County, beyond the area of this map. Separate parts of this escarpment are known locally as Wilson Bluff and Lockhart Bluff.

There are other shorter escarpments similar to those already described, among which may be mentioned the Bald Knob escarpment, situated about two miles south of Lola. This escarpment has a northwest-southeast direction with an extent of a little over one mile. The determining sandstone is the Hardinsburg, the lower slope being underlain by the Golconda limestone and shale. Northeast of the Bald Knob escarpment, about half way between it and Lola, is another one subparallel with it, of about equal extent in a northwest-southeast direction, which is determined by the Bethel sandstone underlain by the Renault limestone.

The Ohio river escarpment, formed by the erosion of the Ohio River valley, continues from Carrsville to near the southwestern corner of the quadrangle, except where it is interrupted by the tributaries to the river, the most important of which is Bayou Creek, whose valley forms a gap about one mile in width. Four miles north of Bayou Creek there is another narrow gap formed by Long Branch, and a number of other narrow valleys or ravines, occupied by lesser tributaries, intersect the bluff at intervals. The Ohio

River escarpment is constituted of various geological formations in its different parts, and the character of the bluff from place to place is determined by the formations which constitute it. The bluff is highest and most abrupt for two miles below Carrsville where the constituent formation is the Pottsville sandstone. Where limestone formations are the underlying rocks the escarpment slope is more gentle, but where the Bethel or Cypress sandstones are present the bluffs are nearly as abrupt, but not as high, as the Pottsville bluff near Carrsville.

Drainage. The master stream controlling all the drainage of this part of western Kentucky is of course the Ohio River, and by far the greater portion of the Golconda quadrangle drains directly into the river through the tributary creeks, although a small part of the southeastern portion is drained by tributaries of the Cumberland river and thence into the Ohio. The two largest creeks draining the area are Deer Creek in the northeast, and Bayou Creek in the southwest. To the west of the Deer Creek basin, in the northern part of the quadrangle, is Buck Creek, emptying into the Ohio at Carrsville, whose drainage basin is considerably smaller than either of the other two streams mentioned. The drainage areas of all three of these streams lie east of the conspicuous Carrsville escarpment. The region west of this escarpment is drained chiefly by Long Branch and Love's Branch and their tributaries, neither of which has a drainage basin as large as any one of the three streams which drain the area east of the escarpment.

Previous work. The first systematic geologic work undertaken in that part of western Kentucky under investigation, was in 1889 and 1890, when E. O. Ulrich made a study of the region for the Kentucky Geological Survey. The results of this work were not fully published, however, until 1905 in Professional Paper No. 36, of the United States Geological Survey[1], after parts of the years 1902 and 1903 had been spent in the field. The geological portion of this report is under the sole authorship of Ulrich, Smith's contribution being devoted to the ore deposits and mines. The geological map

[1]The Lead, Zinc, and Fluorspar Deposits of Western Kentucky, by E. O. Ulrich and W. S. Tangier Smith.

accompanying this report, published on a small scale, covers Livingston, Crittenden, Caldwell and a part of Lyon Counties, including, therefore, the area with which the present report is concerned. Ulrich's work was seriously limited by the lack of proper topographic maps, and therefore could be only of a reconnaisance nature. The character and succession of the stratigraphic units of the Chester series were imperfectly understood at that time, so that the fault structures shown upon the maps were based more upon the location of mines and prospects than upon the accurate recognition of the several formational units present in the area. Because of the different conditions under which the work of the two surveys was conducted, the detailed mapping of the faults, as shown in the present report, are notably different from those shown by Ulrich.

In his Professional Paper Ulrich introduced a new system of classification for the formations of Mississippian age in the Ohio and Mississippi Valleys, which the more intensive study of the region during the past decade has proven to be inadequate to express the true conditions. His principal innovations, so far as they affect the region here under discussion, were the resurrection of the Ste. Genevieve limestone as one of the important units in the stratigraphic succession, and his inclusion of the Ste. Genevieve as the lowest unit in the Chester Group. In addition to the Ste. Genevieve the Chester was divided into the Cypress sandstone, the Tribune limestone, and the Birdsville formation, in ascending order. The studies of recent years have established the fact that the Ste. Genevieve proper is not allied to the Chester, but should be associated with the underlying St. Louis limestone, although the higher portion of the upper or Ohara member of the Ste. Genevieve limestone as defined by Ulrich is now known to be separated from the lower portion by a distinct unconformity, which is the true line of demarcation between the Chester series and the older Mississippian. The Cypress sandstone, as recognized by Ulrich is now known to be different from the Cypress sandstone as that formation was originally defined by Engelmann in southern Illinois. The Tribune limestone is indicated at four points on Ulrich's geological map.[1] More recent work has shown that the limestone at Tribune, five miles east of Marion, the locality from which the formation was named, is really a limestone which belongs high up in the Birdsville formation, as defined by Ulrich. The locality east of Joy is situated in the midst of a broad area of the true Cypress sandstone, with no limestone of any sort near it. The two localities southeast of Princeton do lie above the sandstone mistakenly identified as Cypress by Ulrich, and therefore do occupy the position assigned to the formation in its definition. Another outcrop identified as Tribune in the same report, but lying across the Ohio River at the Fairview mine at Rosiclare, Illinois, occupies a position beneath the sandstone mistakenly called Cypress.

The Birdsville formation, as defined by Ulrich, consists of a series of sandstone units separated by limestone-shale units, which have proven to be sufficiently distinct to permit them to be mapped as separate formations, which has been done in the map accompanying this report. As a matter of fact, the Birdsville formation, as used by Ulrich, comprises the major portion of the entire Chester series as this series is commonly manifested in the Ohio Valley.

Since the publication of Professional Paper No. 36, a number of reports and papers have been published by Fohs upon the Kentucky fluorspar district, but all of these deal with the economic aspects of the mining industry rather than with the systematic geology of the region.

In 1917 a volume was published by the Kentucky Geological Survey on the "Mississippian Formations of Western Kentucky," containing two papers one under the authorship of Charles Butts, the other by E. O. Ulrich. These papers deal largely with the subdivisions of the Chester Series. Butts' knowledge of the Chester series was derived chiefly from his mapping of the Equality and Shawneetown quadrangles in Illinois, and from reconnaisance work in Kentucky, to which studies he was introduced by the writer of the present report in 1915. In his paper he defines a number of new formations,

[1]Professional Paper, U. S. Geol. Survey., No. 36, pl. 2.

subdivisions of the old Birdsville, all of which had already been differentiated and mapped by the writer in considerable areas in the southern Illinois counties. Ulrich's paper consists of a restatement of his position regarding the interpretation of the Chester Series, in which he corrects some of the mistakes he had made in Professional Paper No. 36, to which his attention had been called, and in which he clings to other mistakes and makes at least one new, serious error in the correlation of the true Cypress sandstone of the Ohio Valley with the lower part of the Okaw limestone of western Illinois. In this report he still clings to the inclusion of the Ste. Genevieve limestone in the Chester Series.

All of the intensive work upon the Chester Series of formations which has been conducted in the Ohio and Mississippi Valley regions of Illinois, has a most direct bearing upon the geology of the Kentucky portion of the Golconda Quadrangle. Without the work which has been carried on in the areas of lesser deformation by faulting, the elaboration of the stratigraphic succession in this much faulted area would have been a task of extreme difficulty. This intensive study was started by the writer in 1911, since which time it has been continuously carried on, and had been preceded by considerable reconnaisance work which had been in progress intermittently for six years previous to the date mentioned. During the entire period almost no statement of results was prepared for print, the publication of results being withheld with the hope that some agreement might be reached with Ulrich in regard to the interpretation of the section[1]. Several long manuscripts were prepared, all but the latest one of which were placed freely in Ulrich's hands for his information and consideration. The first full statement of results of these investigations upon the stratigraphic succession in the Chester Series appeared in a

[1]A short paper defining certain new Chester formations appeared in Trans. Ill. Acad. Sci., vol. 6, pp. 118-129 (1913), and essentially the same material was included in the introduction to Monog. I, Ill. State Geol. Surv., pp. 23-29 (1914).

paper on "The Chester Series in Illinois,"[1] and in the "Report on the Geology of Hardin County, Illinois,"[2] which includes a description of the northern or Illinois portion of the Golconda Quadrangle, the Kentucky portion of which forms the subject of the present report.

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[1] Weller, Jour. Geol., vol. 28, pp. 281-303, 395-416 (1920).
[2] Ill. State Geol. Surv., Bull. No. 41, pp. 121-222 (1920).

CHAPTER II

STRATIGRAPHIC GEOLOGY, IOWA SERIES.

Introductory Statement.

The hard rocks exposed at the surface in the Golconda quadrangle all belong to the Mississippian and Pennsylvanian Systems, but beneath the oldest of the exposed formations it is necessary to assume the presence of a great series of sedimentary rocks of earlier Paleozoic age, although the entire sequence of sediments that would be penetrated by deep drilling in the area cannot be predicted. It is reasonably safe to assume, however, that the older formations which are exposed in the Hicks dome in Hardin County, Illinois, which is situated less than ten miles north of the area here described, continue beneath this Kentucky portion of the Golconda quadrangle. The oldest exposed beds in this dome are limestones of middle and perhaps lower Devonian age. Still older Paleozoic sediments of Silurian, Ordovician and Cambrian age are quite certainly present beneath the Devonian limestones, but the actual surface outcrops of formations of these ages are at so great a distance from the area under consideration that it would be unwise even to hazard a guess as to what their character may be beneath this part of Kentucky.

The geological column which may be reasonably predicted for the area is shown in the accompanying table, the formations from the St. Louis limestone to the top of the column being known from surface exposure, those next below down to and including the Devonian limestone being inferred from their presence in surface exposures only ten miles to the north. The formations beneath the Devonian limestone are wholly conjectural.

Pennsylvanian	Pottsville sandstone, 200 feet or less.			
Mississippian	Chester Series	Upper Chester	Kinkaid limestone, 180 feet or less.	
			Degonia sandstone, 30 feet.	
			Clore limestone and shale, 40 feet.	
			Palestine sandstone, 60 feet.	
			Menard limestone, 80 feet or more.	
			Waltersburg sandstone, 50 feet, more or less.	
			Vienna limestone, 30 feet, more or less.	
			Tar Springs sandstone, 100 to 150 feet.	
		Middle Chester	Glen Dean limestone, 60 feet.	
			Hardinsburg sandstone, 100 feet.	
			Golconda limestone, 80 to 170 feet.	
			Cypress sandstone, 100 to 125 feet.	
		Lower Chester	Paint Creek shale and limestone, 20 to 40 feet.	
			Bethel sandstone, 80 to 120 feet.	
			Renault limestone, 60 to 80 feet.	
	Iowa Series	Meramec Group	Ste. Genevieve Limestone	Lower Ohara limestone, 20 feet.
				Rosiclare sandstone, 20 feet.
				Fredonia limestone, 180 to 200 feet.
			St. Louis limestone, 350 feet.	
			Warsaw limestone, 250 feet.	
		Osage formation, 550 feet.		
Devonian	Chattanooga shale, 400 feet.			
	Devonian limestone, 350 feet.			
Silurian, mainly limestone.				
Ordovician, mainly limestone, possibly with some sandstone near the top and bottom, and some shale in the higher part.				
Cambrian, sandstones and dolomitic limestones.				

The several stratigraphic units in the geological column, as exposed in this part of Kentucky, will be described in order, beginning with the oldest.

The Meramec Group.

Ulrich established the Meramec Group[1] to include the Warsaw, Spergen, and St. Louis formations. In the same place he recognized the Ste. Genevieve limestone and considered it as constituting the lowermost division of the Chester Group. More recent work has established the fact[2] that the upper or Ohara member of the Ste. Genevieve limestone, as defined by Ulrich, is divisible into two parts by a distinct line of unconformity, and that the true Chester elements in the faunas are confined to that portion of the formation that lies above the unconformity. Furthermore, the original Ste. Genevieve limestone of Shumard is equivalent only to that part of Ulrich's Ste. Genevieve which lies beneath the unconformity. In following the unconformity within the Ohara to the west, there is intercalated between the two divisions of this member of the Ste. Genevieve as interpreted by Ulrich, an important sandstone formation, the Aux Vases sandstone, which in places attains a thickness of 80 feet or more. That part of Ulrich's Ste. Genevieve limestone which lies below the unconformity, along with the original Ste. Genevieve limestone of Missouri, have been shown to be most closely related, both faunally and stratigraphically with the underlying St. Louis limestone, while the "Upper Ohara" lying above the unconformity, is truly Chester, and is the exact equivalent of the Renault formation of the Mississippi Valley section. Under these circumstances it becomes necessary to join the true Ste. Genevieve with those formations of Ulrich's Meramec into one Group, and rather than to introduce a new term in the nomenclature of these formations, it seems best to redefine the Meramec to include the Ste. Genevieve limestone, and it is in this manner that the name Meramec is used in the present report. The

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[1]Prof. Paper, U. S. Geol. Surv., No. 24, table opp. p. 90 (1904); also Prof. Paper, U. S. Geol. Surv., No. 36, p. 24 (1905).

[2]Weller, Ill. State Geol. Surv., Bull. No. 41, pp. 150-159 (1921).

only exposed formations of the Meramec Group within the Kentucky portion of the Golconda quadrangle are the St. Louis and the Ste. Genevieve formations.

St. Louis Limestone.

Name. The name of the St. Louis limestone was taken from the city of St. Louis, Missouri, where this formation is well exhibited in the Mississippi River bluffs. The name was first applied by Engelmann[1] in 1847, and has been used by all writers on the geology of the Mississippi Valley since that time, although Englemann believed that the formation was the highest stratigraphic unit beneath the coal bearing series.

Distribution. In the Golconda quadrangle in Kentucky, the St. Louis limestone is confined in its distribution to the northeastern part of the area. At Tolu, on the Ohio River, just east of the eastern border of the quadrangle, the formation is well exposed in the banks of Hurricane Creek. The best exposure that has been observed within the area under consideration lies along the road just within the eastern boundary of the quadrangle, about one mile south of the Ohio River bank.

Within the area occupied by the formation, rock exposures are not numerous, and where outcrops do occur they are commonly of small extent. Because of this, and because the exposures of the underlying Ste. Genevieve limestone are of the same character, it is not easy to establish the boundary between these two formations with any degree of accuracy. The field examination of the northeastern portion of the quadrangle has not been as thorough as of the remaining portion of the area, but so far as observations have been carried, no St. Louis limestone has been observed southwest of the road extending northwest from Irma to the Ohio River bluffs a little more than two miles west of the eastern boundary of the quadrangle. In the Ohio River bluffs on the north side of the river, in Hardin County, Illinois, the exposures of the St. Louis and Ste. Genevieve limestones are essentially continuous, and no sharp line of demarkation between the two formations can

[1]Amer. Jour. Sci., 2nd ser., vol. 3, pp. 119-120 (1847).

be established, so that even under the most favorable conditions this boundary has to be placed more or less arbitrarily, and under the conditions of exposure in this part of Kentucky it is even more difficult to map the line separating the two formations.

Lithologic Characters. The St. Louis limestone is commonly a hard, dense, compact rock, dark blue to nearly black in color upon freshly broken surfaces, the exposed weathered surfaces being smooth and light bluish gray in color. In the adjacent portion of Illinois where the formation is much better exposed, the upper 75 to 100 feet of the formation are somewhat lighter in color than the lower portion, and there are some beds which are more or less crystalline in texture. So far as it has been observed the formation is free from oolitic beds, this being a useful lithologic character in separating the formation from the overlying Ste. Genevieve limestone which has oolitic beds scattered throughout its entire thickness, with oolitic beds of considerable thickness in its upper portion. The individual beds of the St. Louis limestone are rather thin or of moderate thickness, varying from less than a foot to two or three feet. The formation is characterized by a considerable amount of chert which is commonly dark in color when seen imbedded in the undisturbed limestone, but which becomes lighter colored on weathering. The chert commonly occurs in lenticular or irregular masses distributed along horizontal lines parallel with the bedding planes, and seems to be more abundant near the surface. The residuum from weathering of the St. Louis limestone consists of a red clay with imbedded masses of chert.

Thickness. There is no opportunity for determining the thickness of the St. Louis limestone in the Kentucky portion of the Golconda quadrangle, but across the Ohio River, in Hardin County, Illinois, the formation has been estimated to be 350 feet thick[1], and there is no reason to suppose that there is any notable difference in the thickness of the formation on the two sides of the river.

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[1]Ill. State Geol. Surv., Bull. No. 41, p. 104 (1921).

Stratigraphic Relations. The exposures of the St. Louis limestone in the Kentucky portion of the Golconda quadrangle are not such as to permit the stratigraphic relations of the formation to be determined. The exposures across the river in Illinois are more satisfactory, but the actual contact between the St. Louis and the underlying and overlying formations are not exposed in an entirely satisfactory manner even there. All evidence goes to prove, however, that there was no break in the continuity of sedimentation, either below or above the St. Louis limestone, in consequence of which the boundary lines at both limits of the formation have been placed somewhat arbitrarily.

Paleontology. Much of the St. Louis limestone is unfossiliferous and even where fossils are present they are preserved in most localities in such a manner that their identification is commonly a matter of some doubt. The fossil which is the real index of the formation is the coral genus *Lithostrotion.* Two species of this genus occur in the formation, *L. proliferum,* which is characterized by its cylindrical corallites, not in contact laterally, and *L. canadensis,* with its corallites polygonal in cross section, due to their close lateral contact on all sides. *L. proliferum* is present throughout the whole of the formation, from bottom to top, while *L. canadensis* is commonly restricted to the higher portion of the formation, in this region at least. In the exposures about one mile southwest of Tolu, just within the eastern border of the Golconda quadrangle, the residual material upon the hill slope facing to the south, is filled with broken, silicified fragments of *L. proliferum,* and some of the beds of limestone at this locality are filled with colonies of this coral. *L. canadensis* is much less common, and where it does occur it is commonly in the form of more or less isolated colonial masses, most of them silicified, either imbedded in the limestone matrix or occurring as loose masses among the residual materials.

Correlation. There are no important questions of correlation associated with the St. Louis limestone. The formation is widely distributed from Iowa to Alabama, and is everywhere characterized by the species of *Lithostrotion* which have been mentioned, and it possesses similar lithologic characters throughout.

Ste. Genevieve Limestone.

Name. The Ste. Genevieve limestone was first defined by Shumard[1] but he gave no really adequate description of the formation. The name of the formation was taken from Ste. Genevieve, Missouri, the type locality specified by Shumard being in the Mississippi River bluffs a mile or two below the town. For many years following the original definition of the formation, both the name and the formation itself were overlooked, and the beds were commonly included in the St. Louis limestone.

When Ulrich first entered upon the investigation of the geology of western Kentucky he differentiated a formation lying above the St. Louis limestone which he named the Princeton limestone[2] from the town of Princeton in Caldwell County, but later, a visit to Ste. Genevieve convinced him that his Princeton limestone was the equivalent of Shumard's Ste. Genevieve, and in his final report[3] he adopted the older name for the formation, and gave a much fuller description of it than had been published elsewhere. The formation is now known to have as wide a geographic distribution as the St. Louis limestone, being recognized from Iowa to Alabama.

In western Kentucky and the adjacent parts of Illinois, Ulrich divided the Ste. Genevieve limestone into three members, the Fredonia limestone member below, the Rosiclare sandstone member in the middle, and the Ohara limestone member above. More recent investigations have shown that Ulrich was in error in his interpretation of the higher or Ohara member of the formation, for this limestone is divisable into two parts by a distinct line of unconformity, well exhibited by a conglomerate layer in the quarry section at Cedar Bluff, near Princeton, the type locality for the member. Only the beds beneath this line

[1]Trans. St. Louis Acad. Sci., vol. 1, p. 406 (1859); Mo. Geol. Surv., Rep. for 1855-1871, p. 293 (1873).

[2]Crittenden Press, Dec. 1890; also, Bull. U. S. Geol. Surv., No. 213, p. 207 (1903).

[3]Prof. Paper, U. S. Geol. Surv., No. 36, p. 39 (1905).

of unconformity are properly referable to the Ste. Genevieve, the higher beds being the Renault limestone of the Chester Series, and intercalated between the two beds in the western Illinois section is the important Aux Vases sandstone formation. In the present report only that portion of the limestone between the unconformity and the Rosiclare sandstone will be called Ohara, and this will in every case be referred to as ''Lower Ohara,'' although no ''Upper Ohara'' will be recognized, this being the Renault limestone.

Distribution. In the Golconda quadrangle the Ste. Genevieve formation occupies nearly the whole area east of the Bethel Hill escarpment, and north of a line a little south of Lola. The southern border of the area is irregular, with two projecting, wedge-like, extensions to the south, one southwest and the other southeast of Lola. Through much of its distance the border of this formation is in fault contact with the adjacent formations, the only places where the Ste. Genevieve occurs within the area under consideration, in its proper stratigraphic sequence with the overlying formations being in the north half of the western border of the areas, and along the escarpment lying between the Bald Knob escarpment and Lola. In his generalized mapping of the area Ulrich has limited the Ste. Genevieve area about Lola on the east by a fault lying to the west of Deer Creek, and called by him the Deer Creek fault, along which the Ste. Genevieve limestone is shown to be faulted against the St. Louis limestone on the east. No evidence for such a fault has been detected during the prosecution of the field work of the present survey, but on the other hand undoubted Ste. Genevieve limestone has been recognized east of Lola to a point less than one-half mile from the eastern border of the quadrangle. The one boundary line between the Ste. Genevieve and the underlying St. Louis is across the northeastern corner of the quadrangle, and this has not yet been definitely located. Three other smaller areas of Ste. Genevieve limestone are present in the quadrangle. The first of these is along Flat Lick Creek three miles east of Lola, in a triangular fault block whose eastern extremity extends across the eastern border of the quadrangle. The extent of this area is considerably less than one square mile. A second area somewhat larger than the last, but less than a square mile in extent, lies in the extreme southeastern corner of the quadrangle. This, however, is a part of a much larger area which spreads eastward into the adjoining quadrangle. The third area is very small indeed, and is present in a ravine cutting the Bethel Hill escarpment two and one-half miles southwest of Lola.

The greater portion of the Ste. Genevieve area, as indicated above, is underlain by the Fredonia limestone member, the Rosiclare sandstone being restricted almost entirely to an area lying between the Bethel Hill escarpment and a line drawn north from Lola. The larger areas of the sandstone occupy the dip slopes of two hills, the first just north of Hopewell Church and the other about two and one-half miles farther north. All of this sandstone is indicated as Cypress on Ulrich's map, which is the Bethel of this report. There are two small areas of Rosiclare sandstone east of Deer Creek, about three miles from the Ohio River. The same sandstone outcrops in three areas lying south of an east west line through Lola, one in the ravine about two and one-half miles southwest of Lola, west of the faults bordering the Bethel Hill escarpment; a second below the escarpment lying between the Bald Knob escarpment and Lola: and the third in the triangular fault block about three miles east of Lola. A small sandstone outcrop, apparently Rosiclare, is present at the road corner one-half mile west of Salem, near the southeastern corner of the quadrangle.

The distribution of the "Lower Ohara" member of the formation is even more restricted than the Rosiclare sandstone. It has been definitely recognized only along the Milford road two and one-half miles east of Carrsville, at the foot of Bethel Hill two miles northwest of Lola, and in the triangular fault block on the margin of the quadrangle east of Lola. It is not certain that the Lower Ohara is continuously present throughout the whole of the area mapped, between the Rosiclare and the base of the Chester Series, although in some places where the formation is not exposed it may be covered by talus accumulations. Because of this situation, and because of the thinness of both this bed and the underlying Rosiclare sandstone, these two members are mapped under one color pattern on the accompanying map.

Lithologic Character of the Fredonia Limestone Member. The Fredonia member of the Ste. Genevieve is limestone throughout so far as it has been observed in this district of western Kentucky, and a characteristic feature of the limestone is its oolitic texture. Not all of the Fredonia, however, is oolitic, for it also contains beds that are as hard and dense and compact as any of the beds in the St. Louis limestone, and other beds which are light colored and more or less crystalline in texture. The oolitic beds are characteristic of the formation, however, and the boundary line between the Fredonia and the underlying St. Louis has everywhere been drawn to exclude any of the oolitic beds from the older formation. In general, also, the Fredonia is distinctly lighter in color than the St. Louis, although some of the hard, dense beds of the formation are nearly as dark as beds in the St. Louis. There is, however, no line of sharp demarcation between the St. Louis and the Ste. Genevieve, and in the ancient sea which covered this region during this portion of geological history, sedimentation was continuous and passed without interruption from the older to the younger formation. Under these conditions the boundary line between the two formations will always have to be more or less arbitrarily placed.

Another characteristic of the Fredonia limestone which it shares in common with the St. Louis, is the large amount of chert which it contains, especially the lower half of the formation, although chert is present locally at least, to the very top of the formation. The chert occurs most commonly in the residual accumulations from the weathered limestone, and in many places quantities of this chert are present imbedded in red clay, where no actual limestone outcrops are visible. The chert commonly occurs in the limestone in horizontal bands spread out along bedding planes. The bands are more or less continuous or they may be made up of discontinuous, usually flattened lenticular or irregular concretionary masses. Cherty limestone beds at near the top of the Fredonia are well exhibited in the bank of Deer Creek near the bridge three and one-half miles east of Carrsville, on the Milford road. The residual chert from the Fredonia resembles that from the St. Louis limestone, although many of the masses are smoother and less irregular in shape, but there are no characteristics which are sufficiently uniform or constant in character to make it possible to certainly differentiate the residual cherts of the two formations.

Much of the residuum from the upper portion of the Fredonia is quite free from chert, and may be recognized at once by its deep red color. The surficial materials exposed along the road at Lola, and both north and south of this place, are of this character, and are unlike the residuum from any other formation in the district.

Lithologic Character of the Rosiclare Sandstone Member. As it occurs in surface outcrops the Rosiclare sandstone is a porous, yellow-brown or in some places red-brown sandstone, of rather fine texture. The character of the bedding exhibited by the formation varies from place to place, in some places being thinly bedded, while elsewhere the layers are more or less massive, locally being two or three feet thick. In most localities the beds of this formation have been more or less disturbed by reason of the solution of the underlying limestone, which has permitted the blocks of sandstone to slip down and assume various attitudes. In places there are notable sink holes, the solution of which has taken place beneath the Rosiclare sandstone, with the consequent slumping of the sandstone masses which now lie upon the sloping sides of the sink holes. In other situations where no sink holes are present, the Rosiclare sandstone beds exhibit dips in various directions, not at all consistent with any known structure in the region, and varying in direction among blocks only separated by a few feet, which can only be accounted for by assuming that the beds have been allowed to settle through the removal of the underlying limestone by solution. This tumbled appearance of the Rosiclare sandstone in many of the localities where it occurs is a characteristic feature of the formation.

In the part of Kentucky under investigation the Rosiclare sandstone has nowhere been observed in an unweathered condition, but in some localities in the adjacent portion of Illinois, where the formation has been observed in mine excavations or elsewhere, the fresh rock is seen to be notably calcareous in character, in fact it seems to be largely a limestone with quantities of sand grains incorporated in it. At the surface, where it has been subjected to the agencies of weathering, the calcareous portion of the Rosiclare has been removed by leaching, leaving a porous sandstone. There is no reason to suppose that the characters of the formation are any different in the region under consideration than in that part of the quadrangle north of the Ohio River, and if the formation is encountered in mine shafts it doubtless will occur as a highly arenaceous limestone, similar to the rock in Illinois.

Lithologic Character of the "Lower Ohara" Limestone Member. The lithologic character of the "Lower Ohara" limestone is not notably different from that of the Fredonia lying beneath the Rosiclare sandstone. It includes rather light or moderately dark colored beds of limestone, some beds of which are oolitic. If an outcrop of this limestone were observed in such a situation that its stratigraphic relations could not be determined, it would not be possible to identify it as "Lower Ohara" rather than Fredonia, either from lithologic or faunal characters. So far as it has been observed the "Lower Ohara" is not a cherty limestone, being more like the higher portion of the Fredonia in this respect.

Thickness. The exposures of the Fredonia in the Kentucky portion of the Golconda quadrangle are not of a character to permit the determination of the thickness of the member, but doubtless it is not greatly different from the thickness of the same limestone across the Ohio River in the Illinois portion of the quadrangle, where it is about 180 feet thick, or even somewhat more than this. The Rosiclare sandstone is a bed only about 20 feet in thickness. The best exposure of this member, exhibiting the sandstone *in situ* through its entire thickness is along Turkey Creek flowing east from the foot of Bethel Hill two miles northwest of Lola. The "Lower Ohara" member of the Ste. Genevieve is nowhere exposed sufficiently well to allow the determination of its thickness with accuracy, but probably it nowhere attains so great a thickness as 40 feet, and it may vary from this amount to nothing at all, although in the localities where it has not been observed in its proper position in the stratigraphic sequence the bed may be covered with talus. The combined thicknesses of the three members give a possible thickness of approximately 250 feet for the entire formation.

Stratigraphic Relations. As has been pointed out already, there is no break in the stratigraphic sequence in passing from the St. Louis limestone into the overlying Fredonia member of the Ste. Genevieve, but above the Ste. Genevieve there is an undoubted line of unconformity, although it is obscure in most localities because of the lack of proper exposures. In the large quarry at Cedar Hill, near Princeton, Kentucky, which is the type locality for Ulrich's Ohara member of the Ste. Genevieve, the top of the "Lower Ohara" is followed by a limestone conglomerate bed in the base of the overlying Renault limestone. This conglomerate is one foot, more or less, in thickness, the included pebbles are more or less angular limestone fragments of a character similar to some of the beds lower down in the section, and it may be interpreted as a true basal conglomerate. This same unconformity is again well exhibited in the Illinois portion of the Golconda quadrangle, in the river bluff below Rosiclare, above the railroad leading to the Fairview incline. The rock surface has been well exposed at this place by quarrying operations, and the line between the "Lower Ohara" and the overlying limestone is well exhibited as an uneven, wavy line above which is an abrupt change in the lithologic character of the strata and also in the fossil contents of the rocks. At this locality in the river bluff there is no basal conglomerate present in the overlying formation, but in the exposures east of Shetlerville, also in the Illinois portion of the Golconda quadrangle, conglomerate beds are present at this horizon.

In the Kentucky portion of the Golconda quadrangle there are no good exposures exhibiting the unconformity above the Ste. Genevieve, but at one locality one and one-half miles a little southwest from Lola there is an exposure of limestone conglomerate which must be at this horizon, although the underlying bed is not exhibited. The apparent variation in thickness of the "Lower Ohara" and the possible absence of the bed in places, suggests a period of erosion subsequent to its deposition, during which a part or the whole of the bed was removed, and a consequent unconformity between it and the overlying formation.

Paleontology. Much of the Ste. Genevieve is not highly fossiliferous except as the more or less fragmentary remains of organisms are exhibited upon the weathered surfaces of the limestone. Upon these weathered surfaces the stem joints of the crinoid *Platycrinus penicillus* may be detected in most localities, and somewhat less commonly the bases of the same crinoid. These stem joints are characterized by their elliptical outline and from their margins there are a number of projecting, spinose processes resembling the handles upon a boat's steering wheel. The bases of the crinoid are characterized by the presence of three distinct ridges passing from the stem facet to the margins. This crinoid, which has been referred to in the literature as *Platycrinus huntsvillae,* is particularly abundant in the Ste. Genevieve limestones, both the Fredonia and the "Lower Ohara" members, but it has nowhere been observed at any locality in the Ohio or Mississippi Valleys or elsewhere, in any bed above the unconformity at the top of the "Lower Ohara" limestone, although most diligent search has been made for it during the whole of the time that these formations have been under investigation by the writer. The species does occur in the underlying St. Louis limestone, but much less commonly, and wherever it occurs in considerable numbers it is safe to identify the rock containing it as Ste. Genevieve in age, especially where its presence is accompanied by oolitic texture of the limestone. Locally, in the Fredonia member of the Ste. Genevieve limestone, small pentremites are rather common, the species most often met with being *P. princetonensis.* Pentremites of any sort are among the rarest fossils in the St. Louis limestone, although this Ste. Genevieve species, *P. princetonensis,* has been collected at a number of localities in that formation in Missouri.

The coral species, *Lithostrotion proliferum* and *L. canadensis,* which are so characteristic of the St. Louis limestone have nowhere been observed in the Ste. Genevieve, but examples of the coral *Michelinia princetonensis* do occur in the Fredonia limestone in some places, and as this species is unknown in the St. Louis limestone, its presence may always be taken as evidence of the Ste. Genevieve. In places this coral is found mingled with the residual cherts of the formation.

Another fossil which is a good index for the Ste. Genevieve limestone, is the brachiopod *Pugnoides ottumwa.* This species has not yet been observed in the Kentucky portion of the Golconda quadrangle, but this is probably because no systematic or thorough search has been made for the fossils here. It is present in collections from Rosiclare, Illinois, however, and it has been collected in many localities all the way from Iowa to Alabama, and has nowhere been observed outside of the Ste. Genevieve limestone.

The Rosiclare sandstone is commonly not fossiliferous, but at one locality in the triangular fault block three miles east of Lola, it does contain a number of poorly preserved shells and bryozoans.

The ''Lower Ohara'' limestone contains fossils similar to those of the Fredonia. The weathered surfaces commonly exhibit examples of the stem plates of *Platycrinus penicillus,* and other more or less distinct forms, but this member is not known to have any especial index fossil which will serve to distinguish it from the Fredonia.

Correlation. The Ste. Genevieve limestone has been recognized from Iowa to Alabama. Throughout much of its distribution it consists entirely of limestone, although in Iowa it contains some shaly beds. In the Mississippi Valley sections a sandstone member has been observed at a number of localities, which may be the equivalent of the Rosiclare, but it is not a continuous member of the formation in that region as it seems to be in the Ohio Valley. Throughout the whole extent of the formation it is characterized by the *Platycrinus penicillus-Pugnoides ottumwa* fauna, and it undoubtedly comprises one contemporaneous horizon throughout the entire extent of its outcrop.

CHAPTER III

STRATIGRAPHIC GEOLOGY, CHESTER SERIES.

Renault Limestone.

Name. The Renault formation was named by Weller[1] from Renault Township in Monroe County, Illinois. In its typical expression the formation includes beds of sandstone and various sorts of shale, as well as limestone members. The Monroe County expression of the formation was clearly laid down under near shore conditions which gave rise to the great lithologic heterogeneity exhibited, but the Ohio Valley region where the Golconda Quadrangle is situated was located fifty miles or more from the shore line of the period, and consequently the clastic shore deposits are wanting, and the Renault formation is largely limestone with some calcareous shale beds.

In Hardin County, Illinois, the lowermost beds lying above the "Lower Ohara" limestone of the Ste. Genevieve, have been designated as the Shetlerville formation,[2] although they have been mapped under the same color as the overlying Renault. Further consideration, and further observation in the field, seem to indicate that the Shetlerville would better be considered as a *member* of the Renault, rather than as an entirely distinct formation, and it will be considered in such manner in the present report.

Distribution. In the Kentucky portion of the Golconda Quadrangle the Renault limestone is widely distributed. Excellent exposures are present in the western part of the area, between fault No. 1 and the Ohio River bluffs, beginning about five miles from the southern border of the Quadrangle and extending northward for about three miles. In the southern half of this district especially, essentially the entire thickness of the formation is present in the river bluffs and in the hill slopes forming the valley sides of a number of tributaries,

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[1]Trans. Ill. Acad. Sci., vol. 6, p. 122 (1913); also Ill. State Geol. Surv., Monog. I, p. 24 (1914).

[2]Ill. State Geol. Surv., Bull. No. 41, pp. 133-142 (1920).

eastward to the great fault, No. 1, which drops the Pottsville sandstone to a level with this Lower Chester limestone. Throughout much of this district the actual ledges of the Renault limestone are much covered with talus, and at no locality is the formation sufficiently well exposed to make possible a study of the complete succession of beds which comprise it. In the northern half of this western district a somewhat less thickness of the formation is present because of a slightly downdropped fault block north of fault No. 3.

In the northwestern part of the Quadrangle, west of the fault No. 1, the Renault is again exposed along the river bluff at the north and along the west wall of the tributary occupied by the fault. None of these exposures are very good, however, because of the thick talus covering, and along the valley wall adjacent to the fault the presence of the limestone is indicated only by reason of the existence of numerous sink-holes.

The best exposures of the Renault limestone in the whole of the Kentucky portion of the Golconda Quadrangle, are along the Bethel Hill escarpment. North of Bethel Hill, on the Lola-Joy road, the outcrops lie east of the line of faults which help to determine this escarpment, but south of this point they lie west of the faults. In the bluffs rising from Deer Creek, east of fault No. 16, the Renault is present but is largely covered with talus. Perhaps the best and most nearly continuous exposure of the formation in the whole Quadrangle is on the Milford road two and one-half miles east of Carrsville. Another good exposure is along the Lola-Hampton road where that highway ascends the Bethel Hill escarpment two miles southwest of Lola. Along the line of this escarpment there are many other localities where the Renault limestone can be studied, the best exposures are situated in ravines which cut through the escarpment, but outcrops may be looked for in many places elsewhere than in the ravines.

A small area of Renault limestone is present between the Bonanza Mine, one and one-half miles southwest of Lola, and the road to Lola. This area is only a small fraction of a square mile in extent, and much of it is obscured by surficial material, but the limestone is well exposed above the spring just west of the public highway.

The northwest-southeast escarpment between faults No. 31 and No. 42, whose northwestern extremity is about one-half mile south of Lola, is formed by the Bethel sandstone capping the Renault limestone. The extent of the Renault outcrop along this hillside is in a narrow belt about one and one-half miles in length. The exposures of the limestone are well scattered along the hillside, but at no place is the formation at all continuously uncovered.

Two other small areas of Renault are present in the Quadrangle, both of them within the faulted belt which crosses the eastern boundary three miles east of Lola. The larger area is situated in the triangular fault block northeast of fault No. 48, in which the Fredonia limestone is present along Flat Lick Creek. The Renault limestone in this block is very poorly exposed, only a few small outcrops being visible from beneath the thick covering of talus, the presence of the limestone being assumed in most of the area by reason of the topographic features and from the stratigraphic succession from the lower to the higher formations. The second of the areas is in a wedge-shaped fault block between faults No. 44 and No. 45, continuing eastward into the adjacent quadrangle. The outcrops are rather meager, being situated in the south side of a valley tributary to Flat Lick Creek, opposite to and a little east of the Belt Mines.

Lithologic Characters. The Renault formation, including the Shetlerville member, is made up of limestone interbedded with some notable shale beds which occur at various horizons in the formation. The limestone of the formation is commonly bluish gray in color on freshly broken surfaces, most of it is hard and weathers with smooth surfaces which are lighter gray than the unweathered rock, in places being nearly white. The rock varies in texture from compact and dense to some beds that are more or less crystalline, and there are some thin, platy beds intercalated in certain of the shale beds. At a number of localities some distinctly buff or yellow, noncrystalline limestone has been observed near the top of the formation, and in some places the higher limestone beds contain a limited amount of chert which is commonly light colored, in the weathered condition at least, and breaks up into small, subcubical masses which are found scattered in the residuum.

The shales of the Renault formation exhibit considerable variation. In places they are entirely argillaceous, thinly laminated and fissile, elsewhere they are more or less calcareous with thin, platy layers of limestone. At several localities in the Quadrangle there is a thin bed of red or variegated shale near the top of the formation, which is possibly a persistent horizon. The basal or Shetlerville member of the formation is dominantly a calcareous shale with thin beds of limestone, and is the most conspicuously fossiliferous zone in the whole formation.

Thickness. The thickness of the Renault formation, including the Shetlerville member, has been estimated as being about 75 or 80 feet in Hardin County, Illinois.[1] In the Kentucky portion of the Golconda Quadrangle, the thickness of the formation is similar to that across the Ohio River, although there are places where it may be somewhat thicker, perhaps nearly 100 feet in the western part of the area; elsewhere, as south of Lola, it may not exceed 60 feet. The average thickness of about 75 feet may be accepted for both the Illinois and Kentucky portions of the Quadrangle.

Stratigraphic Relations. It has already been pointed out that the Renault rests unconformably upon the "Lower Ohara," this unconformity being established by the presence, locally at least, of a basal conglomerate, by the uneveness of the plane of contact, by the more or less abrupt lithologic change and by the nearly complete faunal change in passing from the older to the younger formation.

The actual contact of the overlying Bethel sandstone upon the Renault limestone has not been seen in this Quadrangle on the Kentucky side of the Ohio River, but a clean cut contact is exhibited east of Cave in Rock, in Hardin County, Illinois,[2]

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[1]Ill. State Geol. Surv., Bull. No. 41, p. 145 (1921).
[2]Ill. State Geol. Surv., Bull. No. 41, pp. 145-146 (1921).

where the sandstone succeeds the limestone abruptly with no intergradation of sediments, the lowermost layer of the sandstone having imbedded in it flat pebbles and more or less irregularly disposed slabs, much lime sand, quartz sand of large, rounded grains, and many fragments of fossils, some of which are worn and rounded. These characteristics of the basal bed of the Bethel sandstone certainly indicate a condition of unconformity above the Renault at that locality, and the same stratigraphic relation doubtless persists throughout this portion of the Ohio Valley. Another fact which may be indicative of this unconformity is the varying thickness of the Renault, due perhaps to the differential erosion of the Renault surface before the deposition of the Bethel sandstone.

Paleontology. Fossils are not uncommon in the calcareous shale beds of the Renault formation, and they are also present in the limestones, although not commonly in such a condition as to permit their being easily separated from the matrix. The most fossiliferous horizon is the lowermost, Shetlerville member, and wherever this bed is well exposed good collections can be secured. In the following list the species which have been collected from two localities are recorded. Locality No. 1 is situated about one-third of a mile south of the road from Joy to Berry's Ferry, in the upper portion of a ravine along fault No. 1 bounding the downdropped Pottsville block in the western half of the Quadrangle, the locality being four miles nearly due west of Joy. Locality No. 2 is along the road from Lola to Hampton where it crosses the Bethel Hill escarpment. The species from the two localities are recorded in the two columns 1 and 2, these numbers corresponding with the two localities indicated above.

Faunal List of the Shelterville Member of the Renault Formation.

	I	II
Triplophyllum spinulosum (M.-E. & H.)	X	X
Amplexus geniculatus Worthen	X	X
Eupachycrinus sp	X	
Talarocrinus buttsi Ulrich		X
Pentremites pinguis Ulrich	X	X
Pentremites princetonensis Ulrich	X	X
Pentremites pulchellus Ulrich	X	X
Mesoblastus glaber (M. & W.)		X
Fistulipora excelens Ulrich		X
Eridopora punctifera Ulrich	X	X
Stenopora tuberculata (Prout)	X	X
Fenestella cestriensis Ulrich	X	X
Fenestella serratula Ulrich	X	X
Fenestella tenax Ulrich	X	X
Polypora cestriensis Ulrich	X	
Septopora subquadrans Ulrich	X	X
Cystodictya labiosa Weller	X	X
Glyptopora punctipora Ulrich	X	X
Diaphragmus elegans (N. & P.)	X	X
Girtyella indianensis (Girty)		X
Girtyella brevilobata (Swallow)		X
Dielasma illinoisensis Weller		X
Spiriferina transversa (McChesney)	X	X
Spiriferina subspinosa Weller	X	X
Spirifer leidyi N. & P.	X	X
Spirifer increbescens Hall var.	X	X
Reticularia setigera (Hall)		X
Eumetria vera (Hall)	X	X
Cliothyridina sublamellosa (Hall)	X	X
Composita trinuclea (Hall)	X	X
Phillipsia sp.	X	

The species in the foregoing list which are restricted to the fauna of the Shetlerville member of the Renault formation are, *Amplexus geniculatus, Talarocrinus buttsi,* and *Spiriferina subspinosa,* and in the report on the Geology of Hardin County, Illinois,[1] this faunal zone has been named the *Amplexus geniculatus* zone. The remaining species, with perhaps one or two exceptions, are common members of the more general Renault fauna as it occurs in many localities in the Ohio and Mississippi Valleys, and to other Chester faunas. It will be noticed that the bryozoan genus *Archimedes* is not recorded in either of the faunas mentioned, and the absence of the spiral axes of the species of this genus is in keeping with the usual com-

[1] Ill. State Geol. Surv., Bull. No. 41, p. 139 (1921).

position of the faunas of the Renault formation. There are localities where *Archimedes* does occur in this formation, in most cases rather rarely, but in very many Renault faunas it is entirely absent as in the present instances. The rarity of *Archimedes* in the Renault is quite in contrast with the common occurrence of numerous species of the genus in most other Chester faunas, and in its general composition the Renault is a perfectly characteristic Chester assemblage of species with *Archimedes* missing or rarely present.

The Shetlerville member of the Renault formation seems to have furnished the bulk of the Ohara fauna recorded by Ulrich,[1] upon the basis of which he referred the Ohara, and with it the whole of his Ste. Genevieve limestone, to the Chester Group. The fauna is a Chester assemblage, but it is only remotely related to the faunas of the underlying beds which alone are truly Ste. Genevieve. This horizon is the so-called Zone 3 of the Ohara limestone of Ulrich's later work,[2] and the evidence presented by him leads the reader of his report to the conclusion that he has collected this characteristic Chester fauna in association with the characteristic Ste. Genevieve species *Platycrinus penicillus* and others. In his lists, however, he neglects to separate his species into the various localities, but records one generalized list including all the species which he has collected from all of the localities which he either correctly or incorrectly referred to this horizon. It has already been shown that the Rosiclare sandstone of northern Livingston County was all mapped as Cypress (-Bethel) by Ulrich, and if he had made collections from the limestones beneath this sandstone, really from the Fredonia limestone, they would have been recorded by him as coming from the Ohara. The locality to which he has most commonly appealed when referring to the presence of well known Fredonia species in his Ohara, is near Levias, in Crittenden County, Kentucky, but a visit to this locality in 1918 by the writer, established the fact that he had mapped the Rosiclare as "Cypress"

[1]U. S. Geol. Surv., Prof. Paper No. 36, p. 47 (1905).
[2]Ky. Geol. Surv., Miss. Series in western Ky., pp. 139-141 (1918).

(-Bethel), just as he had done in Livingston County. Such facts as these serve to nullify the elaborate evidence which he has presented to prove that the Ste. Genevieve limestone should be included in the Chester series.

Correlation. Although the Renault limestone of the Ohio Valley differs notably in its lithologic characters from the heterogeneous assemblage of limestones, shales and sandstones, which constitute the same formation in the Mississippi Valley counties of Illinois, the faunal evidence establishes the equivalence of the formation in the two regions. The whole question of the correlation of the formation in these two regions has been fully considered in the Hardin County Report[1] and need not be repeated here. It has been shown from the study of extensive fossil collections, that with the exception of four species which are wholly restricted to the Shetlerville member of the Renault, every Renault species known from the Ohio Valley region is also present in the typical Renault of Monroe and Randolph Counties, Illinois, or in the Paint Creek formation which is the next higher limestone member of the Chester series, these Paint Creek species being only two in number. The faunal evidence for the correlation of Ulrich's so-called ''Upper Ohara'' of western Kentucky with the Renault of the Mississippi Valley is so conclusive that the name Renault can be unhesitatingly extended into the Ohio Valley region, as is done in the present report.

Bethel Sandstone.

Name. In his report on the Lead, Zinc, and Fluorspar deposits of Western Kentucky, Ulrich[2] identified the sandstone overlying his Ohara member, as the Cypress sandstone of Engelman, a formation which had been described many years earlier from exposures along Cypress Creek in Union County, Illinois. The intensive work upon the Chester formations in southern Illinois which has been in progress during the past few years, has shown that the true Cypress is a higher forma-

[1] Ill. State Geol. Survey, Bull. No. 41, pp. 150-159 (1921).
[2] U. S. Geol. Surv., Prof. Paper No. 36, p. 53 (1905).

tion in the Chester series, and consequently a new name was demanded for this "Cypress" of Ulrich. This name has been supplied by Butts,[1] the name being taken from the exposures which are exhibited in the vicinity of Bethel School, three and one-half miles west of Marion, in Crittenden County, Kentucky. Curiously enough, the name might as well have been applied to the formation from the exposures at Bethel Hill, in that part of the Golconda Quadrangle under consideration, on the road from Lola to Joy.

Distribution. The distribution of the Bethel sandstone in that part of western Kentucky which is under consideration, follows closely the distribution of the underlying Renault limestone, the sandstone areas being adjacent to and overlying the limestone, capping the hills whose lower slopes are Renault. In the northwestern portion of the area, in the hills extending back from the Ohio River bluffs to fault No. 1, separating the Chester formations from the Pottsville, a considerable area is underlain by the Bethel sandstone. In the southernmost part of this area, between faults No. 3 and No. 4, the Bethel occupies only a rather narrow belt on tops of the hills, but north of fault No. 3 and extending northward to fault No. 2, this sandstone underlies the whole upland surface from the river bluffs to fault No. 1. In the northwestern part of the quadrangle the Bethel sandstone with the overlying younger formations dips gently to the southwest, it occupies its highest portion in the bluffs bordering the river bottoms just west of the point where fault No. 1 intersects the bluff at the north. From this point the formation extends as a comparatively narrow belt along the river bluffs to a point a short distance north of the mouth of the Love Chapel Hollow, where the dip of the beds carries the formation below the level of the alluvial deposits of the river bottom. The outcrop also extends southward from the same point of origin along the west wall of the valley determined by fault No. 1, and passes across the divide into the valley of Love's Branch, where it occupies a considerable

[1] Ky. Geol. Surv., Miss. Form. western Ky., p. 63 (1917).

area both north and south of the creek, just west of the fault, but in following the formation down the valley the dip of the strata carries it beneath the level of the flood plane about one-half mile east of the point where the valley joins the Ohio River bottom.

East of Carrsville the Bethel sandstone is present, but poorly exposed, in the basal part of the bluff between the mouth of Buck Creek and fault No. 16, and the same belt of outcrop continues for a short distance up the valley followed by the Carrsville-Milford road, but with little or no actual exposure. East of fault No. 16, by reason of the upward dislocation of the strata, the Bethel sandstone occupies the whole of the upland surface between the fault and the Bethel escarpment. Farther south the outcrops of this sandstone adjacent to the Bethel escarpment lie west of the line of faults which determine the escarpment. The formation is present, but only little exposed, in the floor of the valley of the large tributary of Buck Creek from the east, the gentle dip of the strata carrying the outcrop beneath the surface about two miles west of the Bethel escarpment.

Along the road from Joy to Lola the Bethel sandstone is well exposed just west of the Bethel Church and again just east of the same church at the top of Bethel Hill. Fault No. 23 crosses the valley leading to the north just west of Bethel Church, so that the outcrop of Bethel sandstone is repeated at a lower level about one-fourth of a mile north of the road, and continues from this point to the southeastern bend of the valley, and thence on to fault No. 20 and southward along the west side of the fault to the foot of Bethel Hill. The outcrop which is so well exposed at the top of Bethel Hill continues southward along a belt of varying width, depending upon the topographic relations, for a distance of more than four miles to fault No. 26. There are numerous excellent exposures along this belt in the bluffs and in some of the ravines which intersect the bluffs. A small outcrop of the formation is also present in the upper part of the east-west valley north of Hampton, about one mile northeast of that village.

In the complexly faulted belt about one-half mile in width, extending southwestwardly from Lola past the Bonanza Mine, the Bethel sandstone is well exposed in a number of the fault blocks, the outcrops starting at a point one-half mile southwest of Lola and continuing for about four miles.

The northwest-southeast escarpment between faults No. 30 and 41, whose northwestern extremity is about one mile southwest of Lola, is determined by the Bethel sandstone, and excellent exposures of the formation are present along the road along the top of the bluff and in the ravines west of the road.

Along the road leading to the northeast, branching off from the Lola-Salem road one and one-half miles southeast of Lola, there are abundant exposures of Bethel sandstone. These outcrops start about one mile from the road junction mentioned, and continue with slight interruption to the eastern boundary of the quadrangle. These outcrops are in the complexly faulted belt which continues northeastwardly into the adjacent quadrangle, and the outcrops encountered along the road are in three different fault blocks. A half mile south of the road, near the eastern boundary of the quadrangle, the Bethel sandstone is also present in another block of this much faulted belt.

Near the extreme southeastern corner of the Golconda Quadrangle, in the fault block lying between faults 64 and 67, is one of the Chester sandstone formations which may be the Bethel, and has been so mapped, temporarily at least, but observations in the quadrangle to the south may show it to be one of the higher sandstones in the Chester series.

Lithologic Characters. The Bethel is the lowermost one of the several important sandstone formations in the Chester Series of the Golconda Quadrangle. It is moderately fine grained and nearly uniform in texture, much of it is massive and compact so that the formation is commonly a bluff forming bed. Some parts of the formation are notably cross-bedded, and other parts are more or less evenly bedded. Locally there are some thinly bedded portions of the formation which are less resistent than the more massive layers. The color of the sandstone is yellow to yellow-brown, the weathered surfaces being considerably darker than the fresh rock, and in places the unweathered sandstone is nearly white. Some parts of the formation are composed of mottled sandstone, the spots being darker brown than the surrounding material and varying in size up to nearly a quarter of an inch, where present these spots are commonly thickly crowded.

Although the Bethel sandstone is a bluff forming bed and is exposed in many places in more or less vertical cliffs, yet, wherever a Bethel sandstone escarpment is present the accumulation of talus at the foot of the slope and the weathering away of the summit of the formation, has reduced the height of the abrupt portion of the cliff far below the total thickness of the formation.

Thickness. The usual thickness of the Bethel sandstone in the Golconda Quadrangle is from 60 to 75 feet, but in places it exceeds this and attains a thickness as great as 100 feet or more. The greatest thickness of the formation in this part of Kentucky is in the northwestern part of the Quadrangle, in the Ohio river bluffs just west of fault No. 1. This outcrop is nearly opposite the high bluff below Shetlerville, on the Illinois side of the Ohio River, where the thickest development of the Bethel sandstone in Hardin and Pope Counties, Illinois, is present, the thickness on both sides of the river being about the same.

Stratigraphic Relations.—The unconformable relations of the Bethel sandstone at its contact with the underlying Renault limestone have been discussed already. The stratigraphic relations of the formation with the overlying Paint Creek shale are nowhere clearly shown in the Kentucky portion of this quadrangle, neither are they shown in an entirely satisfactory manner in the adjoining part of Illinois. At one locality in Hardin County, Illinois, however, there is a distinct conglomerate bed at or near the base of the Paint Creek, which suggests an unconformity above the Bethel, and at another locality, in Johnson County, Illinois, the Bethel sandstone is wanting entirely so that the Paint Creek rests upon the Renault, a condition which suggests that a time interval, during which a considerable amount of erosion took place, elapsed between the close of the Bethel epoch and the beginning of the deposition of the Paint Creek. Whatever the stratigraphic relations of the Bethel and Paint Creek formations north of the Ohio River, the same relations doubtless extend into this part of the Golconda Quadrangle, and it is altogether probable that the Paint Creek rests unconformably upon the Bethel.

Paleontology. Like the Chester sandstones generally in this part of the Ohio valley, fossils are not commonly met with in the Bethel. No animal fossils whatever have been observed in the Kentucky part of the quadrangle, but a few scraps of brachiopods and bryozoans of common Chester types have been observed in southeastern Illinois. Fragments of plant stems are present in the sandstone in many places, but they are rarely well enough preserved to permit the determination of their relationships, the only recognizable forms being the trunks of a species of *Lepidodendron.*

Correlation. Because of the practical absence of fossils in the Bethel sandstone, the correlation of the formation must depend upon its position in the stratigraphic series between two fossil bearing formations which can be correlated over long distances. It has already been shown that the underlying Renault limestone can be correlated from western Kentucky across southern Illinois to the Mississippi River counties in that State. The overlying Paint Creek formation can also be followed from western Kentucky to Monroe and Randolph Counties, Illinois, with some interruption across Jackson and a part of Randolph Counties. In these Illinois counties, along the Mississippi River, the Renault and Paint Creek formations are not separated by a sandstone formation comparable with the Bethel, but by a thin chert or quartzite formation which has been named the Yankeetown,[1] but the equivalent stratigraphic position of the Bethel and the Yankeetown warrants their correlation.

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[1]Weller, Trans. Ill. Acad. Sci., vol. 6, p. 124 (1914); also, Ill. State Geol. Surv., Monog. 1, p. 25 (1914).

Paint Creek Formation.

Name. The Paint Creek formation was named by Weller[1] from good exposures along Paint Creek in Monroe County, Illinois. At a later date the beds overlying the Bethel sandstone in the southern counties of Illinois were proven to be the equivalent of the original Paint Creek beds, and the name was extended to Hardin County, Illinois.[2] The section in the Kentucky portion of the Golconda Quadrangle is identical with that north of the Ohio River, and consequently the name of the formation can be carried over in this state.

Lithologic Characters. The Paint Creek formation of the Golconda Quadrangle in Kentucky is one of the most elusive formations of the whole Chester Series. Lithologically it is composed largely of shale, but associated with the shale in places there are thin, and more or less irregular beds of impure limestone, and also thinly bedded sandstone. The shale of the formation is thinly laminated and fissile in character, and black to greenish in color. In places there is an interbedding of black, fissile shales and thinly bedded sandstone, the shale layers being from several inches to a foot thick, and the sandstone layers thinner.

The limestone of the Paint Creek formation is variable in character, and in some localities it is perhaps wanting altogether. The type of limestone most commonly met with is more or less crystalline and somewhat arenaceous. It is rather dark in color and some portions of it are distinctly reddish in color. The beds are more or less lenticular in form, with a thickness of one foot more or less in their central portion. Such lenticular beds are imbedded in the shales or shaly sandstones of the formation.

In places a considerable portion of the Paint Creek formation is thinly bedded, porous, more or less mottled sandstone, and in some exposures which have been observed there is a distinct alternation of beds of black shale and such thinly bedded sandstones, the alternating beds being from an inch or

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[1]Trans. Ill. Acad. Sci., vol. 6, p. 125 (1914); also, Ill. State Geol. Surv., Monog. 1, p. 26 (1914).

[2]Ill. State Geol. Surv., Bull. No. 41, p. 171 (1921).

two to a foot in thickness, the sand layers commonly being thinner than the shales, although no such exposure has been observed which is more than six feet in thickness.

Because of the dominantly shaly character of the formation the actual exposures are few, and the position of the outcrop has to be located through most of its extent from its topographic expression. In places the position of the formation is shown by a terrace-like interval between the outcrops of the Bethel and Cypress sandstones, which lie below and above the shale, there being no actual shale exposure visible. Elsewhere the position of the shale is determined by a sag or depression in the topographic surface due to the presence of the soft, non-resistant bed between the more resistant sandstones.

Distribution. The most calcareous portion of the Paint Creek formation in the Kentucky part of the Golconda Quadrangle, is in the northwestern part of the area. The formation must be present as a continuous band around the hill at the extreme northwestern part of the Quadrangle, lying north of Love's Branch and west of the valleys along fault No. 1. Around this hill not a single exposure of the formation has been seen, but its position can be determined approximately from the topography. In this part of the quadrangle the beds dip gently to the southwest, the shale must be well up towards the top of the hill at its northeastern corner, but at its southwestern corner it lies just above the level of the Ohio River flood plane. South of Love's Branch the formation outcrops in a number of localities. One of the best exhibitions of the limestone facies of the formation is exposed along the first important tributary to this stream from the south, below the chapel, the mouth of the tributary being a little less than one-half mile west of the Love Chapel. Exposures are also present in two other tributaries of this stream from the south, and in the long tributary whose mouth is a little over one-fourth mile from the mouth of the main valley where are exposures near the mouth of the tributary in the lower portion of a secondary tributary from the east, and again in the higher part of the valley a little more than one-fourth mile from fault No. 1.

Southward from the mouth of the Love's Branch the Paint Creek outcrop is essentially horizontal, just above the level of the Ohio River flood plane. Its position is shown by actual shale outcrops in some of the short ravines, just above the public highway which follows closely the foot of the river bluff, and by the springs which are present along this road. In the valley along which the public road turns east to go over the hills to Joy, there is a good exposure of the Paint Creek at the point where the road starts to ascend the south slope of the valley, and other, even better exposures of the limestone are present higher up in the same valley beyond where the road leaves it. A few other exposures are present in the valley next south of that last mentioned, and in its tributaries, but the formation ends along fault No. 2.

East of Carrsville the Paint Creek formation is present for the distance of about one-half mile in the fact of the bluff extending east from the mouth of Buck Creek, the outcrop being cut off at the east by fault No. 16. The exposures in this bluff are not good because of the talus covering from the overlying Cypress sandstone, but the shaly beds and the thinly bedded sandstone of the formation are exposed in a number of places, and a considerable amount of limestone from the formation is present in the talus towards the east end of the bluff. The formation must continue for a half mile or more along the sides of the valley tributary to Buck Creek along which is situated the Carrsville-Milford road, but no actual exposures have been seen except an inconspicuous one in the foot of the hill along the road ascending the hill between Buck Creek and this tributary. The formation must be present at about the level of the flood plane at the foot of the bluffs east of Buck Creek, but it is completely covered with talus. There are good exposures of the formation, however, in the valley of the larger tributary to Buck Creek from the east which joins the main stream a little less than one and one-half miles from the Ohio River. The outcrops extend more or less interruptedly along the bottom of this tributary valley for about one-fourth mile, consisting of impure, arenaceous limestone, dark shales, and thin sandstones interbedded with dark shales.

Farther south the position of the Paint Creek formation is largely suggested by the topographic features. A very small outcrop of the formation is present in the east-west road one-half mile east of Eli School, two and one-half miles southeast of Carrsville, this outcrop being situated just west of fault No. 6. One of the best exposures of the shale facies of the formation in the quadrangle is present in the public road about three miles northwest of Lola, on the road from Lola to Carrsville leading into the latter place from the east. A second exposure along this same road, one-half mile northwest of the last mentioned locality shows some thinly bedded limestone and thin layers of sandstone, the shale being talus covered although its presence is indicted by the residual red clay.

Near the foot of Bethel hill the Paint Creek shale may be seen with the Bethel sandstone below and the Cypress above. Fault No. 23 crosses the road on this hill slope so that the Bethel sandstone is repeated, being present at both the foot and the top of the hill, with the Paint Creek and Cypress between. The Paint Creek which lies above the upper outcrop of the Bethel sandstone is not exposed, but the formation occupies a belt which can be mapped approximately from topographic features, for a distance of about four miles between faults No. 21 and No. 26. Throughout this whole belt the only actual outcrop of the shale which has been observed is along the road continuing to the south from the Lola-Hampton road, at the road corner one mile northeast of Hampton. This exposure may be seen on both sides of the slight rise in the road only a few rods south of the road corner mentioned. To the east and northeast of this exposure the formation must underlie a rather broad stretch of cultivated fields although no actual exposures have been observed.

The Paint Creek formation is present in the lower slope of the bluff extending to the southwest from the town of Hampton, although the outcrop is largely talus covered. Exposures of the shale, with some limestone may be seen, however, three-fourths of a mile southwest of Hampton, and a single exposure of the limestone has been observed in the creek bed one and one-half miles southwest of the town.

In the complexly faulted belt extending to the southwest from Lola past the Bonanza Mine, the Paint Creek shale is exposed in at least two of the fault blocks. Three miles southwest of Lola and one and three-fourths miles east of Hampton, exposures of the formation, consisting of shale and limestone, may be seen in the northwest wall of the valley, between faults No. 38 and No. 39. A very good exposure of the shale is also present a short distance south of the junction of fault No. 36 with fault No. 25, one and one-fourth miles east of Hampton, and the shale is again exposed in the same valley one-half mile farther southwest.

Overlying the Bethel sandstone which caps the bluff parallel with the Bald Knob escarpment and about one mile northeast of it, half way to Lola, the Paint Creek shale is present, but it is an inconspicuous member of the section. The position of the shale is indicated in the topography by the depression parallel with the bluff and about one-fourth mile from its crest, and at one point along this depression an actual exposure has been seen. Farther to the northwest where the Bethel and Cypress sandstones outcrop around the high hill one and one-fourth miles southwest of Lola, the position of the Paint Creek is shown by a talus covered portion of the slope with sandstone ledges at both higher and lower elevations, but no actual exposures have been seen. This entire belt of shale has been mapped only approximately with the aid of the topography.

The only other occurrence of the Paint Creek formation which has been recognized in the Golconda Quadrangle is near the extreme southeastern corner of the area, in the fault block bounded by faults 63, 64, 65, and 66. The hill top to the northeast, which extends across the eastern half of this block, is underlain by shale and limestone, the best exposures being adjacent to fault No. 64. Similar exposures are present in the valley which originates in the southwest angle of the fault block, and they must be continuous with those on the opposite side of the hill, beneath the overlying sandstone. These exposures have been identified as the Paint Creek, not because of any conclusive paleontologic evidence, but because of the lithologic character of the beds, whose maximum thickness can only be about 30 or 40 feet, there being no other formation in the Chester series of the region with these characters and with such thickness.

Thickness. The entire thickness of the Paint Creek has nowhere been observed in the Golconda Quadrangle, but the maximum interval between the underlying and overlying sandstones which can be occupied by it, cannot exceed 40 feet. In some localities the formation cannot be more than 30 feet thick, and locally it may be as thin as 20 feet. In mapping the quadrangle the practice commonly has been followed of considering the formation as being about 40 feet thick, the belt being placed as is suggested by the topographic features, although the average thickness may not be greater than 30 feet. This thickness is essentially the same as that which has been found in Hardin and Pope Counties, Illinois, across the Ohio River from the region under consideration.

Stratigraphic Relations. The stratigraphic relations between the Paint Creek formation and the underlying Bethel sandstone have already been discussed, and there is some evidence suggesting the presence of an unconformity at the base of the formation. The stratigraphic relations with the overlying Cypress sandstone are even more obscure than with the Bethel sandstone beneath. In general there is more or less evidence for unconformity at the base of most of the sandstone formations in the Chester series in the Ohio Valley, but the slight difference in thickness of the Paint Creek, which may mean erosion preceding the deposition of the Cypress, is about all that can be appealed to here, and the presence or absence of an unconformity at this horizon must be left as undecided.

Paleontology. The shale beds of the Paint Creek formation have nowhere been found to be fossiliferous, but the limestone beds everywhere contain organic remains, although most of them are too poorly preserved to be recognizable. Two fossil collections have been made from the formation in the area studied, the first of them being from the limestone fragments found in the talus slope at the base of the bluff one-half mile east of Carrsville. The second locality is in the complexly faulted belt, three miles southwest of Lola, in the northwest valley wall, a little over one and one-half miles east of Hampton. The species which have been identified will be enumerated in a common list, the occurrence in the two localities being indicated by x in the two columns marked 1 and 2, corresponding to the two localities mentioned.

Fauna of the Paint Creek Formation in the Golconda Quadrangle.

	I	II
Talarocrinus sp.	X	
Stenopora sp.		X
Fenestella cestriensis Ulrich	X	
Fenestella serratula var. **quadrata** Cumings	X	
Fenestella tenax Ulrich	X	
Polypora approximata Ulrich	X	
Polypora cf. **varsoviensis** Prout	X	
Orthotetes kaskaskiensis (McCh.)	X	
Chonetes chesterensis Weller		X
Productus sp.	X	
Productus sp. cf. **adairensis** Drake		X
Diaphragmus elegans (N. & P.)	X	
Dielasma illinoisensis Weller	X	
Girtyella indianensis (Girty)	X	
Spiriferina spinosa (N. & P.)	X	
Spiriferina transversa (McCh.)	X	
Spirifer increbescens Hall, var.	X	X
Reticularia setigerus (Hall)		X
Cliothyridina sublamellosa (Hall)		X
Composita trinuclea (Hall)	X	X
Liopteria sp.		X
Aviculopecten? sp.	X	
Orthonychia chesterensis M. & W.	X	
Phillipsia sp.		X

Correlation. - The faunas which have been secured from the Paint Creek formation in this part of the Golconda Quadrangle are inadequate for the complete correlation of the bed, for most of the species are common to several of the Chester formations. The most significant member of the fauna which has been recorded is *Chonetes chesterensis,* which is known only from the Paint Creek in the Mississippi River counties in Illinois. Some of the faunas which have been collected from the formation in the southern counties of Illinois are much more conclusive in their evidence for the correlation of the formation as it is manifested in the Ohio Valley, with the typical Paint Creek of Monroe and Randolph Counties, Illinois, and the stratigraphic position of the bed in Kentucky establishes its equivalence with the Paint Creek of Pope and Johnson Counties, Illinois.

Cypress Sandstone.

Name. In his description of the Chester section in the southern counties of Illinois, Engelmann numbered the beds from 1 to 10, beginning at the top, the even numbers being sandstones and the odd ones limestone units. For only one of the beds or formations which he recognized did he suggest a geographic name, that being the Cypress Sandstone[1] for his unit No. 8. This name was chosen from the exposures along Cypress Creek, in Union County, Illinois, but the name was not again recognized for many years after its first use. Engelmann himself dropped the name in his final report in the Geological Survey of Illinois reports, and Worthen never used it at any time. The name was first revived by Ulrich,[2] but unfortunately he applied it to the sandstone beneath the Paint Creek shale and limestone, instead of to the unit overlying this formation which has been demonstrated to be the true Cypress of Engelmann by the more recent critical work on the Chester series. Both Engelmann and Worthen believed that this sandstone, No. 8, was the equivalent of the "Basal sandstone of the Chester Group" in the Mississippi River section, now known as the Aux Vases sandstone, but it has been demonstrated more recently that the Aux Vases occupies a position even lower than the Bethel, between the Renault and the Fredonia limestones.

Lithologic Characters. In isolated outcrops it is not possible to distinguish the Cypress sandstone from the Bethel, or in fact from some of the still higher sandstones of the Chester

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[1]Trans. St. Louis Acad. Sci., vol. 2, pp. 189-190 (1863).
[2]U. S. Geol. Surv., Prof. Paper No. 36, p. 53 (1905).

Series. The more or less monotonous character of these Chester sandstones is highly confusing, and it is commonly impossible to determine the formation to which an exposure belongs except through its relations with one of the limestone units of the series whose faunal and lithologic characteristics are more distinctive.

The Cypress is a yellowish-brown sandstone composed of fine and nearly uniform grains of quartz sand. It is commonly lighter colored on freshly broken surfaces than where it has been subjected to weathering, and in places it is nearly white. Much of the formation is more or less massively bedded, although thinly bedded layers are present in places, and may persist along continuous horizons. Some of the beds exhibit distinct cross bedding, but other parts of the formation are evenly bedded, this condition being more conspicuous in the higher part of the formation.

Coal in the Cypress. A mile and one-half south west of Lola, and about one-half mile east of the Bonanza Mine, there is the caved in mouth of a tunnel which is said to have been opened in a coal bed. The workings have been long abandoned, but fragments of the coal which has been taken out can be seen. This seam is reported to be four feet in thickness, but it cannot be seen or measured at the present time. About one-fourth mile southeast of this abandoned tunnel, near the house of Mr. J. S. Roberts, a shaft was sunk about 1915 to the depth of 68 feet, in search of coal. It is reported that in this depth two thin coal seams, one of them 28 inches thick were passed through, but search was being made for a four foot seam which was reported to have been penetrated near the same point in an old well at a depth of 80 feet, but the digging was abandoned before it was carried to the depth of the expected coal seam. In the dump about the shaft there are numerous fragments of coal which are said to have come from the two thin veins which were passed.

The occurrence of coal in both of these prospects can only be in the lower portion of the Cypress sandstone, and if the reports given are dependable this is the most extensive development of coal beds anywhere in the Chester Series of western

Kentucky or southern Illinois, so far as the writer's observations have been carried. The occurrence, however, is probably very local in character, since no evidence of such coal seams in the Cypress have been met with elsewhere in the Quadrangle.

Distribution. In the northwestern portion of the Kentucky portion of the Golconda Quadrangle, the Cypress sandstone underlies the upland region north of fault No. 2 and west of fault No. 1. Good exposures of the formation can be seen at many places in the escarpments which border this area, and in the walls of the ravines and valleys which have been excavated in this region.

East of the great down-dropped block of Pottsville sandstone between faults No. 1 and No. 6, the Cypress sandstone occupies a large part of the rather narrow fault block north of fault No. 13, between faults No. 6 and No. 7 on one side, and No. 12 on the other. The outcrop in this block is well exhibited in the Ohio River bluff east of the main street in Carrsville, and it continues for somewhat more than one mile to the southwest.

The largest area of outcrop of the Cypress sandstone is in the unfaulted region lying between fault No. 12 and the Bethel escarpment. A broad belt with a maximum width of three miles stretches southward from the bluff which extends east from the mouth of Buck Creek to fault No. 16, for more than eight miles to fault No. 26 just south of Hampton. Throughout this belt the Cypress underlies a westerly dipping cuesta plain between the Bethel and Joy escarpments, which is drained by Buck Creek and its tributaries at the north and by the tributaries of one of the branches of Bayou Creek at the south. The town of Hampton lies in the midst of this plain, near its southern end. Throughout this belt there are many exposures of the formation along the roads where they cross the valleys, and along the floors of some of the valleys. Southwest from Hampton a bluff of the Cypress sandstone extends for nearly two miles, parallel to and just north of fault No. 26.

South of fault No. 26 the Cypress sandstone occupies the apex of the down-dropped wedge between faults 26 and 25, with many exposures along the roads and in the floors of the valleys. Southeast of fault No. 25 the Cypress sandstone underlies the northwestern edge of the block between faults 36 and 40, the sandstone being identified by the presence of the underlying Paint Creek shale in the valley wall, and the whole of the narrowly triangular block between faults 25, 34, and 40 is probably the Cypress sandstone, although there is no limestone unit present to make this determination certain.

In the complexly faulted belt extending southwest from the Bonanza Mine the Cypress is present in two of the small fault blocks. The sandstone lying between faults 38 and 39 is clearly the Cypress because of the presence of the underlying Paint Creek shale, but the sandstone in the triangular block between faults 35, 36, and 37, which has been mapped as Cypress is not certainly identifiable because of the absence of any associated limestone beds.

Northeast from the foot of the Bald Knob escarpment, two miles a little west of south from Lola, the Cypress sandstone underlies a belt varying in width from one-half to three-fourths of a mile, with many excellent exposures in some of the ravines and hollows which are present.

In the complexly faulted belt which crosses the eastern boundary of the Quadrangle east of Lola, the Cypress sandstone has been mapped in two blocks, the first between faults 49 and 50, and the second between 53 on one side and 54 and 55 on the other. In neither of these blocks is there any limestone present to assist in the determination of the sandstone, but the relations are such as to suggest the Cypress as the most probable formation. At the extreme south border of the quadrangle the sandstone lying between faults No. 46 and No. 53 is certainly the Cypress, for it is directly overlain by the Golconda limestone, and the same relations obtain at the small sandstone exposure in the apex of the fault block between faults 59 and 56. The only other Cypress sandstone outcrop in the Quadrangle is overlying the Paint Creek formation in the block bordered by faults 63, 64, 65, and 66.

Thickness. There is no continuous exposure of the entire thickness of the Cypress sandstone in this part of Kentucky, but in various places where short, ravine-like valleys lead from the uplands underlain by the Cypress sandstone into the larger valleys or to the Ohio River flood-plane, more or less continuous exposures are to be seen. The thickness of the formation shown in such situations is commonly from 80 to 100 feet, but such exposures probably do not represent the total thickness of the formation, the higher beds being covered by the surficial formations of the uplands, and in addition some portion of the higher beds of the formation has probably been removed from the uplands by disintegration. A maximum thickness of 125 feet is probably not far from a correct estimate, and on the other hand the formation probably is nowhere less than 100 feet thick.

Stratigraphic Relations. The stratigraphic relation of the Cypress sandstone with the underlying Paint Creek formation has already been considered, and while an unconformity at this horizon is at least possible, such a relation has not been demonstrated.

The relations of the formation with the overlying Golconda limestone and shale are nowhere clearly shown in the Kentucky portion of the Golconda Quadrangle, but there are places across the Ohio River in Pope County, Illinois, where there seems to be a more or less complete transition in lithologic characters from the sandstone to the shale beds in the basal part of the Golconda formation, a condition which suggests the absence of any stratigraphic break.

Paleontology. No fossils of importance have been observed in the Cypress sandstone of this portion of the Ohio Valley. In places there are fragmentary remains of plants, with an occasional *Lepidodendron* trunk, but so far as known these fossils are no different from similar remains which are present in other Chester sandstone formations.

Correlation. The Cypress sandstone can be traced eastward from Kentucky across the southern counties of Illinois, as an essentially continuous formation. In the Mississippi River counties of Illinois, Randolph and Monroe, the stratigraphic position of the Cypress is occupied by a thin sandstone which was originally included by Weller[1] in the Ruma formation, but in a later publication the name Ruma has been discontinued[2] and this sandstone is considered as a thinned margin of the Cypress which name is extended to include the thin sandstone to the west as well as the much thicker and more massive sandstone farther east and south.

Ulrich[3] has undertaken to show that the Cypress sandstone of western Kentucky is to be correlated with the lower portion of the Okaw limestone of Monroe and Randolph Counties, Illinois, but the paleontological evidence which has been presented in the Hardin County, Illinois, report[4] shows conclusively that such a correlation is without support.

Golconda Limestone.

Name. This name was first used by the writer for the limestone and shale formation which is exposed in the Ohio River bluffs above Golconda, Illinois, and in the continuation of the same bluffs north of Lusk Creek valley opposite the same town. The first publication of the name, however, was by Butts.[5]

Lithologic Characters. The Golconda formation is constituted of a succession of limestone and shale beds, the details of which are not constant from place to place. In some sections a very large portion, possibly 90 per cent of the formation is made up of shale, while elsewhere from 30 to 50 percent of the whole formation is limestone. The limestone beds vary considerably in character, but in general they are light or dark gray in color, and are more or less crystalline in texture. In places some layers are oolitic. At a number of localities northwest of Hampton the higher portion of the formation

[1] Trans. Ill. Acad. Sci., vol. 6, p. 126 (1914); also, Ill. State Geol. Surv., Monog. 1, p. 26 (1914).

[2] Jour. Geol., vol. 28, p. 298 (1920).

[3] Miss. Form, western Ky., Ky. Geol. Surv., plate D, opp. p. 46 (1917).

[4] Ill. State Geol. Surv., Bull. No. 41, pp. 185-186 (1921).

[5] Ky. Geol. Surv., Miss. Form. western Ky., p. 91 (1917).

is made up of non-crystalline, argillaceous limestone of a gray or yellowish-gray color, in beds from three to six inches thick, separated by gray shale layers of similar thickness. In places the outer surface of some of the limestone beds is stained to a somewhat rusty, yellow-brown color, which may be in blotches. There is really little uniformity in the lithologic characters of the various limestone ledges of the formation, and in any section each ledge of limestone present differs more or less from the others.

The shales of the formation are as variable as the limestones, some beds are dark blue to black in color, others are gray to yellow or greenish, and in a few places a reddish shale has been observed. Some of the beds are entirely argillaceous in character, others are somewhat calcareous, and still others are highly calcareous with thin, plate-like layers of limestone interbedded. In Illinois some of the lower beds of the formation are sandy, there being sandy shales and even thin beds of sandstone, a condition which suggests a continuity of sedimentation from the underlying Cypress sandstone, but such characters have not been observed in Kentucky, although they may be present, hidden beneath the talus accumulations which commonly obscure the formation.

Distribution. In the Kentucky portion of the Golconda Quadrangle, the Golconda formation is not exposed west of the great down-dropped block of Pottsville sandstone between faults No. 1 and No. 6. In the more northern part of the Quadrangle very excellent exposures of the formation are present in the hill between faults No. 6 and No. 12, whose summit is situated east of the Carrsville-Joy road, about one and three-fourths miles south of Carrsville. In this hill the Golconda formation extends for nearly a mile in a northeast-southwest direction, and for a part of the distance it occupies the entire width of the fault block; the best exposures are upon the eastern side of the hill.

The most extensive outcrop of the Golconda limestone is present in the Joy escarpment, whose lower slope is underlain by this formation throughout its entire length, the belt of outcrop being about one-fourth mile in width for most of the distance. West of Hampton these limestone and shale beds form the lower slopes of the walls of the canyon-like valley occupied by the easternmost branch of Bayou Creek, these outcrops being continuous with the Joy escarpment outcrop. In the north wall of this valley the outcrops continue to fault No. 12, the gentle westerly dip of the beds bringing the upper surface of the formation to a lower and lower level in that direction. The outcrop in the south wall of the same valley continues along the sides of another canyon-like valley occupied by a branch of Bayou Creek coming in from the south, and from the mouth of this valley it continues in a southwesterly direction in the lower part of the bluff forming the southeast side of the main valley of Bayou Creek, and then in a direction a little east of south in the bluff limiting the Ohio River flood plane south of Bayou Creek to the south boundary of the Quadrangle.

Throughout the entire extent of the Joy Escarpment-Bayou Creek outcrop of the Golconda formation, there are many scattered exposures although much of the outcrop is talus covered because of the dominance of the shale beds. Some of the best exposures are in the hill slope just south of Joy, and in the valley walls of Bayou Creek near the eastern end of the canyon-like portion of the valley two miles west of Hampton, and more especially in the tongue-like extension of the south wall of the valley two and one-half miles from Hampton. Very excellent exposures, mostly shale, may be seen along the road ascending the bluff just east of the village of Bayou, just over the southern boundary of the Quadrangle.

West of the Joy escarpment the Golconda formation has been exposed by erosion in two of the deeper valleys in the westerly sloping plane from the summit of the escarpment, these valleys being respectively about one mile and about two miles north of the east branch of Bayou Creek which has been mentioned. In both of these valleys the Golconda outcrop is abruptly terminated at fault No. 12.

South of Hampton the Golconda formation outcrops in the wedge-like fault blocks bounded by faults 26 and 27, and by 27 and 25. In the first of these blocks the outcrop is continuous with that of the Joy escarpment, but is a little down-dropped by reason of the dislocation along fault No. 26. In the second of the fault blocks mentioned, a belt underlain by the Golconda formation between one-fourth and one-half mile in width, crosses the block southwest of the area of Cypress sandstone which occupies the wedge-like apex. This belt continues in a southwesterly direction along fault No. 27 for one and one-half miles, spreading out in the valley which crosses the block one-half mile from the southern boundary of the Quadrangle. In this same valley the formation is present also in the eastern side of the block, and it probably continues clear across. The broad flat valley at the southern boundary of the Quadrangle in this same fault block, just east of fault No. 27, is also undoubtedly underlain by the Golconda formation, although no actual exposures have been seen.

A short distance east of the outcrops last described, the Golconda formation outcrops in the southern part of the fault block between faults 34 and 41, the extent of the outcrop being shown in the topography of the broad, flat valley which occupies that part of the block. In all of these fault block outcrops south of Hampton, which have been described, the Golconda formation is mostly shale, and very few actual exposures can be found, but enough occurrences of the limestone with the characteristic fossil species have been observed, to assure the presence of the formation, and throughout this region its limits are well shown by the topographic features, most of the streams whose valleys are excavated in this formation having broad, flat bottomed valleys. In a number of places the abrupt constriction of the valley where it crosses a fault and leaves the Golconda shale for a hard sandstone formation is a very noticeable feature.

In the complexly faulted belt extending to the southwest from the Bonanza Mine, there are two outcrops of the Golconda limestone and shale. One of these is in the triangular block bounded by faults 36, 37, and 38. Only two actual exposures have been seen, in the southeast wall of the valley which occupies nearly the middle of this faulted belt, one at the mouth of a tributary from the south, and the other a few rods farther north. The limestone exposed at these localities is lithologically different from any limestone that has been observed elsewhere in the Golconda formation, but the fossils which have been collected at the more northerly one of the two exposures must be either Golconda or Glen Dean in age, and the rock looks much less like the Glen Dean than the Golconda, so it has been mapped as that formation. The second outcrop is a narrow belt southeast of fault No. 34, and is really in the northern portion of the fault block containing the Golconda outcrops between faults 34 and 41 at the southern border of the Quadrangle, which has been described. There are only two or three exposures of the limestone and shale in this outcrop, but the lithologic characters exhibited correspond well with the Golconda formation elsewhere.

The Golconda formation occupies the lower slope of the Bald Knob escarpment between faults No. 31 and 43. Very excellent exposures are present, with an abundance of fossils in some of the glade-like openings south of the summit of Bald Knob, but west from the summit exposures are almost wanting, although the topographic characters of the slope indicate the presence of a non-resistant shale formation.

The fault block lying between faults No. 46 and No. 53 includes two considerable areas of the Golconda formation. The southernmost of these is well shown along the public highway on the hill slope one-half mile west of Old Salem Church. From this point the outcrop extends nearly a mile to the northeast, and a little more than a mile southwest, occupying the low lands and the lower slopes of the hills. A short distance north of the exposures in the road the formation occupies nearly the full width of the fault block, and near the southern extremity of the outcrop it does continue completely across the interval between the bounding faults. At a number of localities in this area there are excellent exposures, and the most diagnostic fossils of the formation have been found at various places.

The second area underlain by the Golconda formation between faults 46 and 53, is in the block limited by the two cross faults No. 50 and 51, about two miles southeast of Lola. In this block there are only a few actual exposures of the limestone or shale, and in none of these localities have the most diagnostic fossils of the Golconda been collected. All of the fossils found, however, are such as might be expected in the Golconda limestone, and the lithologic characters, so far as seen, and the apparent thickness of the beds correspond more nearly with the Golconda than with any of the other Chester limestones of the district. Furthermore, the Golconda age of this limestone fits best in the sequence of formations constituting the succession of blocks formed by the cross faults between faults 46 and 53.

The only other Golconda limestone outcrops in the Quadrangle are near the southern boundary in the much broken up belt between faults 53 and 56. One of these areas is towards the southern boundary of the Quadrangle, in the much broken up belt between faults 59 and 56, and another in the block between faults 60, 59, and 56. Both of these areas are small, but both have afforded the most diagnostic Golconda fossil species.

Thickness. In its typical exposures in the Ohio River bluffs near Golconda, Illinois, the thickness of this formation is from 130 to 150 feet. A similar thickness is present in much of the Kentucky portion of the Golconda Quadrangle, but in parts of the Quadrangle the formation is considerably thinner, and in another part it is distinctly thicker. In the Bald Knob escarpment, and in the Golconda outcrops west of Old Salem Church, the formation cannot exceed 80 feet in thickness, and this reduced thickness seems to be due to the removal of the higher beds of the formation preceding the deposition of the overlying sandstone, for in the hill west of the Old Salem Church the *Pterotocrinus capitalis* beds continue to the top of the shale exposed, while normally it is restricted to the lower half of the formation. The greatest thickness of the formation is in the extreme southwestern part of the Quadrangle, where no less than 175 feet referable to the formation, are exposed in the bluff rising from the Ohio River bottom.

Stratigraphic Relations. The stratigraphic relations of the Golconda formation with the underlying Cypress sandstone have been considered already, and it is altogether probable that sedimentation was continuous from the lower to the higher formation. At the summit of the Golconda there is undoubtedly an unconformity. At a number of localities within the Quadrangle the overlying sandstone can be seen resting directly upon an uneven surface of a limestone bed of the Golconda formation, the change from limestone to sandstone being abrupt, with no suggestion whatever of transition beds. Furthermore, the varying thickness of the Golconda formation strongly suggests an erosion interval between this formation and the next succeeding one, during which there were varying amounts of erosion from the Golconda surface. This evidence is still stronger because of the absence of the higher beds of the formation where it is the thinnest. The evidence afforded by the formation in the outcrops which have been studied in the southern counties of Illinois is also strongly indicative of an unconformity at this horizon, and it is believed that this condition prevails throughout western Kentucky and southern Illinois.

Paleontology. The limestones of the Golconda formation are made up of fragments of shells and other animal remains, but good fossils are difficult to secure in most cases, except such as are weathered out upon the surfaces of some of the ledges. The best preserved fossils occur in some of the calcareous shale beds of the formation, and upon some of the surfaces of thin platy limestones interbedded with such shales. In places the cleanly weathered out fossils from such beds may be collected in great numbers where the formation is not talus covered, the best collecting ground being in more or less barren glades upon the hill slopes underlain by the formation. One of the best fossil localities of this formation in the Kentucky portion of the Golconda Quadrangle, is upon the southeasterly facing slope below Bald Knob, a little over two miles south of Lola. Another locality is near the southern border of the Quadrangle, three and one-fourth miles west of the eastern boundary, in the south end of the hill between faults 46 and 53, south of the Salem-Burna road. A representative Golconda fauna is that from the southeastern slope from Bald Knob in which the following species have been recognized.

List of Species From the Golconda Limestone on the Southeast Slope of Bald Knob.

Triplophyllum spinulosum (M. E. & H.)
Pentremites platybasis Weller.
Pterotocrinus capitalis Lyon.
Pterotocrinus sp. (wing plates).
Acrocrinus shumardi Yandell.
Taxocrinus sp.
Scytalocrinus bisselli Worthen.
Zeacrinus? sp.
Cromyocrinus gracilis Wetherby.
Eupachycrinus sp.
Fistulipora excellens Ulrich.
Eridopora macrostoma Ulrich.
Stenopora tuberculata Prout.
Stenopora n. sp.
Anisotrypa symmetrica Ulrich, var.
Fenestella cestriensis Ulrich.
Fenestella serratula Ulrich.
Fenestella tenax Ulrich.
Archimedes communis Ulrich.
Archimedes intermedius Ulrich.
Archimedes lativolvis Ulrich.
Archimedes meekanus Hall.
Archimedes negligens Ulrich.
Archimedes terebriformis Ulrich.
Polypora aff. **approximata** Ulrich.
Productus ovatus Hall.
Productus inflatus McChesney?
Diaphragmus elegans (N. & P.).
Camarophoria explanata (McChesney).
Rhynchopora perryensis Weller.
Dielasma cf. **illinoisensis** Weller.
Girtyella brevilobata (Swallow).
Spiriferina spinosa (N. & P.).
Spiriferina transversa (McChesney).
Spirifer aff. **leidyi** N. & P.
Reticularia setigera (Hall).
Eumetria vera (Hall).
Cliothyridina sublamellosa (Hall).
Composita trinuclea (Hall).
Orthonychia chesterensis M. & W.?

The most diagnostic species in the fauna of the Golconda formation is *Pterotocrinus capitalis,* a peculiar crinoid whose ventral surface is crowned by five massive plates which stand out in a radial manner between the groups of arms. No complete example of this crinoid has been found by the writer either in Illinois or Kentucky, although a complete specimen has been illustrated by Lyon.[1] The parts commonly met with are the separated, massive plates from the ventral side which have been mentioned, and much less commonly the bilobed base of two plates. This crinoid is not uniformly distributed throughout the entire Golconda limestone and shale, being confined to the lower half, but wherever this lower portion of the formation is exposed a little search will almost invariably lead to the finding of the *capitalis* plates, and in some places they occur in great numbers. Many of the Golconda species are present also in other Chester formations, both below and above this horizon. Great numbers of *Archimedes* axes are commonly present along with numerous brachiopod species. This is the horizon for the first introduction of the little brachiopod *Camarophoria explanata,* although the species is not restricted to this fauna, but recurs in all of the higher limestones of the series.

At one locality in southern Jackson County, Illinois, a peculiar fauna has been collected in which there are great numbers of peculiar gastropods and some pelecypods. A similar fauna containing nearly all of the same peculiar species has been recognized in the basal part of the Okaw limestone in Randolph County, Illinois,[2] an occurrence which has an important bearing upon the correlation of these two formations. It is interesting to record that a number of these same peculiar species, among which *Euphemus randolphensis,* may be mentioned, have been collected from near the base of the Golconda formation two miles west of Hampton.

From the outcrop which has been referred to the Golconda formation in the triangular fault block bounded by faults 36, 37, and 38, two and one-half miles southwest of Lola, a small fauna has been collected which is of special interest, in which the following species have been identified.

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[1] Geol. Rep. Ky., vol. 3, pl. 3, figs. 1-1k (1875).

[2] Descriptions of a number of these species may be found in the report on Hardin County, Illinois, Ill. State Geol. Surv., Bull. No. 41.

List of Species From the Golconda Limestone From Two and One-Half Miles Southwest of Lola.

Pentremites pyramidatus Ulrich.
Orthotetes sp.
Productus inflatus McChesney.
Productus ovatus Hall.
Diaphragmus elegans (N. & P.).
Pustula punctata (Martin).
Camarophoria explanata (McChesney).
Liorhynchus carboniferum Girty.
Dielasma illinoisensis Weller.?
Spirifer leidyi N. & P.
Cliothyridina sublamellosa (Hall).
Composita trinuclea (Hall).
Aviculopecten.

The most notable member of this fauna is *Liorhynchus carboniferum,* represented by a single specimen, which is one of the most characteristic members of a Chester fauna which is typically represented in Oklahoma, Arkansas, and other localities farther south than the Kentucky-Illinois basin. This is the first real contact point between the Chester faunas of this Kentucky-Illinois basin and the *Liorhynchus* fauna of Arkansas[1] and may have some bearing upon the correlation of the beds in these two regions, although further observations are desirable. It is unfortunate that the locality from which this fauna has been collected in Kentucky is not so situated that its Golconda age is unquestionable, but the presence of Camarophoria shows it to be not older than the Golconda, and *Productus inflatus* is not known in any higher fauna of the section, so that the determination of its age is probably correct.

Correlation. The correlation of the Golconda limestone of the Ohio Valley with the lower Okaw of the Mississippi River counties of Illinois is assured, although the diagnostic *Pterotocrinus capitalis* has not been found in western Illinois. The most conclusive evidence for this correlation is found in the presence of the pecular molluscan fauna in the basal part of undoubted Golconda limestone of Johnson County, Illinois, associated with *Pterotocrinus capitalis,* and again in the basal part of the Lower Okaw in Randolph County, Illinois. The discovery of some of the same unusual species in the basal part

[1]See 'Fauna of the Moorefield Shale of Arkansas," by G. H. Girty, Bull. U. S. Geol. Surv., No. 439 (1911).

of the Golconda west of Hampton adds strength to this correlation.

The presence of *Liorhynchus carboniferum* in the Golconda suggests the correlation of the formation with the Moorefield shale of Arkansas, and the Mayes formation of Oklahoma, but much more evidence must be forthcoming before such a correlation can be considered as being established.

Hardinsburg Sandstone.

Name. The Hardinsburg sandstone was first differentiated as a distinct unit in the Chester Series of the Ohio Valley, from studies that were carried on in Pope and Hardin Counties, Illinois. Butts recognized the same formation as far east as Breckenridge County, Kentucky, in the course of his reconnaisance work in western Kentucky and selected the name which is applied to the sandstone from the town of the same name in the county mentioned.[1] The formation has been traced entirely across southern Illinois, its thickness becoming much reduced to the west, and in Randolph County, Illinois, it is a discontinuous sandstone member in the midst of the formation which was first called the Okaw limestone by Weller.[2]

Lithologic Characters. The Hardinsburg sandstone resembles the other sandstones of the Chester Series in this portion of Kentucky. It is yellowish brown in color, rather fine in texture, and has been deposited in beds of varying thickness, some of the layers being as massive as any of the Chester sandstones in the region, other parts of the formation being thinly bedded with distinctly flaggy layers, and some beds are essentially sandy shales. In some exposures the sandstone exhibits much cross-bedding, but elsewhere the bedding is very even. In general the color of the Hardinsburg is somewhat paler than that of either the Cypress or the Bethel sandstones, and in places the freshly broken surfaces are nearly

[1]Ky. Geol. Surv., Miss. Form, W. Ky., p. 96 (1917).

[2]Trans. Ill. Acad. Sci., vol. 6, p. — (1914); also, Ill. State Geol. Surv., Monog. I, p. 27 (1914).

or quite white in color. The weathered surfaces are distinctly grayish in color in many places. The sum total of the lithologic characters of the formation contains nothing which will serve to distinguish the formation with certainty from other sandstones in the series, and it cannot be certainly recognized in small, isolated outcrops, or in fault blocks which are wholly sandstone. The only means of identifying the formation without some element of doubt, is in determining its stratigraphic position with reference to either the underlying or overlying limestone formation.

The topographic expression of the outcrop of the Hardinsburg sandstone suggests in places the presence of a considerable shale member in the midst of the formation. This condition exists in different portions of the Quadrangle, but the best exposures of such a shale are near the Lola-Salem road, two and one-half miles southeast of Lola. At this locality the shale is well exposed in the east bank of the creek a few rods northeast of the highway, and it may be seen at a number of points near the main road for one-half or three-fourths of a mile towards Lola. Because of the nonresistant character of the shale, and its usual talus covering, the thickness of the bed cannot be determined. In character the shale varies from a black fissile shale, through sandy layers, to sandstone.

Distribution. The northernmost expression of the Hardinsburg sandstone in this part of the Golconda Quadrangle, is at Carrsville. Much of the town is underlain by this formation which occupies the wedge-shaped termination of the fault block between faults 6 and 7. In the hill towards the river bank, in the northwestern part of the town, this sandstone is overlain by the Glen Dean limestone. The total extent of the Hardinsburg sandstone outcrop at this point is about nine-tenths of a mile in a northeast-southwest direction, with a maximum width of less than two-tenths of a mile.

This formation underlies a very large area, relatively, in the Golconda Quadrangle, but its entire distribution is to the east of the large, down-dropped Pottsville block between faults No. 1 and No. 6. The broad, westerly sloping surface extending to the west from the crest of the Joy escarpment is underlain by the Hardinsburg sandstone, this belt being nearly four miles wide towards the southern boundary of the Quadrangle, and being as much as two and one-half miles wide two miles south of Joy. Between the east branch of Bayou Creek and Joy, the Hardinsburg occupies much of the surface of the narrow fault block between faults 6 and 12, the dislocation along this portion of fault No. 12 being less than the thickness of the sandstone. In the lower parts of this block this formation occupies its entire width, but in the hills the two next higher units in the Chester series are present. Close to the southern boundary of the Quadrangle, for a distance of about two miles west from the continuation of the Joy escarpment, the southward extension of the Hardinsburg sandstone is terminated by fault No. 28.

The greater portion of the wedge-shaped block between faults 26 and 27 is occupied by the Hardinsburg sandstone, the western edge of the block being Golconda limestone which passes beneath the sandstone. All of the uplands of the fault block between faults 27 and 25, for the distance of one and one-half miles northward from the southern boundary of the Quadrangle, are underlain by the Hardinsburg sandstone.

In the belt lying upon the northwest side of fault No. 31, beginning at a point about one and one-half miles southwest of Lola, the Hardinsburg sandstone continues in a southwest direction to the southern boundary of the Quadrangle, the outcrop for a part of the distance being more than one-half mile wide. In much of this area the determination of the sandstone is assured by the presence of the Golconda limestone beneath it, but in the smaller fault block at the north, bounded by faults 29, 31, 34, and 35, nothing but sandstone is exposed, but the dislocation along fault No. 34, where it borders this block, is clearly shown at one point to be downthrown on the northwest side, and it is reasonable to assume that the movement has been about sufficient to bring the Hardinsburg into the position shown. The wedge-shaped block at the south, its broader end extending beyond the southern boundary of the Quadrangle, has been mapped as Hardinsburg, although no limestone outcrops are present, and critical field studies in the quadrangle next south may make it necessary to change this determination.

At the summit of the high point two miles south of Lola, known as Bald Knob, excellent exposures of the Hardinsburg sandstone may be seen, and the formation underlies the southwesterly sloping surface from the crest of the Bald Knob escarpment. Along the line of fault No. 31 this outcrop continues for a distance of about one and three-fourths miles, but farther east the extent of the outcrop is less because of the extension of fault No. 41 in a northeasterly direction beyond fault No. 31. Along the southeastern border of this outcrop a narrow, wedge-shaped block of Hardinsburg sandstone has been dislocated downward in such a manner as to terminate the southern extremity of the Golconda limestone outcrop along the face of the Bald Knob escarpment.

A very small area underlain by the Hardinsburg sandstone is present towards the headwaters of Deer Creek in the down-dropped belt between faults 42 and 46. The valley has been excavated through the overlying Glen Dean limestone, but scarcely more than 20 or 30 feet of the sandstone can be present above the level of the flood plane of the creek.

The fault block between faults 46 and 53 consists largely of the Hardinsburg sandstone throughout much of its length. In the southern part of this belt the formation is well exposed in the road running southwest from the hill one-half mile west of Old Salem Church, the exposures terminating at the hill known as the ''Devil's Backbone.'' In a northeasterly direction the beds of this block dip very gently to the northeast, and beyond the lower lands underlain by the Golconda formation, north of the public highway last mentioned, the Hardinsburg outcrops continuously to the cross fault No. 52, for a distance of nearly two miles. Still farther to the northeast, the block between cross faults 52 and 51 has been mapped as Hardinsburg although no limestone exposures are present to assist in the determination of the age of the sandstone, this identification of the formation being based upon the fact that the several smaller faulted segments of the larger block, seem each to be dropped successively lower from the north towards the south, and with this situation the block in question can only be Hardinsburg. In the segment next north, between cross faults 51 and 50, the summit of the hill at the eastern border of the block must be Hardinsburg, providing that the determination of the underlying limestone and shale formation as Golconda, is correct.

The Hardinsburg sandstone occupies the whole or a part of three, and perhaps four of the smaller fault blocks close to the southern border of the Quadrangle, about three miles from the southeast corner. The block bounded by faults 53, 59, and 60 is entirely sandstone and has been mapped as Hardinsburg from its relations with the surrounding fault blocks, this segment, however, continues southward into the next quadrangle which has not yet been mapped, and relations may be found later in that direction which will either prove this sandstone to be Hardinsburg, or show it to be one of the other formations. The sandstone exposures in the two blocks adjacent to the one last mentioned, one to the east and the other to the southeast, are certainly Hardinsburg because of the underlying exposures of Golconda limestone. The fourth area is in the point of the wedge-shaped block between faults 56 and 61. This is entirely sandstone with no limestone to suggest its age, but it extends southward into the adjoining quadrangle, and further observations in that direction may show what sandstone this outcrop really is.

Thickness. The entire thickness of the Hardinsburg sandstone is nowhere exhibited in the Kentucky portion of the Golconda Quadrangle in such a manner as to permit its direct measurement, but estimates made in a number of places show that the formation must include about 100 feet of strata. Whether or not the formation exhibits any notable variation in thickness is not clear. In Hardin and Pope Counties, Illinois, across the Ohio River from this Kentucky area, the thickness does vary somewhat, and in one place is reported to be no greater than 30 feet,[1] but there is no evidence of any such minimum thickness in Kentucky, and it probably does not vary greatly from 100 feet.

Stratigraphic Relations. The unconformity at the base of the Hardinsburg sandstone, at its contact with the Golconda formation, has already been discussed. The stratigraphic relations with the overlying Glen Dean limestone are less well shown, and no actual contact between the two formations has been observed. There is no decisive evidence to show that a condition of unconformity exists at this horizon, and it is not unlikely that the sandstone of the older formation passes through a transition of sandy shales to the shales and limestone of the Glen Dean without any break. The presence of talus accumulations over this portion of the section, whereever it exists within this area, effectually conceals the evidence.

Paleontology. Like the other Chester sandstones of western Kentucky and southern Illinois sections, fossils of any importance are unknown in this formation. In places there may be undefined plant fragments, and an occasional trunk of *Lepidodendron* may be looked for, but so far as we know them at the present time they have no bearing upon the characteristics of the formation.

Correlation. The Hardinsburg sandstone is a widely distributed formation and has been actually traced from section to section across the whole of southern Illinois, and it reappears as a thin and discontinuous sandstone layer in the Mississippi River sections in that state. The actual correlation of the formation through this whole region is based upon its stratigraphic position between two limestone formations which are abundantly fossiliferous, and which can be correlated on the basis of their fossil faunas.

[1]Ill. State Geol. Surv., Bull. No. 41, p. 189 (1921).

Glen Dean Limestone.

Name. The Glen Dean limestone was named by Butts[1] after it had already been differentiated and mapped as a unit in the Chester section in Pope and Hardin Counties, Illinois. The name was selected from a locality in Breckenridge County, Kentucky, in the course of reconnaisance studies in that portion of the state.

Lithologic Characters. The Glen Dean formation is made up of limestone and shale in varying proportions, the two types of sediments apparently changing from one to the other horizontally, the change being accomplished in very short distances in some places. In some localities, as in the outcrops in the belt between faults 42 and 46, two miles more or less southeast of Lola, the formation is largely limestone, but farther to the southwest, along the same belt much more shale is included in the formation. The limestone generally, in the Glen Dean formation, is rather light gray in color, and much of it is somewhat coarsely crystalline. Some beds, however, are notably siliceous in character, and at one locality three and one-fourth miles south of Lola, a highly fossiliferous, decomposed, siliceous limestone has the appearance of a brown sandstone in the weathered condition, while the unweathered portion is very hard and bluish gray in color, the fossils being clearly shown only in the weathered rock. Wherever their position can be determined these siliceous limestone beds seem to be present near the base of the formation. The limestone layers in the Glen Dean are commonly thicker, and are decidedly less variable in character than those in the Golconda limestone lower down in the section.

The shales of the Glen Dean formation have not been satisfactorily observed in many localities because of the thick covering of talus which is present in most places. So far as they have been seen they vary from dark blue or nearly black, to gray or greenish in color, and are in no respect different from some of the shale beds in the Golconda formation. One of the best shale exposures is in the northwestern part of the town of

[1]Ky. Geol. Surv., Miss. Form. W. Ky., p. 97 (1918).

Carrsville. In places the shales seem to constitute essentially the entire thickness of the formation.

Distribution. In general the Glen Dean formation occurs in two belts in the Kentucky portion of the Golconda Quadrangle, the first of these just east of the Carrsville escarpment, and the other just west of fault No. 46, south of Lola. Besides these two belts there are a few other localities where the formation outcrops.

The outcrops in the belt just east of the Carrsville escarpment are present between faults 6 and 12. The northernmost occurrence in this belt is in the town of Carrsville where the formation makes up the hill in the northwestern part of the town lying between faults 6 and 7. Both shale and limestone beds are well exposed at this locality, with their diagnostic fossils, and they are perhaps the very best exposures of the formation in the whole district mapped.

Two and one-half miles southwest of Carrsville the Glen Dean apparently occupies the entire width of the block between faults 6 and 12, but the actual exposures of the formation are scarce. Much of the area which is actually underlain by the formation in this place is flat bottom land, the topographic features being developed because of the presence of the nonresistant beds constituting the formation. This area occupies much of the down-dropped block between the cross faults 13 and 14, and among the limestone exposures which have been met with, diagnostic Glen Dean fossils have been observed in at least one locality.

South of the down-dropped block last mentioned, there is a narrow elongate block, five miles or more in length, in which the Glen Dean formation is present in three outcropping areas. The northernmost of these areas is the larger and extends from a point one-half mile north of the Joy-Berry's Ferry road, adjacent to fault No. 14, for a distance of about two miles in a southwesterly direction. Throughout this whole distance the limestone underlies a narrow belt upon the eastwardly sloping hill side. The dip of the beds is to the west and at both the northern and southern parts of the area the

Glen Dean belt swings around the ends of the elongate hill and continues for a short distance along the eastern walls of the valleys occupied by fault No. 6, heading on the two sides of the Joy-Berry's Ferry road. The limestone exposures in this belt are few, but in places where there are no outcrops of limestone the presence of the formation is suggested by the presence of sink holes. Just north of the highway that has been mentioned a limestone ledge may be seen in a sink-hole, and a few rods south of the road the limestone is exposed in a hill-side gully. The best exposures on this outcrop are in the southern part, where the limestone can be seen in a number of places, and where a considerable group of sink-holes exist along the east-west road a mile south of the main highway which has been mentioned. In two of the short, ravine-like valleys upon the western slope of the southern portion of the hill, there are other good limestone and shale exposures.

The second outcropping area of the Glen Dean limestone in this block between faults 6 and 12, is about three-quarters of a mile in length, and consists of a narrow belt completely surrounding the hill whose northern end lies a little more than two and one-half miles southwest of the Joy-Berry's Ferry road. In this area the most extensive outcrops of the limestone are present about the southwestern corner of the hill, some distance up the slope, and other good exposures may be seen about the northwestern corner of the same hill. The third area is about a mile in length, but is narrower than either of the others, and it too is in the form of a narrow belt completely surrounding a long narrow hill whose northern extremity is a little more than two and one-half miles southwest of the Joy-Berry's Ferry road. In this hill the limestone is well exposed over the whole southeastern slope, and good exposures continue for nearly one-half mile along the southeastern face. Elsewhere around the hill only a few limited limestone exposures are present, the greater portion of the formation being entirely talus covered.

At the top of the hill north of the east fork of Bayou Creek, about two and one-half miles northwest of Hampton, where is situated the road corner nearly one and one-half miles southwest of Goodhope Church, a few fragments of limestone may be found in the field occupying the western slope, only a few rods from the house. It is also reported that a limestone ledge has been encountered in a shallow excavation at this same locality. If limestone does underlie this hill top it can be no other than the Glen Dean formation, and if it is present here it may be present also beneath the surficial deposits on some of the high ground farther north, although no evidence of such occurrence has been encountered. The presence of the formation has been indicated on the map only on the hill which has been specially mentioned, for here alone has definite evidence of the limestone been observed.

Along the southern boundary of the Quadrangle, beginning a little more than one and one-half miles from the river bluffs, the Glen Dean outcrops along a belt extending eastward for somewhat more than one and one-half miles to the iron bridge across one of the branches of Bayou Creek. The presence of the formation along this belt is occasioned by the downward dislocation on the south side of fault No. 28. Extensive exposures of the limestone are present in the steep bluffs just north of the road which traverses this belt in a general east-west direction, and in the western portion of the area the presence of limestone is indicated by the sink-hole topography as well as by actual exposures in some of the sink-holes. At one place a line of sink-holes follows the course of the fault for some distance. The easternmost exposure in this area is in the creek bank at the south end of the iron bridge which has been mentioned.

The most extensive area of outcrop of the Glen Dean limestone in the whole of the Kentucky portion of this Quadrangle, is in its southern portion, lying for the most part between faults 42 and 46. Throughout this belt the formation forms the valley walls from a point just south of the Lola-Salem road, more than three miles in a southwest direction. In some of the valleys this limestone occupies the entire width of the fault block. The actual limestone exposures in this belt are conspicuous in the hill sides and along the creek beds in some parts of this area, but elsewhere they are completely hidden by talus accumulations. At its southern extremity, beyond the southwestern termination of faults 42 and 43, this outcrop of the Glen Dean stretches farther to the west, and occupies the lower slope of a northwest-southeast escarpment one and one-half miles in length, extending nearly the whole distance between faults 41 and 46. The middle portion of this escarpment is nearly one and one-half miles from the southern boundary of the Quadrangle, and it forms the southwest walls of the valleys occupied by the two widely diverging terminal branches which unite to form Deer Creek.

Just east of the northern extremity of the belt of outcrop just described, the Glen Dean limestone is present in the slopes of the hill situated in the southernmost angle between faults 46 and 52. The exposures are present upon both the southern and northern slopes of the hill, the greatest length of outcrop in a northwest-southeast direction being somewhat less than one-half mile.

Thickness. The thickness of the Glen Dean formation in this region does not vary greatly, the two extremes probably being 60 and 80 feet. There are no exposures where the entire thickness of the formation can be measured directly, and the determination has to be largely in the nature of an estimate, but in a number of places these estimates cannot be far from the true thickness of the formation. This estimated thickness probably averaging 70 feet, corresponds closely with that exhibited by the same formation as it is shown in the outcrops north of the Ohio River in Hardin and Pope Counties, Illinois.[1]

Stratigraphic Relations. The stratigraphic relations of the Glen Dean limestone with the underlying Hardinsburg sandstone are probably conformable, as has been pointed out already. Because of the thick covering of talus deposits there is no evidence observable for certainly determining the stratigraphic relations which exist between the Glen Dean and the overlying Tar Springs sandstone, but it is not improbable that

[1]Ill. State Geol. Surv., Bull. No. 41, p. 194 (1921).

this sandstone follows the underlying limestone abruptly, just as the Hardinsburg sandstone follows the Golconda limestone, and that a condition of unconformity exists between the two formations.

Paleontology. The most diagnostic fossil of the Glen Dean limestone in this part of the Ohio Valley, and one which is known to characterize the formation from Randolph County, Illinois, on the west, to Breckenridge County, Kentucky, on the east, is the bryozoan *Prismopora serrulata.* This species has not been met with so commonly in this part of the Golconda Quadrangle as in some other regions, although it has been collected in most of the outcropping areas which have been described. The only locality where it has been found to be a really common species is in the outcrops at Carrsville. The only extensive fauna which has been collected from the formation in the region mapped, is from some decomposed layers of a very siliceous limestone near the bottom of the formation, which is exposed in the floor of the nearly straight, narrow, north-south valley tributary to Deer Creek from the south, whose mouth is situated nearly one-half mile northeast of the junction point of the two widely diverging, terminal branches of the stream. The species which have been identified from this locality are as follows.

Fauna From the Glen Dean Limestone, Three and One-Quarter Miles South of Lola.

Triplophyllum sp.
Amplexus? sp.
Pentremites sp.
Anisotrypa symmetrica Ulrich?
Fenestella compressa Ulrich?
Fenestella serratula Ulrich?
Fenestella tenax Ulrich?
Archimedes swallovanus Hall.
Septopora subquadrans Ulrich?
Orbiculoidea sp.
Orthotetes sp.
Orthotetes sp.
Productus ovatus Hall.
Productus sp.
Diaphragmus elegans (N. & P.).
Camarophoria explanata (McChesney).
Dielasma illinoisensis Weller.
Spiriferina spinosa (N. & P.).
Spirifer increbescens Hall, var.

Reticularia setigera (Hall).
Eumetria vera (Hall).
Cliothyridina sublamellosa (Hall).
Sphenotus sp.
Sphenotus (?) sp.
Spathella (?) sp.
Edmondia sp.
Edmondia sp.
Edmondia sp.
Nucula randolphensis Weller.
Nucula sp.
Parallelodon micronema M. & W.
Liopteria sp.
Myalina sp.
Schizodus depressus Worthen.
Sulcatopinna sp.
Aviculopecten baldwinensis Weller.
Aviculopecten sp.
Aviculopecten sp.
Aviculopecten sp.
Aviculopecten sp.
Aviculopecten sp.
Aviculopecten sp.
Pterinopecten? sp.
Allorisma sp.
Allorisma sp.
Cypricardinia indianensis Hall.
Bellerophon sp.
Patellostium sp.
Worthenia? sp.
Porcellia sp.
Zygopleura sp.
Bulimorpha sp.
Holopea sp.
Holopea sp.
Orthonychia chesterensis M. & W.
Conularia sp.
Orthoceras sp.
Solenocheilus sp.
Discitoceras sp.
Stroboceras sp.
Pronorites sp.
Phillipsia sp.
Cladodus sp.

Correlation. The *Prismopora* fauna of the Glen Dean serves to correlate this formation throughout the Ohio Valley region of Kentucky and southern Ohio, with the higher portion of the Okaw limestone, as that formation was originally described, in Randolph County, Illinois. This horizon, characterized by the same bryozoan species and by a number of other peculiar forms, is recognizable also as far south as northern Alabama, where it is present in the basal part of the Bangor limestone of that state.

Tar Springs Sandstone.

Name. The Tar Springs Sandstone is the fourth of the important sandstone units in the Chester Series of western Kentucky. The name of the formation was first used by Owen many years ago for a sandstone in Breckenridge County, Kentucky,[1] the name being taken from certain bitumen bearing springs which emerge from the formation. In recent years it has been found that at least this portion of the Chester section in Breckenridge County is essentially the same as in the more western part of Kentucky and in southern Illinois, indeed the names of the two preceding formations, Glen Dean limestone and Hardinsburg sandstone have been taken from localities in this county, and therefore the name of this formation has been carried over into the more western region.

Lithologic Characters. The characters of all the Chester sandstone formations in the Ohio Valley are much alike, and commonly they can be distinguished with certainty only from their stratigraphic association with the accompanying limestone formations. Like the others the Tar Springs sandstone is a fine grained, yellow or yellow-brown sandstone, variable in its bedding characters, some parts being thinly bedded, others being more massive, some parts being cross-bedded and others evenly bedded. In general, however, it seems to be true that the Tar Springs includes more comparatively thinly bedded or flaggy layers than the earlier sandstones, although some portions of the Hardinsburg resembles it in this respect. A good deal of the formation also seems to be a brighter brown in color than any of the older sandstones. None of the characters are sufficiently outstanding, however, to make any certain identification of the formation possible without reference to the associated limestones.

Throughout the southern counties of Illinois the Tar Springs sandstone includes in its midst, somewhere near the

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[1]Geol. Surv. Ky., vol. 2, pp. 86-88 (1857).

middle of the formation, an important shale bed, in places as much as 40 feet thick which locally includes a thin bed of carbonaceous material or impure coal. In the Golconda Quadrangle in Kentucky the same shale bed is probably present, its best exhibition being along the Salem-Burna road, about one-half mile from the eastern boundary of the Quadrangle. Much of the shale at this locality is a slightly pinkish slate color, some layers with an abundance of fragmentary plant remains and with at least one carbonaceous or impure coal layer two or three inches in thickness. In one respect the Tar Springs sandstone of this region differs from the formation as exhibited across the Ohio River in Illinois, and that is in the amount of sandstone overlying the shale member. At the locality which has been mentioned on the road west of Salem, there cannot be more than 20 feet of sandstone overlying the shale, while in the southern Illinois counties there may be as much sandstone above the shale as there is beneath it.

Distribution. The area occupied by the Tar Springs sandstone in the Quadrangle is much less than that underlain by either the Hardinsburg or the Cypress sandstones. In the narrow belt bounded by faults 6 and 12 the Tar Springs sandstone overlies each one of the areas of Glen Dean limestone which has been described. In the block between the two cross faults 13 and 14, this formation is restricted to the more elevated ground towards the southern angle of the irregularly quadrangular block. In the elongate block extending southwest from fault No. 14, the Tar Springs is well exposed along the public highway for a distance of about one-half mile, beginning about three-fourths of a mile west of Joy, and continuing to fault No. 5, beyond which the Pottsville sandstones are exposed. This outcrop of the Tar Springs sandstone is about one and three-fourths miles in length, capping this elongate hill just east of fault No. 5.

In the second hill of this elongate fault block, beginning about one-half mile southwest of the southern extremity of the one last mentioned, the Tar Springs sandstone occupies the summit, the outcrop being a little over one-half mile in length.

The best exposures are at the southern extremity of the hill. On the summit of the third of this series of hills, beginning about one-fourth mile southwest of the southern extremity of the second one, the Tar Springs outcrop is confined to a narrow belt which is interrupted for a short space about a third of the distance from the north end of the hill.

Near the southern edge of the Quadrangle, beginning about two and three-fourths miles east of the Ohio River bank, the Tar Springs sandstone caps the ridge south of fault No. 28. This outcrop is nowhere more than a small fraction of a mile in width, and extends eastward for one and three-fourths miles to fault No. 27.

The most extensive area of the Tar Springs sandstone which is present in the region under consideration, lies along the southern boundary of the Quadrangle between faults 31 and 46, and extends southward into the adjoining quadrangle for an unknown distance. The formation covers the whole of the upland surface extending southwest from the escarpment limiting the headwaters of Deer Creek. From the eastern side of this outcrop the formation stretches off to the northeast, between faults 42 and 46, being present in a succession of more or less isolated outcrops which cap the hills whose lower slopes are underlain by the Glen Dean limestone, as already described. Where the Lola-Salem road crosses the belt between these two faults, an oblique cross fault, No. 47, nearly north and south in direction, cuts off the northeastern, wedge-shaped extremity of the larger fault segment. Beyond this cross fault sandstone only is present as the surface rock, with no limestone exposures of any sort to aid in the determination of the sandstone. This sandstone has been mapped as Tar Springs principally because it is commonly true throughout the whole area, that such wedge-shaped terminations of the fault blocks, when faulted off from the main portion, have dropped downward, and in the present case the natural supposition is that this sandstone is the same as the formation which caps the hills farther south, dislocated downward to a lower position.

A small outcrop of the Tar Springs sandstone occupies the summit of the hill lying in the southern angle between faults 46 and 52, whose lower slopes are occupied by the Glen Dean limestone.

In the much tilted fault block between faults 53 and 56, limited by the cross faults 57 and 58, in which is situated the Old Salem Church two and one-half miles west of Salem, the Tar Springs sandstone has been mapped as occupying the western half of the block. The basis for this determination is the presence of a thin and very cherty formation overlying the sandstone, which has been considered as representing the Vienna limestone of the southern Illinois counties. The sandstone itself is not well exposed, but in some of the ravines in the area a thick shale member is present near the top of the formation which is certainly the same bed as the shales which are exposed in the road three-fourths of a mile west of Salem, which have been considered as occupying a position in the upper part of the Tar Springs formation.

The last area of outcrop of the Tar Springs sandstone in the Quadrangle, is a rather extensive one lying between faults 62 and 63, near the southeastern corner of the Quadrangle. At the south this area is limited by fault No. 64, and in a northeasterly direction it crosses the eastern boundary into the adjacent quadrangle. Exposures are numerous in the southern half of this area, but the northern half is more level and is largely tillable land with few rock exposures. At no locality in the area does the formation underlying the sandstone appear at the surface, but in the east-west road crossing the area near its middle line, upon the gentle westerly slope of the hill one mile west of Salem, the residuum of an exceedingly cherty limestone is well exhibited, which has been interpreted as the Vienna limestone, and if the identification of these chert beds is correct the Tar Springs age of the sandstone is established.

Thickness. Nowhere in the entire region mapped is the entire thickness of the Tar Springs sandstone exposed in continuous section, but in the outcrop along the southern boundary of the Quadrangle there is certainly somewhat more than

100 feet of sediments represented. In the adjoining portion of Illinois there are places where the Tar Springs sandstone attains a thickness of 150 feet, the limits of thickness probably being between 100 and 150 feet. The thickness of the formation in this part of Kentucky doubtless corresponds closely with that in the southern Illinois counties.

Stratigraphic Relations. No satisfactory evidence has been met with bearing upon the stratigraphic relations of the Tar Springs sandstone with either the underlying or overlying formations, neither contact being visible at any locality which has been met with in the Quadrangle. Neither is there any satisfactory data in any of the southern Illinois sections which have been studied. In those parts of the Chester section which are best known the sandstone formations rest unconformably upon the underlying limestone, but the passage from a sandstone formation into an overlying limestone is more likely to be through a series of transitional beds. If these conditions hold, then the Tar Springs sandstone may rest unconformably upon the Glen Dean below, and pass without stratigraphic break into the overlying formation.

Paleontology. The sandstones of the Tar Springs formation are as barren of organic remains as are any of the other Chester sandstones of the Ohio Valley region, the only forms which are likely to be met with being undeterminable, fragmentary plant remains. In the shale beds the fragments of plants are much more numerous, but none have been found which are sufficiently well preserved to be identified. At one locality in Hardin County, Illinois,[1] a collection of well preserved plant remains, ferns, etc., has been secured, and it is possible that something similar may yet be met with in Kentucky.

Correlation. The correlation of the Tar Springs sandstone is dependent entirely upon the correlation of the underlying and overlying limestones. The formation in this part of Kentucky is clearly the exact equivalent of the Tar Springs of Breckenridge County, following as it does in both regions,

[1]Ill. State Geol. Surv., Bull. No. 41, p. 201 (1921).

the fossiliferous Glen Dean limestone. The formation has been successfully traced across the southern counties of Illinois from Hardin to Union, but in Randolph County there is no sandstone in the section occupying the position of the Tar Springs, but instead an unconformity above the Okaw limestone.

Vienna Limestone.

Name. The Vienna limestone has been named by Weller from the exposures of the formation in the vicinity of Vienna, Johnson County, Illinois.[1] The formation has been recognized entirely across Johnson and Pope Counties, Illinois, and it is believed to be present both east and west of these areas.

Lithologic Characters and Distribution. The most notable characteristic of the Vienna formation in the area of its typical development in the southern counties of Illinois, is the large amount of chert and other siliceous material incorporated in the limestone, and in the association with the limestone of a notable dark shale member. Much of the chert of the formation occurs in the form of platy layers from one to four inches thick, which are a chocolate brown color internally with the upper and lower surfaces commonly decomposed to the depth of a fraction of an inch, to a gray color. These platy layers break up into subcubical masses and occur abundantly in the residuum of the formation.

In the Kentucky portion of the Golconda Quadrangle a formation has been met with in two localities only, which is believed to be the Vienna limestone, but in neither locality is the formation well exhibited. The first of the localities is in the public road upon the gentle westerly slope of the hill one mile west of Salem and one and one-half miles east of Old Salem Church. The roadbed upon this slope is strewn with chert in small subcubical masses, and by some platy layers of chert that are essentially in place, which resemble in all respects the characteristic chert of the Vienna limestone in Johnson and Pope Counties, Illinois. A few loose fragments

[1]Jour. Geol., vol. 28, p. 396 (1920).

of limestone have been observed in the roadside at the same locality, and it is undoubtedly true that this hill slope is underlain by a cherty limestone formation, although the area of outcrop cannot be large. Every other limestone of the Chester Series which is known in the southern Illinois counties has been recognized in this Kentucky portion of the Golconda Quadrangle, and this cherty limestone is totally unlike any of the others in its lithologic characters. In view of the close resemblance of the chert to that of the typical exposures of the Vienna limestone, it has been so identified, although no paleontological evidence for establishing the correlation has been secured.

The only other occurrence of this cherty limestone formation is farther west along the same road, in the hill slope a few rods west of the Old Salem Church. In this locality the beds are rather steeply dipping towards the east and the formation is not well exposed, but cherty layers similar to those in the road farther east are present, and a few loose fragments of limestone have been observed. The mapping of the narrow belt of this formation which must extend throughout the length of the fault block bounded by faults 53, 56, 57, and 58, has been done more or less arbitrarily in the absence of satisfactory exposures.

Thickness. There are no data for the determination of the thickness of the Vienna limestone in this part of the Golconda Quadrangle, with any degree of accuracy. The maximum thickness of the formation in Pope County, Illinois, is about 70 feet, but it becomes much thinner than this towards the east, and it is altogether likely that an estimated thickness of 30 feet will be approximately correct for the region under consideration.

Stratigraphic Relations. The stratigraphic relations of the Vienna limestone are not determinable in this portion of the Golconda Quadrangle, and in the sections which have been studied in the southern counties of Illinois no evidence has been secured to show that there is any unconformity either beneath or above the formation.

Paleontology. No fossils have been secured from the Vienna limestone in this portion of the Golconda Quadrangle, but where the formation is more typically developed the limestone contains numerous fossils locally, among which the bryozoan *Prismopora serrulata,* which is so characteristic of the Glen Dean limestone, is present in places, and also a species of pelecypod, *Sulcatopinna missouriensis,* which is especially characteristic of the Menard limestone, which is the next higher limestone unit in the Chester Series. Others more or less common and widely distributed Chester species are present.

Correlation. As has been pointed out, the correlation of this bed in the southeastern part of the Golconda Quadrangle is dependent wholly upon its lithologic characters. The formation has been actually traced across Pope, Johnson, and eastern Union Counties, Illinois. Probably it is represented also in Hardin County, Illinois, and it may be represented in the Randolph County, Illinois Chester section by the dark shales which are present in places between the upper portion of the Okaw limestone and the typical expression of the overlying Menard limestone.

Waltersburg Sandstone.

Name. The Waltersburg sandstone has been named by Weller[1] from a locality in Pope County, Illinois, where the formation is well exposed, although the greatest thickness of the formation is farther east in Johnson County of the same state. The formation has not yet been recognized east of Pope County in southern Illinois, but re-examination of Hardin County would doubtless establish the presence of equivalent beds there.

Lithologic Characters and Distribution As known in the Kentucky portion of the Golconda Quadrangle the Waltersburg sandstone occurs in only one locality, in the east half of the small fault block bounded by faults 53, 56, 57 and 58.

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[1]Jour. Geol., vol. 28, p. 389 (1920).

In this fault block, which is situated near the southeastern corner of the Quadrangle, the rock strata, so far as they are exposed, dip rather steeply to the east. In the center of the block with a north-south strike, there is an exposure of cherty beds which have been identified as the Vienna limestone, and if this determination is correct, the sandstone beds overlying that formation must be the Waltersburg sandstone. The best exposures of the formation is in the roadside gullies at Old Salem Church. The rock is a thinly bedded ripple-marked sandstone, some portions of it almost an arenaceous shale. There are a few other outcrops north and south of the road passing the Church just mentioned, all of them being thin-bedded sandstone. The color and texture of these sandstones is similar to that of other Chester sandstone units, being yellowish brown and fine grained. In the exposure near the church the color is perhaps darker than in some of the other outcrops, and exhibits a reddish hue in some parts.

In the area of its maximum development, in eastern Johnson County, Illinois, the Waltersburg formation is a massive, cliff forming sandstone entirely similar to the Bethel, Cypress, and other massive Chester sandstones, but as the formation is traced both to the east and to the west from this locality, it becomes a much thinner formation, loosing its massive character and changing to a thinly bedded, more or less shaly sandstone. The character of the formation in this Kentucky locality is not conspicuously different from its more eastern development in the southern Illinois counties.

Thickness. It is not possible to determine the thickness of the formation accurately in the one locality where it has been observed, because neither the eastern or the western boundary of the outcrop can be determined with certainty, and because it is not certain that the amount of dip is constant. Judging from the development of the unit elsewhere, it must be a thin formation in this region, and probably does not exceed thirty or forty feet in thickness.

Stratigraphic Relations. The stratigraphic relations of the Waltersburg sandstone are not clear in this Kentucky locality because of the inadequate exposures, but where the formation is best exhibited in Illinois there is no definite evidence to show that any unconformity exists either below or above.

Paleontology. No fossils of any sort have been observed in the Waltersburg sandstone in Kentucky or elsewhere. Fragmentary plant remains and *Lepidodendron* trunks may be looked for, however, similar to those which are known to be present in most of the other Chester sandstones in the Ohio Valley.

Correlation. There is no important question of correlation involved in the Waltersburg sandstone. The formation has been actually traced across Pope, Johnson, and a part of Union Counties, Illinois, but there seems to be no equivalent bed in the Mississippi River section of the Chester Series in Randolph County, Illinois, the stratigraphic position of the bed being included in the unconformity between the Okaw and Menard limestones.

Menard Limestone.

Name. The Menard limestone was named by Weller[1] from the exposures of the formation in the Mississippi River bluffs just below Menard, Randolph County, Illinois, where is situated the Southern Illinois Penitentiary, the typical exposures being between the prison and the city of Chester.

Lithologic Characters. The lithologic characters of the Menard limestone are very uniform from the typical exposures in the Mississippi River bluffs, across the southern counties of Illinois, to western Kentucky. The formation is made up of limestone and shale, the limestone predominating. Only rarely are any of the beds in the formation crystalline, like those of the Golconda and Glen Dean limestones, and this difference will commonly serve to distinguish the Menard from either of these older units. For the most part the limestone is compact and dense in texture, hard and more or less brittle, commonly breaking with a more or less splintery fracture. In this portion of the Ohio Valley the rock is mostly dark colored,

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[1]Trans. Ill. Acad. Sci., vol. 6, p. 128 (1914); also, Ill. State Geol. Surv., Monog I, p. 28 (1914).

in places almost black on freshly broken surfaces, but the weathered surfaces are light bluish gray and are characteristically smooth, being quite different in this respect from most of the Glen Dean and Golconda exposures, whose more crystalline texture causes them to weather with rough surfaces. The character of the bedding is a notable feature of the formation, the limestone layers varying from less than a foot to nearly two feet thick, separated by shaly partings, the surfaces of the limestone ledges being distinctly hummocky in character.

The shales of the formation are commonly bluish or grayish in color, and they vary from completely argillaceous to more or less calcareous. The thickness of the layers varies from less than an inch to several feet, but commonly the layers between the more massive limestone ledges are very thin.

Distribution. West of fault No. 1, which limits the large, down-dropped block of Pottsville in the western half of the Golconda Quadrangle, there is a single exposure of the Menard limestone. This outcrop is situated about two miles north of the southern extremity of the Ohio River bluffs north of the valley of Bayou Creek, just west of the cross fault No. 5, between faults 1 and 4. In this outcrop the higher portion of the formation is exhibited. It is much talus covered, and probably includes a greater amount of shale than is present in lower portions of the formation throughout the region. This exposure is less than one-half mile in length, and the limestone may be seen in the lower portion of the slope which rises from the public highway at the foot of the bluff.

The most typical exhibition of the Menard limestone in the whole area under consideration is present in the series of more or less isolated hills which rise from the flood plane of Bayou Creek towards its juncture with the Ohio River flood plane. These outcrops lie between faults 6 and 12, in the segment southwest of the long, oblique, cross fault No. 15. There are four of these hills in all, the southernmost one being decidedly smaller than the others, and the northern one being not wholly detached from the high ground east of the flood plane. The total length of the exposure in these hills, including the covered flood plane area between them, is about three miles. The most accessible exposures of the limestone are along the east-west road which crosses the southern extremity of the northernmost hill, but good exposures are also present in all of the other hills to the south. Still farther northeast, about two miles from the cross road just mentioned, the formation is exposed in the base of the Carrsville escarpment, between faults 6 and 15 near the apex of the narrow angle formed by these faults. All of these exposures are very characteristic lithologically, and they contain the diagnostic Menard fossils.

The only other Menard limestone outcrop in the Quadrangle is in the southeastern part, in the triangular fault block between faults 63, 65 and 66. The actual exposures in this locality are meager, a few ledges being present by the roadside just west of the road corner on the Salem-Lola road, one-half mile west of Salem, and others a few rods north of the road corner, just west of fault No. 65. Satisfactory fossil collections have been secured from neither of these exposures, but the lithologic character of the rock is quite like the Menard, and it is believed that the determination of the formation is correct.

Thickness. The total thickness of the Menard limestone is not clearly shown in any of the outcrops in the region under consideration, but it is believed that the formation occupies the entire height of the hills which have been described as rising from the Bayou Creek flood plane, two of the larger of which rise 80 feet or more, and the third one something more than 60 feet. In the southern Illinois counties where a somewhat more satisfactory estimate of the thickness of the formation can be made, there are between 80 and 100 feet, and in all probability a similar thickness exists in this portion of western Kentucky.

Stratigraphic Relations. The stratigraphic relations of the Menard limestone with the underlying and overlying formations is obscure throughout southern Illinois where the Chester section has been studied in most detail, and they are even more obscure in this part of Kentucky. No horizon at all near the lower contact of the formation has been observed anywhere in the Quadrangle, in southern Illinois there is no apparent unconformity, and the same condition doubtless prevails in Kentucky. In the outcrop of the formation in the Ohio River bluffs north of the valley of Bayou Creek, the limestone is capped by the overlying Palestine sandstone, the base of the sandstone being only moderately covered with talus in some places. There seems to be an abrupt change from the Menard to the overlying sandstone, which may indicate the presence of an unconformity at this horizon, but more conclusive evidence is desirable.

Paleontology. The Menard outcrops in the Kentucky portion of the Golconda Quadrangle have not afforded an abundance of fossils, although sufficient search for them has not been made. A small collection has been made from the locality in the Ohio River bluff, and the following species have been recognized.

Fauna of the Menard Limestone in the Ohio River Bluff, Two and one-half Miles Above the Mouth of Bayou Creek Valley.

Productus ovatus Hall.
Diaphragmus fasciculatus (McChesney).
Spirifer increbescens Hall.
Eumetria costata (Hall).
Composita subquadrata (Hall).
Sulcatopinna missouriensis (Swallow).

In this fauna the diagnostic species *Sulcatopinna missouriensis* has been identified, and with it are the characteristic large forms of *Spirifer increbescens* and *Composita subquadrata.* These species serve to distinguish the Menard limestone from other Chester limestones. The *Sulcatopinna missouriensis,* or a closely related species does occur rarely in the Glen Dean formation, and more commonly in the Vienna, but its association with the large, typical examples of *Spirifer increbescens* and *Composita subquadrata* is indicative of the Menard limestone in most cases, the representatives of these two brachiopods in the older Chester limestones being notably smaller, the older *Spirifer* being either a variety of *S. increbescens,* or a distinct species, and the older *Composita* being *C. trinuclea.* This same combination of species is met with in some places in the next higher limestone, the Clore, but in that formation there are commonly associated with them numerous examples of the delicate bryozoan *Batostomella nitidula,* which is not commonly a member of the Menard fauna.

Correlation. The faunal characters of the Menard limestone which have been outlined, characterize the formation throughout its entire extent from western Kentucky to Randolph County, Illinois, and in association with the notable uniformity of the lithologic characters of the formation throughout this entire area, establishes the correlation of the formation from one side of the basin to the other. There is no unit of the whole Chester Series which exhibits so great uniformity throughout its entire extent as does the Menard, the chief lithologic difference which has been observed being the somewhat darker color of the dense, compact limestone in the Ohio Valley, when compared with the exposures in the Mississippi River sections.

Palestine Sandstone.

Name. The Palestine sandstone was first described and named from the outcrops in Palestine Township, Randolph County, Illinois,[1] and it is the first one of the Chester sandstones which extends continuously across the Chester basin from the Ohio Valley to the Mississippi River, with approximately the same thickness. All of the earlier sandstones which have been described in this report, thin notably or disappear entirely before reaching the Mississippi River sections, while the Aux Vases sandstone, which has its greatest development in the Mississippi River sections is entirely lacking in the Ohio Valley, where it would separate the Renault limestone from the underlying Ste. Genevieve limestone, if it were present.

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[1]Weller, Trans. Ill. Acad. Sci., vol. 6, p. 128 (1914); also Ill. State Geol. Surv., Monog. I, p. 29 (1914).

Lithologic Characters. In the western Kentucky Chester section the sandstone units seem to become more thinly bedded in the higher portion of the series. The most massive formation of them all is the lowest, or Bethel sandstone, though the Cypress is a close second. Each successive sandstone becomes, on the average, somewhat more thinly bedded, although all of them have some massive layers. The Palestine sandstone is exposed in only a few limited outcrops in this portion of the Golconda Quadrangle, but wherever it is present the more or less flaggy character of the beds is a noticeable feature. It is a rather fine grained sandstone, similar in texture to other Chester sandstones, and its color is brown, perhaps with less yellow than most of the earlier formations.

Distribution. Most of the Palestine outcrops in the Kentucky portion of the Golconda Quadrangle, are situated around the southern end of the great, down-dropped block of Pottsville which is present in the western half of the region. West of the Pottsville block, between faults No. 1 and No. 4, there are two outcrops of the formation. One of these occupies the summit of the hill just west of the oblique cross fault No. 5, whose lower slopes are underlain by the Menard limestone. The second one is in the triangular apex of the segment between faults 1 and 4, which has been dislocated downward along fault No. 5, bringing the Palestine sandstone to a somewhat lower level than the outcrop on the hill top just to the west.

The southernmost extremity of the hill lying between the bottom lands of Bayou Creek and the flood plane of the Ohio River is separated from the Pottsville portion of the hill farther north, by fault No. 11, and in this southern extremity the lower portion of the hill slope, for an elevation of 30 or 40 feet from the level of the flood plane, is occupied by the Palestine sandstone. The best exposures are upon the western side of the hill adjacent to the shore of the elongate lake which is present in the flood plane at that point. There are other exposures in the lower portion of the small valley just east of the road, on the south side of the hill, and still others along the southeastern slope.

East of the down-dropped Pottsville segment, the Palestine sandstone is well exposed in the triangular fault block bounded by the faults 6, 10, and 11. In the shoulder-like extension to the south, from the Pottsville hill, one and one-half miles from the south end of the hill between the two flood planes, the Palestine sandstone forms a line of low bluffs along the southeast side of the hill, and there are other exposures in the lower part of the hollow west of the bridge over Sugarcamp Creek. In the isolated hill directly south of the shoulder-like hill just mentioned, the Palestine sandstone is well exposed in its western part, being separated from the Menard limestone which constitutes the eastern two-thirds of the hill, by fault No. 6. The smaller, isolated hill lying west of the one last mentioned is made up wholly of Palestine sandstone.

The only other outcrop of Palestine sandstone in the Quadrangle is near the southeastern corner, just west of fault No. 62. The exposures are along the bed and the west bank of the creek flowing southwest, crossing the Salem-Lola road a little less than one mile northwest of the road corner one-half mile west of Salem, and crossing the road continuing west from the same road corner, about the same distance in that direction. All of the exposures are confined to the stretch of one mile between the two roads.

Thickness. Both the top and the bottom of the Palestine sandstone are nowhere exposed in the same section in this part of Kentucky, so that the thickness of the formation has to be more or less roughly estimated. In the western part of the hill which has been mentioned earlier as being cut by fault No. 6, lying between Sugarcamp and Bayou Creeks, there may be 60 or more feet of the sandstone, and this is probably the thickest exhibition of the formation in the region under consideration. Throughout the southern counties of Illinois this sandstone seems to have an average thickness of about 60 feet, although at one locality there is at least 100 feet, and this average thickness probably continues into the western Kentucky area.

Stratigraphic Relations. There is no conclusive evidence of unconformable relations between the Palestine and the underlying Menard in this part of Kentucky, but there evidently is an unconformity at this horizon in Hardin County, Illinois, just across the Ohio River, and also in the Chester section in Randolph County, Illinois, near the Mississippi River, and it is probably safe to conclude that this unconformity continues into Kentucky. At the top of the formation there is no evidence anywhere of unconformity, and in the Mississippi River section, at least, evidently there is no break in the sedimentary record at this horizon, and it is not unlikely that the same conditions persist throughout the Ohio Valley both in Illinois and Kentucky.

Paleontology. In the southern Illinois counties trunks of *Lepidodendron* are perhaps more commonly met with in the Palestine sandstone than in any other of the Chester sandstone formations. These fossils have not been observed in this portion of Kentucky, but this may be due to the fact that so little exposure of the formation has actually come under observation, and even this has not been thoroughly searched. It will not be unexpected if such fossils trunks come to light in this part of Kentucky, in fact it may be expected that they will be found.

Correlation. The correlation of the Palestine sandstone throughout this part of the Golconda Quadrangle has been based entirely upon the identification of the underlying or overlying limestone formations, in most cases the overlying Clore limestone. When considered in relation to the limestones the formation can be traced all the way from western Kentucky across the southern counties of Illinois to the Mississippi River Chester sections in Randolph County, Illinois.

Clore Limestone.

Name. The Clore formation was first differentiated in Randolph County, Illinois,[1] and at the time it was described it was believed to constitute the highest formational unit in the Chester Series of that portion of Illinois, but later investigations have demonstrated the presence of two still higher units. The formation has been clearly recognized across the southern counties of Illinois, and continues into Kentucky with its typical expression.

Lithologic Characters. The Clore is one of the calcareous units of the Chester Series, but the calcareous beds are associated with a large amount of shale, which in much of the region occupied by the formation is largely in excess of the limestone. Much of the limestone is more or less impure, argillaceous or siliceous, although no chert beds of any importance have been observed. The several ledges of limestone that are present vary considerably in character, but there is but little distinctly crystalline limestone such as is commonly present in the Glen Dean and Golconda formations. Some beds resemble the limestone of the Menard formation, but there is nowhere so much of it, and it is likely to be less pure. Other beds are more or less nodular. Few if any of the beds in this region are more than a foot or two in thickness. The shales of the formation are also variable in character, but because of their nonresistant character they, along with the limestone, are commonly more or less completely talus covered. Most of the shale is blue or gray in color, much of it is almost or wholly argillaceous, but some beds are more or less calcareous, these calcareous beds commonly include thin, platy layers of limestone, upon the weathered surfaces of which the diagnostic fossils of the formation can be found in most localities. On the whole the outcrops of the formation are very poor.

Distribution. The distribution of the Clore formation in this Quadrangle closely follows that of the underlying Pales-

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[1]Weller, Ill. Acad. Sci., vol. 6, p. 129 (1914); also, Ill. State Geol. Surv., Monog. I, p. 29 (1914).

tine sandstone. The formation is present in three different outcrops around the southern extremity of the hill lying between the flood plane of Bayou Creek and that of the Ohio River. On the west side of the hill the shales of the formation are exposed in the roadside along the highway which ascends the hill by a tortuous route about two and one-half miles north of the south end of the hill. This exposure must extend northward around the face of the hill into the tributary valley one-fourth mile north of the road, and also still farther north along the hill slope occupying the wedge-shaped northern extremity of the block between faults 1 and and 4, but except in the roadside gullies mentioned, the whole outcrop is talus covered. At the south end of the hill, south of fault No. 11, the Clore formation must underlie a continuous belt about the more or less separated portion of the hill. The best exposures in this belt are along the southern slope of the hill, west of the public road to Bayou, and along the eastern slope. These exposures consist only of loose, slabby fragments of limestone strewn over the surface. Elsewhere around the hill the position of the limestone and shale formation is indicated in places by the red clay residuum, and elsewhere by springs which emerge from the shale beds. On the east side of the main hill the Clore outcrops in the slopes of the southwardly directed shoulder-like extension which has already been mentioned in connection with the description of the Palestine sandstone. On the southeastern portion of this slope extensive exposures of shale may be seen where the hillside has been much washed and gullied, and also some limestone ledges, and in the short valleys leading down the eastern face of the hill there are scattered limestone exposures belonging to this formation.

The most extensive outcrop of the Clore formation in this Kentucky portion of the Golconda Quadrangle, is in the southeastern part of the area, in the block lying between faults 56 and 62. In this segment the formation underlies a belt two miles in length, extending from the eastern boundary of the Quadrangle to beyond the Salem-Burna road. The presence of the limestone is well shown by fragments in the road side just south of the bridge of the Salem-Lola road, about one mile north of the road corner one-half mile west of Salem. The shales in the hill-side a little more than one-fourth mile north of the bridge, and the shale and limestone one-fourth mile still farther north, all belong to the Clore formation. One-half mile east of the two exposures along the road last mentioned, near the eastern boundary of the Quadrangle, the Clore is well exposed along the floor and west side of a small tributary valley from the north. Southwest of the Salem-Lola road the formation is poorly exposed at intervals upon the eastwardly facing hill-slope, and in the Salem-Burna road the loose fragments of fossiliferous limestone in the slope just west of the bridge one mile west of the road corner indicate the presence of the Clore formation. The most extensive exposures in the whole region are in the beds of the two tributary valleys, one from the northwest, crossing the road a short distance beyond the locality last mentioned, and the other from the west, running parallel to and a little south of the east-west road.

Thickness. The Clore is the thinnest one of the limestone units in the Chester Series, and because of its nonresistant character it is commonly well hidden by talus so that neither its lower nor upper limits can be determined, and the boundary lines of the formation have been mapped more or less arbitrarily. In the exposures clustered around the southern extremity of the high land between Bayou Creek and the Ohio River flood plane, the possible interval between the underlying and overlying sandstones which can be occupied by the Clore formation, cannot be over 30 or 40 feet, which, of course, would establish the limits of thickness of the formation. In the eastwardly sloping hill-side occupied by the Clore formation, between the Salem-Lola and the Salem-Burna roads, in the southeastern part of the Quadrangle, there seems to be a greater interval, perhaps 60 feet, which may be occupied by the formation, but the whole outcrop is completely talus covered so that an exact estimate of the thickness is not possible.

Stratigraphic Relations. There is nothing to indicate with any certainty whether or not there is any unconformity at the horizon separating the Clore formation from the underlying Palestine sandstone, but judging from conditions elsewhere in southern Illinois, there probably was no break in sedimentation in passing from the sandstone into this formation. There is no evidence at hand upon which to base any satisfactory conclusion concerning the stratigraphic relations of the Clore with the overlying Degonia sandstone. The change from the shale and limestone sedimentation to the sandstone seems to be abrupt, which would suggest an unconformity, but the actual exposures have nowhere been observed in contact, nor in very close proximity.

Paleontology. For the purpose of determining the Clore formation from paleontological evidence, diligent search is always made for thin limestone layers imbedded in some of the calcareous shales, upon whose surfaces may be found numerous examples of small, cylindrical branches of a delicate species of bryozoan, *Batostomella nitidula.* This bryozoan is not to be found in every layer of the formation, but somewhere in almost every outcrop it is present in greater or less numbers. In this part of Kentucky such slabs have been observed in both the southwestern and southeastern areas of outcrop. Other fossils which may be looked for in the Clore faunas are the large shells of the typical form of *Spirifer increbescens,* and *Composita subquadrata,* such as are also present in the Menard limestone. A large species of *Productus,* possibly *P. arkansana,* is a very diagnostic member of the Clore fauna, and has not been observed by the writer in any other member of the Chester Series.

Correlation. Both the faunal and lithologic characters of the Clore formation are remarkably constant from western Kentucky, across southern Illinois, to the Mississippi River. In the more western exposures there is probably a greater proportion of limestone, as compared with the shale, but the faunal association does not exhibit any notable differences. These characteristics, along with the lesser thickness of this limestone, than any of the older limestone units in the Series, makes it practicable to recognize the formation with certainty across the entire Chester basin of the Ohio and Mississippi Valleys.

Degonia Sandstone.

Name. The Degonia sandstone was first recognized in Jackson County, Illinois, by Mr. J. M. Weller, and the name was selected because of the excellent exposures which are present in Degonia Township, of that county.[1] Before the prosecution of the field work in Jackson County by J. M. Weller, it was believed that the Clore was the highest formation in the Mississippi Valley section of the Chester Series, and that the massive sandstone lying above that formation was Pottsville in age. This work, however, brought out the fact that a still higher limestone unit was present in the section, overlying this sandstone now called Degonia, and that the base of the Pottsville rested upon this higher limestone where the section is complete. After the recognition of this sandstone as one of the Chester units, it was traced across the southern counties of Illinois as far as Hardin County, and it is now shown to be present in western Kentucky.

Lithologic Characters. In its typical exposures in Jackson County, Illinois, much of the Degonia formation is a massive, cliff forming sandstone, but as it is traced to the east it looses somewhat its massive character and becomes more thinly bedded, resembling in many respects the Palestine sandstone below the Clore formation. In Hardin County, Illinois, in the northern part of the Golconda Quadrangle, the thinly bedded, flaggy character of the formation is especially well developed, and the same characteristic continues southward into the Kentucky portion of the Quadrangle. In texture and color the Degonia in the Ohio Valley resembles the other Chester sandstones, but in places it seems to exhibit a somewhat duller brown color.

Distribution. The Degonia sandstone outcrops in the Kentucky portion of the Golconda Quadrangle occur with the un-

[1]Weller, Jour. Geol., vol. 28, p. 403 (1920).

derlying Clore limestone, capping the hills whose lower slopes are underlain by the older formation. There are three such outcrops towards the eastern border of the Quadrangle, around the southern extremity of the high land lying between Bayou Creek and the Ohio River bottoms. The outcrop on the hill top in the triangular fault block bounded by faults 1, 4, and 5, is exhibited in some exposures along the road which ascends the hill at this point, and in some ledges towards the top of the north slope of the hill. Upon the westwardly facing hill slope towards the northern extremity of this block this sandstone is completely talus covered, although doubtless it is present.

One of the best exposures of the Degonia sandstone in the whole area under consideration is along the southern face of the terminal hill south of fault No. 11. At this locality the formation is exposed in a low bluff along the brow of the hill west of the road leading to Bayou. Other exposures are present along the brow of the hill on the east side, but no such bluffs are developed as are present on the south side.

Upon the shoulder-like hill extending to the south, one and three-fourths miles northeast of the termination of the main ridge, the terrace-like upper surface is underlain by the Degonia sandstone, but the exposures are meager.

In the southeastern portion of the Quadrangle, in the block lying between faults 56 and 62, the Degonia sandstone occupies a belt adjoining the belt of Clore limestone which has already been described. In this outcrop the best exhibition of the sandstone is in the bed of a small intermittent stream extending northeast from the first road corner a little less than one-half mile north of the Salem-Burna road, from the cross-roads one-half mile east of the Old Salem Church. The flaggy, thinly bedded character of the sandstone is well exhibited at this locality. The formation is also exposed along the public road, between the road corner mentioned and Old Salem Church. These exposures are towards the southern end of the outcropping belt, and although most of the formation is covered with surficial deposits, there are occasional exposures above the level of the Clore limestone at intervals all the way to the eastern boundary of the Quadrangle.

Thickness. In its typical development in Jackson County, Illinois, the Degonia sandstone is nearly or quite 100 feet in thickness, and it retains approximately the same thickness across much of southern Illinois. The formation, however, apparently becomes thinner to the east, in Hardin County, Illinois, and this decrease in thickness continues into this part of Kentucky. It is not possible to measure the thickness of the formation with any accuracy in any of the outcrops which have been studied in this part of the Golconda Quadrangle, but it probably does not exceed 40 or 50 feet, and in places, as along the Salem-Lola road one and one-half miles north of the road corner one-half mile west of Salem, there seem to be no more than 20 feet of sandstone referable to the formation.

Stratigraphic Relations. The stratigraphic relations of the Degonia sandstone with neither the underlying nor overlying formations are clearly exhibited at any locality in the Quadrangle, and the relations have not been established anywhere in the southern Illinois counties.

Paleontology. No fossils have been observed in the Degonia sandstone in the Golconda Quadrangle, and the only fossils which may be looked for are fragmentary plant remains and perhaps some *Lepidodendron* trunks.

Correlation. The correlation of the Degonia sandstone in this part of Kentucky is established by the fact that the formation can be traced continually across the Chester basin from the Ohio Valley to the Mississippi River, this sandstone unit between two fossiliferous limestone formations being present wherever this part of the section is exposed.

Kinkaid Limestone.

Name. The Kinkaid limestone was first recognized as a distinct formational unit in the Chester Series, in Jackson and southern Randolph Counties, Illinois, the name of the formation being taken from excellent exposures along Kinkaid

Creek, in Jackson County.[1] In the course of the earlier detailed mapping in the southern counties of Illinois, both the Kinkaid limestone and the underlying Degonia sandstone were included in the Clore formation in one unit, considered as a much expanded development of the more western Clore formation, but when it became desirable to differentiate all three formations in the Mississippi River section, it was found to be easily practicable to recognize and map them also throughout the more southern counties of Illinois and into western Kentucky.

Lithologic Characters. Like all of the other limestone formations of the Chester Series in western Kentucky, the Kinkaid includes much shale, and throughout a part of the Golconda Quadrangle, at least, there is also a sandstone member in the lower part of the formation. The limestone layers of the Kinkaid vary considerably in character, but the beds most commonly met with closely resemble some portions of the Menard limestone. These beds are hard, compact, dense limestone, gray in color, and weathering in smooth, light gray surfaces. They vary in thickness from less than a foot to one or two feet, and are separated by shale layers of varying thickness. Some limestone layers which are more or less crystalline in character are present in the formation, and there are others which are shaly in character, with some dark colored carbonaceous beds.

In the lower part of the formation there is a remarkable and persistent chert layer, five feet or more in thickness. It is a massive ledge, much of the fresh chert being light in color, but varying from white to nearly black. In places large subcubical masses of this chert may be seen upon some of the hill slopes underlain by the bed, with dimensions up to the thickness of the bed. At no other horizon in the whole Chester Series is such a chert bed present. The persistence of this bed is shown by the fact that it has been widely observed in Hardin, Pope and Johnson Counties, Illinois, as well as in western Kentucky. The Kinkaid limestone also includes

[1]Jour. Geol., vol. 28, p. 405 (1920).

other chert beds in the higher part of the formation, but not comparable with the layer just described, their presence commonly being indicated by the presence of chert fragments in the residuum.

The shale layers of the Kinkaid are likely to be more or less completely talus covered because of their nonresistant character, and it is not possible to describe any of them in detail. Enough is known to show that they are variable in character. In parts of southern Illinois there is a very persistent red shale bed near the base of the formation which is commonly associated with olive green shales, but in the Kentucky portion of the Golconda Quadrangle such a red shale bed has nowhere been observed, although olive green beds are exposed. Other layers are black and gray in color, and they vary from wholly argillaceous in character to highly calcareous.

A section through the Kinkaid limestone in the Carrsville escarpment about six miles southwest of Carrsville shows the general constitution of the formation, although the hill slope is so completely talus covered that the details of the succession cannot be determined.

Section of Kinkaid limestone six miles southwest of Carrsville.

6. Pottsville formation, shale and sandstone.		
5. Residuum, red clay and fragments of dark chert	10	feet
4. Limestone and shale, alternate layers, largely talus covered. Most of the limestone is gray in color, hard and compact in texture........	105	"
3. Sandstone, fine-grained, brown in color.........	15	"
2. Chert, white and massive	5	"
1. Limestone and shale, similar to the beds in bed No. 4, but with a larger proportion of shale...	45	"

Distribution. The Kinkaid limestone is best exhibited in this part of Kentucky in the Carrsville escarpment. The formation occupies some portion of the eastern face of this bluff, capped by the resistant Pottsville rocks, from the Ohio River at Carrsville for a distance of ten miles, except for an interval of about one mile west of Joy. At the north end of this escarpment the Kinkaid is also present for nearly a mile, beneath the Pottsville, in the bluff rising from the Ohio River bank, the westward dip of the beds carrying the formation beneath the surface in this direction. At the southern end of the escarpment the Kinkaid also outcrops on both east and west sides of the hill lying between the Bayou Creek valley and the Ohio River flood plane, north of fault No. 11.

In the southeastern portion of the Quadrangle there is an extensive outcrop of the Kinkaid formation in the fault block lying between faults 56 and 62, besides a small area in the block between faults 53 and 56. The most extensive exposures in this region are in the first of the blocks mentioned, at the southern boundary of the Quadrangle and extending for about one mile northward. In this locality the formation forms the lower slopes on both east and west sides of the high hill which is capped by the Pottsville formation. A little farther north the Kinkaid occupies a belt just west of the Degonia sandstone, and extends for the distance of two miles in a northeasterly direction to where it crosses the eastern boundary of the Quadrangle three and one-fourth miles north of the southeastern corner. A mile farther north, on the eastern boundary of the Quadrangle, there is another small area of the Kinkaid limestone which apparently has its greatest extent farther east in the adjacent Quadrangle. In the block between faults 53 and 56 there is only a small area underlain by the Kinkaid limestone, northeast of the cross fault No. 57.

Thickness. In the Carrsville escarpment section which has been given, there are 180 feet of beds which are referable to the Kinkaid, and although this section does not show the top of the underlying Degonia sandstone, that formation must be very near. It is possible that the maximum thickness of the formation in this part of Kentucky is fully 200 feet. On the other hand, in some of the outcrops in the southeastern part of the Quadrangle, there cannot be more than 60 or 80 feet of the Kinkaid present. This difference in thickness is due, without doubt, to the differential erosion of the old Chester land surface, preceding the deposition of the Pottsville formation of early Pennsylvania age, which everywhere lies unconformably upon the underlying formations. Considering the maximum thickness of the Kinkaid, it is one of the thickest if not the thickest unit in the whole Chester section. The thickness exhibited in this region corresponds closely with that which is known to be present in Pope and Johnson Counties, Illinois.

Stratigraphic Relations. The contact of the Kinkaid limestone upon the underlying Degonia sandstone has nowhere been observed, and the stratigraphic relation of the two formations is uncertain, but it is not unlikely that the stratigraphic sequence is unbroken. The stratigraphic relations of the overlying Pottsville with the Kinkaid limestone is everywhere unconformable. This is the unconformity which separates the rocks of the Pennsylvanian age from the Mississippian, and is of much greater consequence and of much greater time value than any of the unconformities which have been noticed between formational units in the Chester Series itself.

Paleontology. Most of the limestone layers of the Kinkaid formation contain some fossils, but many of them are so firmly imbedded in the matrix that they cannot be collected in a condition satisfactory for study. In general the fauna is not a varied one, most or all of the species being present in one or another of the older formations of the Series. The fauna is really more like that of the Menard limestone than any of the other Chester formations, and it would be difficult or impossible to distinguish between these two formations in isolated outcrops, because of the similar lithologic and faunal characters.

The following species of Kinkaid fossils have been collected from the exposures in the Ohio River bluffs just west of Carrsville, from the lower portion of the formation.

Fauna of the Kinkaid Limestone At Carrsville.

Pentremites sp.
Pterotocrinus sp. (wing plates).
Fistulipora excellens Ulrich.
Batostomella nitidula Ulrich.
Stenopora rudis Ulrich, var.
Fenestella tenax Ulrich.
F. serratula Ulrich

Archimedes distans Ulrich.
Polypora corticosa Ulrich.
P. cestriensis Ulrich.
P. approximata Ulrich.
Septopora cestriensis Prout.
Spirorbis sp.
Orbiculoidea sp.
Crania sp.
Orthotetes kaskaskiensis (McChesney).
Productus ovatus Hall.
Diaphragmus fasciculatus (McChesney).
Spiriferina spinosa (N. & P.).
Spiriferina transversa (McChesney).
Eumetria costata (Hall).
Composita subquadrata (Hall).
Bellerophon sp.

No collections from the higher portion of the formation have been secured in the region.

Correlation. The correlation of the Kinkaid limestone throughout its whole extent from western Kentucky across southern Illinois, to the Mississippi River, is based upon the essential continuity of the formation in the same stratigraphic sequence, and in its similar lithologic and faunal characters.

CHAPTER IV

STRATIGRAPHIC GEOLOGY, PENNSYLVANIAN SYSTEM.

The Pennsylvanian rocks have been called the Coal Measures in most of the older geological literature, but since the introduction of the uniform practice of using geographic names for geologic divisions this older name has given way to Pennsylvanian, a name which has been selected from the state of Pennsylvania because of the great development of these rocks in that state. The outstanding characteristic of the Pennsylvanian System in eastern North America, as well as in many other parts of the world, is the presence of numerous important coal beds. Coal beds by no means constitute the whole of the Pennsylvanian System, the aggregate thickness of the sandstones, shales and limestones being greatly in excess of the coal itself. In some great thicknesses of the strata which are included in the Pennsylvanian System, there is no coal at all. Furthermore, this System is not the only geological System which includes coal strata, as the presence of coal beds in the Cypress sandstone of the Chester Series, already described in this report, shows, and in the western part of America there are extensive coal bearing strata which are much younger than the Pennsylvanian.

The lowest division of the Pennsylvanian System in eastern North America is known as the Pottsville Group, named from the city of Pottsville, Pennsylvania. This Group includes numerous formational units which are more or less local in their geographic distribution. All of the Pennsylvanian rocks which are present in the Kentucky portion of the Golconda Quadrangle belong to the Pottsville Group, but they do not represent the oldest of the Pottsville strata, and not even the Middle Pottsville, the single formation which is recognized being Upper Pottsville in age.

Caseyville Formation.

Name. The single Pottsville formation which is present in this portion of Kentucky is the Caseyville formation, which was named by Glenn[1] from the town of Caseyville, Union County, Kentucky. This formation has recently been described by Butts in the Hardin County, Illinois, Report,[2] and the exposures of the formation in the area under discussion constitute a southward extension of the Hardin County area.

Lithologic Characters. The Caseyville formation in this Golconda Quadrangle is made up of shale, sandstone and conglomerate. Generally, if not everywhere throughout the area, the lower 60 feet more or less of the Caseyville, is made up of shales and some thin beds of sandstone. These beds are succeeded by massive sandstones which are much coarser in general, than the sandstones of the Chester Series, in which are included numerous beds of conglomerate, the pebbles of which are white quartz, smoothly rounded, and varying in size up to three-fourths of an inch in diameter. These pebble layers are exceedingly patchy. In places considerable thicknesses of the rock will show no pebbles at all, elsewhere they occur in streaks and bands of varying thickness, or in lenticular patches. These more or less conglomerate sandstone beds of the Caseyville are very resistant in character and are commonly exposed in abrupt bluffs. It is the presence of this stratum which is responsible for the development of the Carrsville escarpment which continues nearly across the entire Quadrangle.

The basal shale member of the Caseyville is nowhere well exposed in the Golconda Quadrangle, its nonresistant character making it especially liable to be obscured by the slumping down of great blocks of the overlying massive sandstone.

Where the Caseyville section is most complete, as in the hills west of Carrsville, the conglomeratic sandstone which

[1]Coal of the Tradewater River Region, Ky. Geol. Surv., Bull. No. 17 (1912).

[2]Ill. State Geol. Surv., Bull. No. 41, p. 225 (1921).

has been described, seems to be overlain by a series of shale beds, and these again by a second massive sandstone member, but there is no section present in the area where a good continuous exposure of the whole formation can be seen.

Coal. In the hills west of Carrsville a coal bed in the Caseyville formation has been exploited to some extent for local use. The seam is not being worked at the present time, however, and apparently has not been worked for some years. The bed is reported to be 24 to 30 inches in thickness, and it is probably the same as the Battery Rock Coal which was mined in eastern Hardin County, Illinois, many years ago.

Distribution. The largest area underlain by the Caseyville formation in the Quadrangle, is in the great down-dropped fault block between faults 1 and 6. The average width of this area is about one and one-half miles, and it extends for a distance of about 10 miles in a southwesterly direction from the Ohio River bank just west of Carrsville. Although this area is a down-dropped block with a dislocation of 1000 feet or more in places, because of the highly resistant character of the Caseyville sandstone, it now stands higher than the area on either side, and includes the highest points in the Kentucky portion of the Golconda Quadrangle.

The remaining outcrops of the Caseyville formation within the area mapped, lie in the southeastern part of the Quadrangle, southeast of fault No. 53, and wherever they exist the topography is characterized by hills of more than usual height. This outcrop crosses the eastern boundary of the Quadrangle in a belt a little more than one-half mile in width, about three and one-half miles north of the southeastern corner of the Quadrangle, and from this point it extends in a southwest direction for about three and one-half miles in a belt averaging a little more than one-half mile in width. Another outcrop is separated from and is situated about one-half mile south of the south end of the last mentioned belt, and continues into the adjacent quadrangle to the south. The northeastern extremity of fault No. 56 is situated within the first of these two outcrops of Caseyville which have been mentioned, and in its continuation to the southwest, for a part of the distance, different beds of the Caseyville lie upon the two sides of the fault, so that the outcrop constituting this belt occupies parts of two fault blocks, one between faults 53 and 56, and the other between 56 and 62. The Caseyville outcrop which extends southward into the next quadrangle caps a high hill between the last two of the faults mentioned, the part which is in the Golconda Quadrangle being a little less than one mile long, and nowhere one-half mile in width.

Thickness. The greatest exposed thickness of the Caseyville formation in the Kentucky portion of the Golconda Quadrangle is probably in the hills lying west of Carrsville, where there is at least 200 feet of strata referable to the formation, and probably considerably more, perhaps as much as 250 feet. In the southeastern part of the Quadrangle there is at least 180 feet of Caseyville. In neither of these areas is the total thickness of the formation present, and in Hardin County, Illinois, there is an estimated thickness of 400 feet.[1]

Paleontology. No fossils have been collected from the Caseyville in this part of Kentucky, and the only ones which have been observed are fragments of *Lepidodendron* trunks. In Hardin County, Illinois,[2] some very good specimens of a number of species of ferns have been secured, and it is not unlikely that similar plant remains may be met with at some time in the shale members of the formation in Kentucky.

Correlation. From the evidence of the fossil plants which have been collected in Hardin County, Illinois, which have been examined by David White, the Caseyville may be considered as occupying a horizon near that of the Sharon conglomerate of western Pennsylvania. None of the plants which have been identified seem to indicate an age younger than the Conoquenessing sandstone, the formation next higher than the Sharon conglomerate, and the flora is apparently older than the lowest of the Missouri coal floras.

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[1]Butts, Ill. State Geol. Surv., Bull. No. 41, p. 227 (1921).
[2]Ill. State Geol. Surv., Bull. No. 41, p. 227 (1921).

CHAPTER V

STRUCTURAL GEOLOGY.

Introductory Statement.

The original position of the several units in the stratigraphic column of the Golconda Quadrangle was nearly or quite horizontal, and each unit was originally deposited in the sea bottom as a continuous, blanket-like formation covering the entire area. The present condition of the beds, that is their lack of horizontality in places, and the remarkable lack of continuity, has been produced by extraordinary disturbances of the earth's crust in this part of Kentucky and the adjacent part of Illinois. The time when these disturbances occurred is not accurately known and cannot be determined at present except within very broad limits, but it is known to have been in very remote geological time which must be measured by many millions of years. During these crustal disturbances great cracks were formed through the strata, and the blocks on opposite sides of the cracks slipped upon each other in such a manner that there is now a considerable amount of vertical displacement on opposite sides of the fracture lines. It is also more than likely that a certain amount of horizontal movement took place, as well as the vertical, but the horizontal movements are not so easily detected from a study of the commonly available surface exposures, as are the vertical ones, although in some mine excavations evidence of horizontal movements is clear.

All of the phenomena exhibited by the rocks of this or any other region, indicative of such crustal disturbances, may be considered under the head of structural geology. In general the crustal disturbances are exhibited in folds and faults. In the Golconda Quadrangle the phenomenon of folding is not conspicuous, although in places the edges of some of the dislocated blocks have been bent or folded very locally, as is exhibited by the steep dips. The common structural phenomena in the quadrangle are the faults, or fractures of the crust along which dislocations of the strata on the two sides has taken place. As complete an understanding as possible of the fault structure is important because it is along these lines that the mineral deposits of the region have been accumulated for the most part.

The development of fault structures in the earth's crust, here as well as elsewhere, has always been due to the accumulation of strains which have finally become too great for the strength of the crustal materials. These strains have been of two sorts, first compression or squeezing strains, and second tension or stretching strains. The faults produced by these two types of strains exhibit differences of such a sort that usually they may be easily recognized. The slipping surfaces or planes in compression faults are likely to be much inclined, and the hanging wall is pushed upward along the inclined surface so that the hanging wall of such a fault is on the upthrow side. Such faults are commonly called thrust faults or reverse faults. In tension faulting the slipping planes are likely to be more nearly vertical, in some cases entirely vertical, and the slipping along the inclined planes is in such a direction that the hanging wall of the fault is on the downthrow side. Faults of this sort are called normal faults. The faults of the western Kentucky region are all of the normal type.

In studying any such faulted region as this portion of Kentucky, it is always desirable to determine, if possible. the reason for the development of the strains which have finally been relieved by the formation of the faults. In the region under consideration the faults are associated with two other unusual phenomena, all of which seem to be related one to the other. These other phenomena are, first, the presence of dikes of igneous rock, and second, the presence of mineral deposits, especially fluorspar, and any explanation which may be proposed must account for all three phenomena.

The dike rocks of western Kentucky and the adjacent part of Illinois are of very different origin from the sandstones, limestones and shales which they penetrate, and with which they are associated, and although these rocks constitute but a small fraction of one per cent of the total surface, their presence is most significant. These dikes were originally in the condition of melted rock or lava, very hot, and were forced upward as more or less vertical masses into crevices of the crust. These dikes must connect below with a great mass of igneous rock buried deeply beneath the surface, and the introduction of such an igneous mass into the earth's crust in this region is believed to be the cause of both the faulting and of the mineralization.

Dikes have been observed at numerous localities in Pope and Hardin Counties, Illinois, and in Livingston and Crittenden Counties, Kentucky, the total area in which they are known being 25 miles or more in length in a northwest-southeast direction, and 15 miles in width. The deeply buried igneous mass doubtless underlies the whole of this area, and the known dikes are merely a few stringers of the material which were forced to a higher level. The actual depth of the buried mass is unknown, for no deep drilling and no mine excavations have penetrated it. This igneous rock was injected into the earth's crust in this region in very remote geological time, by the same sort of forces which produce volcanoes upon the surface, but in this case the melted rock or lava was not backed by sufficient force to cause it to break through the great thickness of overlying sedimentary deposits. The injection of the material into the crust, however, caused the overlying strata to be bowed up, and since the limestones, sandstones and shales which constitute the crust were inelastic and rigid, they were fractured and broken along the lines of faulting which we now recognize. Fractures formed under such conditions are rarely vertical cracks, but are commonly inclined, the inclination being in opposite directions along different fractures, so that the whole mass of the crust is broken into a series of wedge-shaped blocks, which, slipping upon themselves, come to rest and occupy the added length of the segment produced by its upcurvature.

The fracturing of sedimentary rocks in the manner which has been outlined does not take place with entire regularity and symmetry, and consequently the fault pattern exhibited by such an area as the Golconda Quadrangle is very complex. The general northeast-southwest direction of the longer faults is essentially at right angles to the longer axis of the area underlain by the supposed deep-seated igneous intrusion. This is as would be expected, since the greater tensional strain would be along the line of greatest stretching, or the longer axis of the area, the fractures being formed at right angles to the tension force. The stretching in the opposite direction was less because of the shorter distance along which the crust was lengthened by the updoming, and this lengthening was adjusted by the more or less irregular cross faulting of the more elongate northeast-southwest blocks.

It is not improbable that during the enormously long period during which the deep-seated, intruded igneous mass was cooling, while it was still more or less liquid or viscous, the enormous weight of overlying sediments resting upon it, tended to squeeze it out around the edges between the inclosing strata. Such a movement of the igneous material would tend to reduce the elevation of the updomed area and at the same time to increase the width of the dome, and this would occasion other faulting and other adjustments of the crustal blocks subsequent to the original faulting of the region.

The presence of great deposits of fluorspar along some of the fault lines in this Ohio Valley region is also reasonably accounted for by the assumption of the presence of such a deep seated igneous mass as has been postulated. It is known that fluorine gas is given off from igneous magmas, and the presence of such a magma would afford a sufficient source of supply for the fluorine of the fluorspar accumulations. The fluorine gas, creeping up along the fault crevices would act upon the limestone with which it came in contact, changing the calcium carbonate of the limestone into calcium fluoride or fluorspar. The actual process of accumulation of the mineral deposits of the region are of course exceedingly complex, and have been studied by Mr. L. W. Currier,[1] both in Illinois and Kentucky, and a record of the results of his studies will be published by the Survey.

The total area of the Golconda Quadrangle in Kentucky is approximately 180 square miles, and within this area no less than 67 distinct faults have been recognized and mapped. Many of the faults are short, some of them only a fraction of a mile in length, while others are continuous entirely across the quadrangle and are known to extend for greater or less distances into adjacent territory. The amount of vertical displacement along the faults is exceedingly variable, in some places it being known to be 50 feet or less, and elsewhere as much as 1300 feet.

The field criteria which may be depended upon for the determination of the faults in the Golconda Quadrangle are of several sorts. If the unconsolidated surface materials which cover almost the whole of the area were completely removed, the tracing of the faults would be a very simple task, and every one of them could be located with extreme accuracy, but in only a few localities is the slipping plane of any fault actually exposed in surface outcrop, and the geologist must depend largely upon his knowledge of the stratigraphic succession in the district, to work out the fault structure.

When the dislocation along a fault is such as to bring formations of different lithologic character, as a sandstone and a limestone, in line, the location of the fault is determined by the ending of one lithologic type and the beginning of the other. When the beds are completely exposed such a position can be determined with accuracy, but when the outcrops are much covered, as is commonly the case, the presence of the fault may be established, but its actual position may not be determined except within certain limits which will be of variable extent. Along some of the faults the strata close to the line of dislocation have been more or less disturbed by the differential movement, and this disturbance is exhibited by the more or less steeply dipping beds, those on the upthrow side

[1]Ill. State Geol. Surv., Bull. No. 41, pp. 247-304.

being dragged downward and those on the downthrow side being dragged upward. Within this area such more or less steeply dipping beds indicate the presence of a fault, and the strike of the beds indicates the approximate direction of the fault.

In places the sandstones along fault lines have been changed to quartzite through the influence of the rock movements, and such much fractured quartzite ridges in some places stand up in some relief along fault lines because of the superior hardness of this rock. Slickensided or polished surfaces in sandstone or limestone, due to the movement along the fault planes are to be observed in many places along fault lines. In places a row of sink holes is indicative of a fault, where a limestone is present at or near the surface, although no actual limestone outcrops may be exposed. Not uncommonly springs emerge along fault lines for the reason that these fractures furnish more or less open courses for the circulation of underground waters, especially from one level to another, but of course every spring is not upon a fault line. Fractures in the limestone near fault lines are in many places healed with white, crystalline calcite, and where such calcite seams are present it is likely that a fault is near.

Although all of the criteria which have been mentioned are suggestive and furnish clues to the field geologist, the real basis for working out the structure must be his intimate knowledge of the stratigraphic column, and the careful tracing and mapping of the several stratigraphic units which are present. When this is done the lines along which the beds have been dislocated present themselves with great clearness. The faults themselves may not be simple fractures along a single slipping plane. In many places they are fractures of a compound character, the dislocation being distributed through a zone of greater or less width, in some places several hundred feet, which has been more or less crushed or crumpled.

Descriptions of Faults.

The dominant direction of the faulting in the quadrangle is northeast-southwest, and these subparallel faults divide the whole region into a series of fault blocks which, in the more complexly faulted portion of the quadrangle, constitute rather narrow, elongate segments of the earth's crust. In places certain of the elongate blocks are divided by transverse fractures. In general the longer faults are more or less convergent in either one or the other direction, or in both directions, so that the fault blocks which they enclose assume more or less wedge-shaped outlines. In some cases the points of such wedge-shaped blocks have dropped downward relative to the segments on either one or both sides, in the course of crustal adjustments accompanying the strains which have produced the faulting but in other cases these wedge-shaped blocks have remained elevated, and the blocks on both sides have been down-dropped. In not a few places transverse fractures have been developed across the blocks at some distance from their extremities, and in such cases the point of the block has commonly settled somewhat deeper than the main mass of the segment. In places a number of such transverse faults have been developed and the blocks so formed have been displaced in step-like fashion, the distal one being dropped the deepest.

Considered as a whole the distribution of the faulting in the quadrangle may be divided into three areas, the first one lying in the northwestern portion of the quadrangle, another in the southeastern part, and a third connecting the two first mentioned along a belt in which the general direction of the faults is north-south or northwest-southeast. These three regions of faulting will be designated by the letters A, B, and C, the northwestern fault region of the quadrangle being A, the connecting belt B, and the southeastern region C. Throughout the whole quadrangle the faults will be numbered consecutively from 1 to 67, beginning at the northwestern border of region A, the fault numbers in this region being 1 to 15. The faults of the connecting belt B are numbered 16 to 24, and those of the southeastern region C 25 to 67.

Faults of Region A.

Fault No. 1. This fault is the westernmost one of the northeast-southwest faults which continue entirely across the quadrangle. Its northern extremity in Kentucky intersects the Ohio River about two miles west of Carrsville, and its direction is approximately N.30°E. East of it lies a great down-dropped block of Pottsville sandstone, and west of it are various Chester formations ranging from the Renault limestone to the Cypress sandstone. The maximum dislocation along this fault is just equal to or slightly in excess of the total thickness of the Chester series, or approximately 1300 feet. In a northeasterly direction this fault continues across the Ohio River into Hardin County, Illinois, where it has been called the Wallace Branch fault in the Hardin County Report.[1] This fault also crosses the Ohio in a southwesterly direction and has been mapped in Pope County, Illinois, about two miles above Bay City. Branching from this fault to the west are a number of lesser faults which will be considered in order, beginning with the most northern one.

Some prospecting has been done along this fault about a mile southwest of the point where it enters the hills from the Ohio River bottoms opposite Shetlerville, Illinois, and again a little over one-half mile south of the road over the hills from Joy to Berry's Ferry. At both of these localities the work had been abandoned at the time of the present survey, and no evidence of mineral deposits of any value were visible.

Fault No. 2. This fault connects with No. 1 about one-third of a mile north of where the main fault crosses the highway from Joy to Berry's Ferry, its direction being approximately S.60°W. In its extension to the southwest this fault doubtless intersects fault No. 3 somewhere in the Ohio River bottoms or perhaps in the area actually occupied by the waters

[1] Ill. State Geol. Surv., Bull. No. 41, p. 73.

of the river itself, its total length must be a little less than three miles. The dislocation is approximately equal to the thickness of the Bethel sandstone, which is about 100 feet or a little more at this point, the downthrow being on the north.

Some prospecting has been conducted along this fault at the point where it intersects the bluff rising from the Ohio River bottoms, and also a little over one-fourth mile northeast of this point in the sides of Cave Spring Branch.

Fault No. 3. This fault branches off from the main fault No. 1, about two and one-half miles southwest of the point of divergence of No. 2. Its direction is about N.60°W., so that it meets the main fault at approximately a right angle. The projection of the fault in the direction indicated carries it into a fault which is exhibited in the Ohio River bank a mile south of Golconda, along which some prospecting for barite and fluorspar has been carried on with no great success. In Kentucky the down-throw along this fault is on the north and cannot exceed 30 or 40 feet, but in Illinois there is a downthrow of some 40 or 50 feet on the south side. This situation must indicate the presence of other faulting, hidden at the present time by the Ohio River and its alluvial deposits, fracturing the block lying south of the fault.

Fault No. 4. This fault diverges from fault No. 1 about one mile south of No. 3. The divergence is at a low angle, about 18°, and the direction of the fault changes slightly to the southwest until it becomes approximately parallel with the main fault, the distance between the two being about one-third of a mile. It has been traced across the Ohio River into Pope County, Illinois, where it continues in a direction essentially parallel with No. 1. The wedge-shaped block, pointed to the northeast, bounded by faults 1 and 4, is really a splinter-like mass of the earth's crust which is down-dropped relative to the block on the west, but is not so deeply down-dropped as the larger block of Pottsville lying east of the fault No. 1. The pointed, northeastern part of this block has been fractured transversely by a nearly north-south fault, No. 5, situated about one mile from the extremity, the triangular block so formed being more deeply down-dropped than the main portion of the block beyond the transverse fault.

Fault No. 6. This fault is subparallel with No. 1, converging somewhat to the southwest. At the Ohio River in the northern part of the quadrangle, the two faults are nearly two miles apart, but where they both cross the Ohio River in the southwestern part of the quadrangle they are about one and one-fourth miles apart. The block lying between the two faults is a great mass of Pottsville sandstone and conglomerate which is down-dropped between the formations on either side of it, although along the eastern border of the block the underlying Kinkaid limestone of the Chester Series is exposed. This fault intersects the Ohio River bank in the western edge of Carrsville, and it is known to continue in a northeast direction into Hardin County, Illinois, where it has been called the Big Creek Fault.[1] The dislocation along this fault is greatest about a mile south of Carrsville, where the upper part of the Cypress sandstone lies opposite the lower portion of the Kinkaid limestone, giving a dislocation of approximately 750 feet. Farther north and also farther south the dislocation is less. Throughout its extent in Kentucky this fault lies just east of the Carrsville escarpment.

For three-fourths of a mile southwest from Carrsville prospecting has been conducted from time to time along this fault, but apparently without notable results.

Fault No. 7. This fault intersects the Ohio River bank at the foot of the main street in the town of Carrsville. Continuing in a southwesterly direction it intersects fault No. 6 at a low angle, 10° or less, a little less than a mile south of Carrsville. The exact point of intersection cannot be established with certainty, but it cannot be far from the point indicated on the map. The wedge-shaped point between the two faults is occupied by the Hardinsburg sandstone overlain by the Glen Dean limestone in the hill occupying the north-western portion of the town of Carrsville. This fault continues across the Ohio River into Illinois, where it has been called the

[1] Ill. State Geol. Surv., Bull. No. 41, p. 71 (1921).

Daisy Fault.[1] The downthrow is to the west, the amount of dislocation being from the upper part of the Cypress sandstone to near the base of the Glen Dean limestone, about 250 feet.

A small amount of zinc is said to have been mined from one of the fractures of this fault, near the river bank at Carrsville, but the work has long been abandoned.

Fault No. 8. This fault diverges to the northwest from fault No. 6, its direction probably being about N.35° W., and the point of intersection of the two faults being about two and one-half miles from the river bank at Carrsville. The ravine cutting back into the Pottsville bluff at this point has probably been determined by the presence of the fault. The actual position of the fault has nowhere been observed, its presence being inferred from the difference in elevation of the Kinkaid-Pottsville contact on the two sides of the ravine, this difference being approximately 60 feet, which is the amount of dislocation, the downthrow being to the south. It is not possible to determine the distance to which this fault extends in a northwest direction, because after passing the limits of the ravine in which the Kinkaid-Pottsville contact can be observed, it is lost in the great mass of Pottsville itself which does not contain sufficiently distinct beds, sufficiently well exposed, to make it possible to trace the fault into the formation. There is some reason to believe, however, that the fault does continue entirely across the Pottsville block to fault No. 1, for there is an exposure of Kinkaid limestone east of this fault in the Love Chapel Hollow, whose contact with the overlying Pottsville is near the elevation of the same contact south of fault No. 8 at its junction with No. 6. If this fault is continuous to No. 1 then the Kinkaid-Pottsville block lying to the north of it has been dislocated with a tilting motion, the western portion having dropped down relative to the block to the south, while the eastern part of the same block is upthrown north of the fault.

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[1] Ill. State Geol. Surv., Bull. No. 41, p. 71 (1921).

Fault No. 9. This is an hypothetical fault which has not been mapped, and may not be present. If it is present it diverges from fault No. 6 a mile or more south of the point of divergence of No. 8. The reason for assuming that such a fault does not exist is found in the difference of nearly 100 feet in the elevation of the Kinkaid-Pottsville contact in the ravines north and south of the road over the hills from Joy to the Ohio River bottoms, along the line of the fault. Where this road crosses the elevated region between Joy and the Ohio River bottoms, there is an interval of about one mile between the heads of the ravines leading to the north along the line of the fault No. 5, and the one leading to the south along the same fault, where the Pottsville has not been cut through. To the north the lower contact of the Pottsville is at an elevation of 420 to 440 feet, and continues at about the same level to fault No. 8. South of the road the contact is almost exactly 100 feet higher, and continues at that elevation for some miles. This difference may of course be due to the dip of the beds, but in this much fractured region it is much more likely to be due to the presence of a fault through the Pottsville rocks along which there is a downward dislocation to the north of about 100 feet.

Fault No. 10. This fault diverges to the southwest from No. 6, at an angle of about 20° to the main fault, the point of divergence being about five miles from the southwestern corner of the quadrangle. Through a greater portion of its extent the fault is hidden beneath the alluvial deposits of one of the branches of Bayou Creek, but it does cut across the shoulder-like hill which projects southward from the Pottsville bluff, three and one-half miles a little west of north from the point where Bayou Creek crosses the southern border of the quadrangle. The dislocation along this fault is from 80 to 100 feet, with the downthrow on the northwest side. The extreme length of the fault is probably about two and one-half miles, its southern extremity being at the transverse fault No. 11, which will be next described.

Fault No. 11. This fault cuts across the southern extremity of the range of hills which terminate between Bayou Creek and the Ohio River, two and one-half miles from the southwestern corner of the quadrangle. The fault line itself is nowhere actually exhibited at the surface, being entirely covered by surficial materials, but the difference in the stratigraphic constitution of the terminal elevation of the range of hills, as compared with the one next north of it, shows that the two must be separated by a fault. The approximate direction of the fault must be east and west, but of course the exact direction and the exact position are not determinable under the circumstances. The length of the fault is about one and one-half miles, and the dislocation is approximately 150 feet with the downthrow on the north.

Fault No. 12. This is the third of the continuous northeast-southwest faults in the northwestern portion of the quadrangle. It is the third fault which crosses the Ohio River in the vicinity of Carrsville, and is probably the southwestern continuation of the Rosiclare fault of Hardin County, Illinois.[1] Its direction is nearly parallel with fault No. 6, the distance between the two faults varying from a little more than three-tenths of a mile to about twice that distance. The fault crosses the Ohio River a second time, as does No. 6, near the southwestern corner of the quadrangle. The long narrow block lying between faults 6 and 12 is down-dropped relative to the strata to the east of it, but the great Pottsville block lying next west of it is down-dropped still farther, so that in passing from east to west across the two faults there are two successive steps in the downward movement of the blocks. This narrow, elongate block is fractured transversely at three places within its total extent in Kentucky, thus being divided into four separate blocks whose downward movements have not been the same, so that the amount of dislocation along fault No. 12 varies considerably from place to place. For the first two and one-quarter miles southward from the Ohio River the dislocation is not very great, being less that the thickness

[1]Ill. State Geol. Surv., Bull. No. 41, p. 70 (1921).

of the Cypress sandstone, which is exposed on both sides of the fault, the total throw probably being approximately 50 feet or even less. For the next space of a little less than one mile the dislocation is somewhere near 250 feet, then still farther south through a distance of about five miles the dislocation probably varies from 50 to 100 feet, and beyond this it is again increased to about 350 feet or more.

Faults No. 13 and No. 14. These subparallel faults, somewhat less than one mile apart, limit a segment of the elongate fault block between faults 6 and 12, which has settled more deeply than either the mass to the north or that to the south of it, in the course of crustal adjustments in the region. The center of this block is about two and one-half miles from the Ohio River at Carrsville. The actual position of the northernmost one of the two faults can be located only approximately, for the fault itself is hidden by the surficial deposits. The southernmost one also is not actually exposed, but its possible location is somewhat more limited than in the case of the other one. The determination of the presence of the two faults is of course based upon the different stratigraphic constitution of the block lying between them from that of the blocks to the north and south. The dislocation along the fault No. 13 is approximately 250 feet, while that along No. 14 is about 100 feet.

Fault No. 15. This fault crosses the narrowly elongate block between faults No. 6 and No. 12, in a very oblique direction, the divergence being to the south from No. 6. The length of the fault is approximately two and one-half miles although the distance between the two elongate faults is less than one-half mile. Along this fault the more southern segment of the elongate block is down-dropped relative to the more northern one, the amount of dislocation being approximately 175 feet.

Faults of Region B.

The faults of this belt, Nos. 16 to 24, connect the regions A and C. They extend in a general north-south direction, a little east of the middle line of the quadrangle, although the northernmost one has a northwest-southeast direction. The actual connection of this belt with region A is north of the Ohio River in Illinois, somewhat south of the Extension Shaft of the Fairview Mine. The connection with the southeastern group of northeast-southwest faults is about two and one-half miles southwest of Lola. A number of connecting faults constitute this series, in addition to which are others which diverge from the primary ones.

Fault No. 16. This fault intersects the bluff rising from Deer Creek, about four-fifths of a mile east of the mouth of Buck Creek, or about a mile east of Carrsville. The direction of the fault is about N.34°W., and its length in Kentucky is a little less than three miles. It crosses the Ohio River in Illinois, but its course on the north side of the river is hidden by the alluvial deposits. The position of the fault in the bluff rising from Deer Creek is shown by the termination of the Renault limestone outcrop which continues to the east. The position of the fault is also clearly indicated along the road running east from Eli School, which is situated a little more than one mile south of the Deer Creek bluff. Along this road, near the bottom of the hill one-half mile east of the school, is an outcrop of the Paint Creek formation, and just beyond it in the ravine north of the road, the summit of the Renault limestone is exposed at an elevation about 20 feet below the Paint Creek, the Bethel sandstone being present above the Renault. The situation of the outcrops is such that the position of the fault can be limited to a space of not more than three or four rods. There apparently is very little or no disturbance of the strata adjacent to the fault line. The amount of displacement along this fault is approximately the thickness of the Bethel sandstone, which is probably about 100 feet in this part of the quadrangle, with the downthrow on the west.

A little prospecting has been carried on along this fault near the river bluff, but the diggings seem to have been abandoned for a long time.

Fault No. 17. At a point two and three-fourths miles from the Ohio River bank along fault No. 16, the dislocation along belt B is continued in fault No. 17. Its direction is about S.20°W., from its point of departure, and it continues in that direction for approximately one mile along the Bethel escarpment, with a dislocation of about 150 feet, the downthrow on the west.

Fault No. 18. Near the southern extremity of fault No. 17 there is a fault diverging from it to the northeast. The direction of this fault is N.55°E., and although the position of the fault is hidden by the alluvial deposits of Deer Creek valley and one of its tributaries, except for a short distance near its junction with 17, it seems to cross Deer Creek about one and one-fourth miles southeast of the bridge on the Milford road east from Carrsville. The position of the fault east of Deer Creek at this place is suggested by the fact that two summits of the ridge-like hill between Deer Creek and a tributary to the same stream, north of this projected fault line, are capped by the Rosiclare sandstone, while the same ridge in its southeastern extension from this line gives no evidence of the presence of this sandstone. The termination of the Rosiclare sandstone outcrop at this position seems to be sufficient evidence for establishing the location of the fault at least to a point a short distance east of Deer Creek. The continuation of the fault to the northeast within the Fredonia limestone has not been established, but additional field observations may lead to further information bearing upon this question. The amount of dislocation along this fault towards its point of origin at 17, is approximately 100 feet, as is shown by this difference in elevation of the basal contact of the Rosiclare sandstone on the two sides, the downthrow being on the north. It is not unlikely that the amount of dislocation decreases in a north-easterly direction and may finally disappear with the dying out of the fault.

Fault No. 19. This fault has a nearly north-south direction in the northern portion of the quadrangle, west of Deer Creek. The evidence for it is not as conclusive as might be desirable, but its presence is strongly suggested by the difference in elevation of the Rosiclare sandstone outcrop on opposite sides of the line drawn, and by the considerable shattering of the Fredonia limestone exposed in the hill along the east-west road three-fourths of a mile south of the bridge over Deer Creek on the Carrsville-Milford road. The southern termination of this fault is apparently at the point where it joins fault No. 18. The downthrow is on the east side and the amount of dislocation is about 60 feet. The location of this fault is not far removed from Ulrich's Deer Creek Fault[1] which he extended to a point some distance south of Lola, but in his map Ulrich shows the dislocation along the Deer Creek fault to be in the opposite direction from what is actually the case along fault No. 19.

Fault No. 20. This fault does not connect directly with 17, but is offset between one and two-tenths of a mile to the east, and really connects with fault No. 18, joining it from the south. This fault continues for about four and one-half miles and is the longest one in belt B, its southern extremity becoming involved with the northeast-southwest faults of region C, southwest of Lola. The direction of this fault is approximately north-south, near the foot of the Bethel escarpment, and throughout most of its length the Ste. Genevieve limestone lies east of it.

Fault No. 21. This fault diverges from 20 less than one-half mile from the northern connection of the main fault with 18. From its point of departure, at an angle of about 15°, it has been traced in a southeasterly direction for about one-half mile. Although this fault is so short a one, it is of some importance because it is known to be mineralized along a part of its extent, and a considerable amount of fluorspar has been taken out along it by shallow mining, about one-fourth of a mile north of the foot of Bethel Hill. The narrow, wedge-like segment, pointed to the north, lying between this fault and No. 20, has dropped downward relative to the rock strata to the east, but is not so deeply down-dropped as the great mass lying west of 20. This block is really a small splinter-like fragment of the great block lying to the east of it, which has

[1]Prof. Paper, U. S. Geol. Surv., No. 36, p. 98 (1905).

been broken off and dragged downward for a short distance with the downward movement of the large block to the west of it.

Fault No. 22. With the dislocation along fault 20, the rock strata both to the east and west were subjected to such strains that a number of fractures were developed extending obliquely into these beds, along which there was some dislocation of the strata. In addition to fault 21 which has been described, two other such faults have been mapped. There may be still others in the district which have too slight dislocation to permit their detection under the thick covering of surficial material, and consequently are not shown. Fault No. 22 extends in a southeasterly direction from 20, diverging at an angle of about 45°, the point of departure being at about the foot of Bethel Hill. The length of this fault is not determinable, it certainly extends for about one mile beyond which point it probably dies out rather promptly. The downthrow is on the north side, and the maximum amount of dislocation is probably about 50 feet.

Fault No. 23. This fault is along a fracture which diverges from 20 in a northwesterly direction at an angle of about 30°, its point of departure from the main fault probably being about two-tenths of a mile south of that of fault No. 22. As in the case of 22 the downthrow is on the north and the maximum dislocation is about 100 feet. The fault must die out in a northwesterly direction within a distance of about one and one-half miles.

Fault No. 24. The fault which may be designated as No. 24 is not one of the continuous faults in belt B, but is subparallel with No. 20, and lies to the west of it. Its northern extremity connects with 23 near its point of origin, and lies about one-tenth of a mile west of 20. It continues in a southerly direction for three and one-fourth miles where it lies about two-tenths of a mile west of 20. At its southern extremity this fault connects with the faults of region C. The narrow, elongate fault block lying between 20 and 24 is downdropped relative to the blocks both to the east and to the west of it, but the dislocation is greatest on the east. The amount of throw along 24 is equal to the combined thickness of the Bethel sandstone and the Paint Creek formation, or somewhat more than 100 feet, the dislocation along 20 being in addition to this the thickness of the Renault limestone and some portion of the Ste. Genevieve limestone, or approximately 200 feet in all.

Faults of Region C.

The southeastern portion of the Golconda Quadrangle is the most complexly faulted portion of the area, and really should be considered in connection with the structure of the adjoining quadrangles to the east and south, which are as yet unmapped. So far as the Golconda Quadrangle is involved there are really two distinct groups of these faults which are not connected, although it is not unlikely that an extension of the mapping to the south may show that the two groups become joined. The faults in the first of these groups are numbered 25 to 41 inclusive, and those of the second group are numbers 42 to 67.

Fault No. 25. This is the westernmost one of the more continuous northeast-southwest faults of group C, although there is a series of several diverging faults connected with it which lead still farther west. This fault connects with those of Group B about two and one-half miles southwest of Lola, on the border of a small area where most complex faulting exists, its termination being against fault No. 20. The direction of the fault varies somewhat from N.20°E. at the southern border of the Quadrangle, to near N.40°E. in the more northern portion of its course. For about one mile from its northeastern termination the dislocation is near or a little less than the thickness of the Bethel sandstone, or about 80 feet, the downthrow being on the southeast side. Beyond this point, due to the presence of a branch fault extending to the west, the direction of dislocation changes and the downthrow is on the northwest side, the maximum amount of dislocation being nearly 200 feet.

Fault No. 26. This fault diverges southwest from No. 25, its point of origin being about one and one-fourth miles east of Hampton. Its direction is about S.72° W., and it forms an angle of nearly 45° with the main fault from which it diverges. In its southwestward course it passes a little less than one-half mile south of Hampton. The fault continues for a distance of about four miles with diminishing dislocation to the southwest, and probably intersects the southern continuation of the Joy escarpment about a mile from the southern boundary of the quadrangle, although the amount of dislocation at this bluff is probably slight. This fault is responsible for the development of the sandstone bluff extending southwest from the town of Hampton for a mile and one-half, the fault being situated near the foot of the bluff. Throughout its whole extent the block on the southside of the fault is downthrown, the maximum dislocation being between 250 and 300 feet a half mile southwest of Hampton, just west of a branch fault having a more southerly direction. At the apex of the wedge-like block between this fault and No. 25, the dislocation is probably about 175 feet. Directly south of Hampton the dislocation is almost exactly the thickness of the Cypress sandstone or about 100 feet.

Fault No. 27. The down-dropped block lying south of fault No. 26 is split by a fault diverging towards the south, whose point of origin is on fault No. 26 just south of Hampton. The direction of this fault is about S.40° W. from its point of origin, becoming about S.45° W. at the southern boundary of the Quadrangle. The wedge-shaped block between faults 27 and 26 is down-dropped relative to the blocks on both sides, the greatest dislocation of nearly 300 feet being on the north as has been stated. The dislocation along fault No. 27 is probably about 100 feet at its point of origin, becoming less to the southwest.

Fault No. 28. A little more than one-tenth of a mile north of the south boundary of the Golconda Quadrangle, a fault with a nearly east-west direction branches off from fault No. 27 and can be traced for a distance of two miles and probably dies out within three miles. As in the cases of the last two wedge-shaped blocks which have been described, the point of this wedge also has dropped downward in the course of the crustal readjustments, the amount of dislocation at the point of origin being about 150 feet, bringing the bottom of the Tar Springs sandstone about opposite the bottom of the Hardinsburg sandstone.

About a quarter of a mile south of fault No. 28, and subparallel with it, is a second fault branching off from No. 27. This fault, however, lies south of the boundary of the Golconda Quadrangle, and is not designated by any number in this place, and the relations of the block lying between these two faults and the block to the south has not been determined.

Fault No. 29. With fault No. 29 we enter upon the description of an exceedingly complex group of faults which occupy an area of less than one square mile in the hills two and one-half miles southwest of Lola. Within this fault complex it has not been possible to work out all the details of the fault structure with complete satisfaction. A considerable number of faults have been recognized and mapped, but there may be others as yet not detected, and it must be considered that the structure as shown is somewhat generalized.

Fault No. 29 diverges from No. 25 to the northeast, its direction being about N.55°E. Its length is a little less than one and one-half miles, and it terminates at one of the more elongate northeast-southwest faults, No. 31, whose direction is subparallel with No. 25. The downthrow along this fault is on the south side, the maximum dislocation, about 300 feet, is at the northeastern termination of the fault, if the sandstone at this point has been correctly identified as Hardinsburg. At its southwestern termination the dislocation is less than the thickness of the Bethel sandstone.

Fault No. 30. This fault has its southwestern termination at near the middle point of fault No. 29, from which point it extends to Lola and perhaps beyond, with a direction of about N.33°E. It is along this fault, a little over one and one-half miles southwest of Lola that the Bonanza Mine is situated, this being the only operating mine in the district at the time of the present survey. At Lola the dislocation along this fault is less than the thickness of the Fredonia limestone, which is present on both sides of it, and its extent to the northeast within the Fredonia limestone has not been determined. Throughout its entire length the downthrow is on the southeast side, the greatest dislocation bringing the Bethel sandstone against the Fredonia limestone. It has not been determined what part of the Fredonia limestone is present at the surface along the fault, but it is probably some of the higher beds, and the total amount of dislocation may not be over 100 feet. The amount of throw doubtless decreases and finally dies out altogether in a northeasterly direction. The mining which was formerly carried on by the road side in the town of Lola was probably along this fault at a place where different horizons of the Fredonia limestone are present upon the two sides of the fault.

Fault No. 31. This is one of the more elongate of the northeast-southwest faults of Group C, its length within the quadrangle being nearly four miles. Its northeastern point of origin is at fault No. 30 about one-half mile southwest of Lola. From this point it continues to the southern border of the Golconda Quadrangle, and beyond, with a direction about S.25°W. It is against this fault, about one mile from its point of origin, that fault No. 29 terminates. The structure between this fault and No. 25 is so complex, with so many cross faults between the two, that the direction of dislocation changes from being downthrown on the northwest towards its northeastern termination, to being downthrown on the southeast side towards the southern boundary of the Quadrangle. The maximum dislocation is probably about 200 feet.

Throughout much of its length this fault is the line of separation between two of the Chester sandstone formations, and is consequently somewhat difficult to follow. Its position is well shown, however, by the steep dips in the sandstone outcrops in the road on the hill slope east of the Bonanza Mines, one and one-half miles southwest of Lola. In the more southern part of its course the fault is more indistinct but in the roadside a little less than three-fourths of a mile east of Burna, almost on the southern border of the Quadrangle, there are some steeply dipping beds which seem to indicate dislocation of the strata along this line, and at a number of intermediate points between those mentioned there are outcrops of steeply dipping beds which are indicative of the same fault.

Faults No. 32 and No. 33. These are two short faults, neither of them more than one-fourth of a mile in length, which transect the narrow, triangular block bounded by faults 29, 30 and 31. At the surface this block is made up of Renault limestone and Bethel sandstone, but the two narrowly wedge-shaped terminal portions of the triangle have been fractured along these two faults and have been down-dropped relative to the middle division.

Fault No. 34. This is a diagonal fault extending for about four miles, terminating at fault No. 31 at the northeast, and at No. 25 at the southwest, its direction being about N.35°E. The most complex faulting of the area lies between the northern portion of this fault and No. 25. Throughout its entire length the downthrow is on the southeast side, the maximum dislocation being about 300 feet.

Fault No. 35. This fault is about one mile in length, it terminates at its northeastern extremity at fault No. 29, and to the southwest at fault No. 34. It forms one side of a trapezoidal block bounded by faults 29, 31, 34, and 35, which has dropped downward relative to all of the surrounding blocks in the course of the crustal readjustments. The amount of dislocation along No. 35 is probably 200 feet or somewhat less.

Fault No. 36. This fault originates at its northeastern termination at about the same point as fault No. 35, but its direction is more southwestwardly and its southwestern termination is at fault No. 25. Its total length is about one and one-half miles. Throughout its entire length the downthrow is on the southeast side, but the amount of dislocation varies considerably because of the much faulted condition of the wedge-shaped segment lying between faults 35 and 36.

Fault No. 37. This is a short cross fault less than one-half mile in length, which connects faults Nos. 35 and 36, its direction being N.10°E. The block of sandstone lying east of this fault is not associated with any limestone exposure, but it is probably the Cypress, and if this determination is correct the dislocation has dropped the block lying west of the fault about 150 feet or more.

Fault No. 38. This is another short cross fault having a more nearly east-west direction than the last one. Its length is about one-fourth mile, its eastern extremity abutting against fault No. 37 near its southern terminus. The triangular block lying north of fault 38 is down-dropped relative to the blocks on all sides of it, the dislocation along fault 38 being 250 feet or more.

Fault No. 39. This fault is nearly east-west in direction, and lies about one-fourth mile south of fault 38. It is less than one-half mile in length and terminates against faults 34 and 36. The irregular polygonal block lying north of it is down-dropped relative to the block on the south, the dislocation being somewhat less than 100 feet.

Fault No. 40. This fault is an oblique cross fault between faults 25 and 34, and cuts off the southern portion of the narrow, wedge-shaped segment between the two faults. The evidence for mapping this fault is somewhat slender, but it seems to be justified by the steeply dipping sandstone beds where it crosses the road one and one-fourth miles southeast of Hampton, and by the apparent interruption of the Paint Creek shale outcrop. The direction of the fault as mapped may not be accurate, but it must have a general north-south direction. The downthrow is on the west side of the fault, the amount of dislocation being somewhat less than 100 feet.

Fault No. 41. Throughout practically its whole extent this fault separates sandstone formations, and for a considerable portion of its length the Hardinsburg sandstone is present on both sides so that the amount of dislocation is less than the thickness of that formation. The direction of the fault is about N.45°E., its length within the Golconda Quadrangle being about three miles. This fault crosses the southern boundary of the Quadrangle about one-fourth mile northwest of Burna on the road to Hampton. At a point between three and four-tenths of a mile northeast of the point where the fault crosses the boundary of the Quadrangle there is a good exhibition of slickensided surfaces in the sandstone along the fault, and notable disturbances of the sandstone are exhibited in the creek bed a little less than a mile from the Quadrangle border. A little less than two miles from the southern border of the Quadrangle this fault intersects and crosses fault No. 31, its presence beyond this point of intersection being indicated by the discontinuance of the outcrop of Glen Dean limestone to the west, at a point two and one-half miles a little south of east from Hampton. In this more northeastern portion of the fault the dislocation brings the Hardinsburg sandstone on the west against the Tar Springs sandstone on the east, a dislocation of about 200 feet. This is the last fault in the westernmost group of faults in Region C of the Quadrangle.

Fault No. 42. This is the westernmost one of the eastern group of faults in Region C. Its direction is N.35°E., converging with fault No. 46 towards the north, although the two faults do not intersect because of the junction of 46 with the cross fault No. 44. This fault has been traced somewhat less than four miles in a southwest direction, to the point where it dies out and disappears. Its extension into the Fredonia limestone to the northeast has not been followed, although it probably extends in that direction for some distance. Throughout its entire length the downthrow is on the east side, the maximum dislocation being about 500 feet.

Fault No. 43. This is a short, divergent fault, whose northern point of origin is about a mile from the southern extremity of fault No. 42, from which it diverges to the southwest at an angle of about 10°. Its southern termination is about opposite that of 42, and the wedge-shaped block lying between the two faults is really a splinter-like fragment of the larger block to the west which has been dragged down with the dislocation along fault 42, but not so deeply as the larger block east of 42.

Fault No. 44. This fault has a direction of N.75°E., its western termination being against the northern part of No. 42, while its eastern termination is probably at fault No. 55, east of the eastern boundary of the Quadrangle. The dislocation along this fault changes from place to place because of the several different blocks which are adjacent to it on the south. In its western half the downthrow is on the south, but to the east it is on the north.

There has been some prospecting along this fault line, one of the Belt mines being situated upon it near the point where the fault crosses Flat Lick Creek, about three miles east of Lola.

Fault No. 45. This is a fault which diverges to the northeast from the last one described, its direction being about N.62°E. It crosses the eastern boundary of the quadrangle a little more than one-fourth mile north of the last one, and the wedge-shaped block between them is down-dropped relative to the segments on either side, although the amount of dislocation is not great.

There has been some prospecting along this fault, the most extensive workings being at the Belt Mines where a considerable amount of fluorspar has been produced.

Fault No. 46. This is one of the more continuous faults in Region C. Its northern termination is at the cross fault No. 44, about one and three-fourths miles east and a little north of Lola. Its direction is about N.28°E., converging with fault No. 53 in a southwest direction, and the two probably join at some point south of the border of the Golconda Quadrangle. The total length of the fault within the Quadrangle is a little over five miles. This fault is characterized to a much greater degree than any of the others in the Quadrangle by steeply dipping beds adjacent to it, especially the beds just east of the fault. Along the southernmost two miles of its course dips of 50° to 60° are not unusual, and some dips as high as 78° have been observed. An excellent exhibition of these steeply dipping beds may be seen in the public highway between Salem and Burna, about four miles west of Salem, at the hill known as the "Devil's Back-bone." In the northern part of the course of the fault the steep dips are not so noticeable. The greatest dislocation along this fault is at the southern border of the Quadrangle where it is about 300 feet, with the downthrow on the west. The block lying between faults No. 53 and No. 46 comprises a part of a complexly faulted area which extends to the northeast into the adjoining quadrangle.

Fault No. 47. This is an oblique cross fault between faults 42 and 46, situated from one mile to a mile and one-half from the northern termination of the block between these faults. The direction of this fault is nearly north and south, and its length is about one-half mile. The trapezoidal block lying between this fault and faults 42, 46, and 44, is made up wholly of one of the Chester sandstone formations, with no associated limestone outcrop to assist in the determination of the sandstone. It is probable, however, that this terminal portion of the larger wedge-shaped segment has dropped downward in the course of the crustal adjustments, as such blocks have commonly done in this district, in which case the downthrow along fault No. 47 is on the northeastern side, and the amount of dislocation is 70 feet or more, possibly as much as 100 feet.

Fault No. 48. This is a short fault which forms the southwestern side of a triangular fault block, the center of which is a little more than two and one-half miles east of Lola. The length of the fault is a little less than three-fourths of a mile. The dislocation differs in amount from place to place for three different blocks join the fault on the southwest or downthrow side, the amount of dislocation probably varying from 60 to 100 feet or more. It is against this fault that fault No. 53 terminates at its northern extremity.

Fault No. 49. This is really the northern one of a series of cross faults which divide the block lying between faults 46 and 53, although its eastern extremity is probably not against 53, but rather against the cross fault No. 48, which has been last described. The position of the fault is more or less hypothetical for the reason that it separates two sandstone blocks which are somewhat alike lithologically. The direction of the fault is somewhere near east-west, probably a little northeast, but its exact direction and position cannot be determined. The downthrow is on the southern side of the fault, the amount of dislocation cannot be determined from surface outcrops but it brings the Bethel sandstone on the north against the Cypress sandstone on the south, and may be 100 feet or less. In neither of the two blocks adjoining this fault on the north or south are there any outcrops other than sandstone, and the absence of limestones makes the determination of the sandstones uncertain to some degree.

Fault No. 50. This fault is subparallel with the last one, and is somewhat more than one-fourth of a mile south of it. As with the last fault the downthrow is on the south and the amount of dislocation may be as much as 100 feet, bringing the Golconda limestone on the south against the Cypress sandstone. The actual position of the fault cannot be determined with certainty from the surface outcrops because of the surficial deposits. It has been placed on the map to the south of all sandstone exposures which must be adjacent to it, but if the outcrops were more numerous it might have to be shifted somewhat.

Fault No. 51. The third of the series of cross faults between 46 and 53 seems to be less nearly parallel with the second one than that one is with the first, its direction apparently being a little north of west rather than south of west. Here again the downthrow is on the south side of the fault and the amount of dislocation may be about 100 feet.

Fault No. 52. This is the last one in this series of cross faults, it is probably subparallel with the last one and is situated about one-half mile south of it. The actual position of the fault is more or less problematical, for no evidence of it whatever has been observed in the surface outcrops. The presence of such a fault must be assumed, however, because of the stratigraphic constitution of the areas to the north and south of it, and its position cannot be far removed from that shown on the map. Along this fault also, as along the three similar faults which have been described, the downthrow is on the south side with the amount of dislocation somewhere near 100 feet.

Fault No. 53. This is one of the longer faults in Group C, and is nearly parallel with No. 42 which lies about one mile to the west of it, and at its northern extremity it abuts against the cross fault No. 48. From its point of origin it has been traced for five and one-half miles to the southern boundary of the Quadrangle. About one mile from its northern termination a fault diverges towards the east, and in the southern portion of its course there are a number of cross faults through the block lying between it and 56. South of the point of departure of the diverging fault which has been mentioned, the downthrow is on the eastern side, and throughout nearly half its length the dislocation must be somewhere near 700 feet, bringing the upper Golconda against the lower Pottsville, but at the south edge of the quadrangle the dislocation is very much less. The Pottsville block lying between faults 56 and 53 is the most deeply down-dropped block in the faulted area occupying the southeastern portion of the Quadrangle.

Fault No. 54. The point of origin of this fault is about one mile from the northern extremity of 53. It diverges from the main fault in an angle of about 10°, its direction being nearly N.45°E. The wedge-shaped mass of sandstone which forms the block between this fault and the main one from which it diverges has no limestone outcrop either below or above the sandstone, so it is not possible to determine with certainty which sandstone it is, but it is probably the Cypress, and if this determination is correct this wedge-shaped block has remained relatively higher while the blocks on either side of it have been down-dropped.

Fault No. 55. This is a fault which diverges from 54, lying between it and No. 53, its direction being about parallel with 53. It forms one side of a narrow, wedge-shaped sandstone block with no limestone associated with it to assist in its determination. The sandstone, however, is probably Bethel, and if this determination is correct it constitutes a block which has remained even higher in position during the crustal readjustment, than the Cypress block last described. Only the southwestern extremity of this block extends into the Golconda Quadrangle, its broader portion extending into the adjoining quadrangle to the east.

Some prospecting has been carried on along this fault near the eastern border of the quadrangle, but the workings have been long abandoned.

Fault No. 56. The direction of this fault is near N.30°E. It intersects the south border of the Quadrangle about two and one-half miles west of the southeast corner, and its extent in a southwesterly direction is unknown. It has been traced in a northeasterly direction for a distance of about four and one-half miles, where it terminates by dying out in the Pottsville formation. Through the greater part of its extent the downthrow is on the west side, with a maximum dislocation of about 125 feet, this decreasing to zero at its northeastern extremity. Along the southern one and one-fourth miles of its course, by reason of the introduction of cross faulting, the direction of dislocation changes and the most deeply down-dropped beds lie to the east of this fault. The block lying east of fault No. 56 is considerably broader than those for some distance to the east or west of it, and is also but little broken up by faults diverging from the main bounding faults.

Fault No. 57. This is a cross fault which transects the block lying between faults 56 and 53. Its direction is about N.23°W., and it crosses the Salem-Burna road about two and one-half miles west of Salem, a short distance east of Old Salem Church. The length of the fault is a little less than one-half mile. Lying on the northeast side of this fault is the deeply down-dropped block of Pottsville with some Kinkaid limestone beneath it, which has already been mentioned. The block southwest of the fault has been much tilted to the east.

Fault No. 58. This is the second of the cross faults which join 56 and 53, and lies about one-half mile southwest of the last one. The two faults are not quite parallel, the present one being nearly north-south in direction, so that the block surrounded by these two faults and the two main ones, 56 and 53, is subtrapezoidal in outline. This block is less deeply down-dropped than the one to the northeast, but more deeply than that on the southwest side.

Fault No. 59. This is the third of the subparallel cross faults between 56 and 53. It lies about one-fourth of a mile west of No. 58 and is nearly north and south in direction. The block lying between faults 58 and 59 has remained higher in position in the course of the crustal readjustments, than the segments either to the northeast of it or to the southwest, so that the downthrow along No. 59 is on the west side, the amount of dislocation being less than the thickness of the Hardinsburg sandstone.

Fault No. 60. This fault lies between faults 56 and 53, but is not a transverse, connecting fault. Its northeastern termination is at fault No. 59, and from here it extends in a southwest direction subparallel with 56 and 53. Its extent in the Golconda Quadrangle is about one-half mile, and when it is traced to the southwest in the adjoining quadrangle it will probably be found to converge with and join one of the two faults which lie next to it, probably with 53. The block lying west of the fault is down-dropped relative to the one on the east, but the amount of dislocation is less than the thickness of the Hardinsburg sandstone.

Fault No. 61. The only fault diverging from fault No. 56 on the east is very close to the southern boundary of the quadrangle. Its direction is nearly north and south, and with the main fault it bounds the wedge-like termination of a sandstone block whose greatest extent must lie south of the Golconda Quadrangle.

Fault No. 62. This fault is essentially parallel with No. 56, and at its southern extremity it apparently intersects No. 64 a short distance south of the southern border of the Quadrangle. Its northern extremity may also intersect fault No. 65, but if this intersection exists it is beyond the limits of the Quadrangle. The downthrow is on the west side of the fault with the greatest dislocation at the southern edge of the Quadrangle, where it is nearly or quite 300 feet.

Fault No. 63. This fault is limited by faults 64 and 65, and although it is a short fault less than one and one-half miles in length, it is essentially parallel with the major faulting of the region, its direction being N.35°E.

Fault No. 64. This fault intersects the eastern boundary of the Quadrangle a little more than one-half mile north of its southeastern corner, and crosses the Quadrangle with a course S.65°W., which is much more nearly east and west than most of the longer faults of the district. Its length in the quadrangle is about one and one-half miles, but its extent beyond the Quadrangle is unknown. The amount of dislocation along this fault is not certainly determinable from the data available within the Golconda Quadrangle, because it has not been possible to determine with entire satisfaction which of the Chester sandstones constitutes the block which occupies most of the south side of the fault. It can be assumed with little doubt that the downthrow is on the north, and the amount of dislocation must differ considerably from place to place for three different fault blocks are adjacent to it on the north within its short extent in the Golconda Quadrangle.

Fault No. 65. The direction of this fault is N.15°E., its length within the Golconda Quadrangle being about one and one-fourth miles. Its southern termination is against fault No. 64, and from this point it has been traced in a northeast direction to the point where it crosses the eastern boundary of the Golconda Quadrangle. The downthrow is on the west side, but the amount of dislocation varies because of the faulting of the block lying west of the fault brings a number of different Chester formations against the Fredonia limestone which lies to the east. Near its southern extremity the dislocation is about 150 feet, in its middle part 700 feet or more, and in the more northern part of its course about 550 feet.

There has been some mining along this fault a little over one-half mile southwest of Salem, but the mine is not in operation at this time.

Fault No. 66. This is a short fault which transects the triangular block bounded by faults 64, 65, and 63. It cuts off the northern extremity of the block mentioned and forms a smaller triangular mass which has been more deeply downdropped than any of the surrounding segments.

Fault No. 67. The course of this fault is about N.30°E. It crosses the southern border of the Quadrangle about one-half mile west of the southeastern corner, and terminates at fault No. 64. Its length within the Quadrangle is but little more than one-half mile, but its extent to the southeast is unknown. The downthrow is on the west, bringing the Chester sandstone in the block south of fault No. 64 into fault contact with the Fredonia limestone on the east. The amount of dislocation is not determinable here because the age of the sandstone west of the fault is uncertain.

The End.

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