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CHAMPLAINIAN SERIES (MIDDLE ORDOVICIAN) IN ILLINOIS

J. S. Templeton

H. B. Willman

BULLETIN 89

ILLINOIS STATE GEOLOGICAL SURVEY

JOHN C. FRYE, *Chief*

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Topographic Mapping in cooperation with the United States Geological Survey.

August 1, 1962

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CHAMPLAINIAN (MIDDLE ORDOVICIAN) SERIES IN ILLINOIS

J. S. Templeton and H. B. Willman

ABSTRACT

The Champlainian (Middle Ordovician) rocks of Illinois consist of a large number of widely distributed rock-stratigraphic units, some of which have not been previously described. In this study many of the formations and members were traced by lithologic criteria, supported in most cases by faunal evidence, from the Mississippi Valley east to New York, west to Colorado, north to Manitoba, and south to Tennessee. Conditions of sedimentation during the Champlainian were remarkably uniform over much of the stable interior part of the continent.

Regional correlations of Champlainian strata in the past have been based essentially on fossils. The continuity of distinctive rock units and the fact that their boundaries are parallel to bentonite beds show that many of the boundaries are essentially isochronous and that the units are essentially time-stratigraphic. Lithologic tracing, based on matching of sequences, offers promise of more detailed correlation than presently is possible by fossil identification. The vertical variations in argillaceous content that distinguish successive units persist through regional changes in gross lithology, even into the greatly thickened sequences at the margin of the Appalachian geosyncline.

This report suggests major changes in commonly accepted correlations. The Maquoketa Shale Group of the Mississippi Valley represents most of the Cincinnatian instead of the Richmond alone, as was thought previously. The continuity of both basal Cincinnatian and uppermost Champlainian (Trentonian) strata suggests that (1) the Upper Utica (Collingwood-Gloucester) beds of New York should be assigned to the Cincinnatian, and (2) the northern and western limestones—Red River, Bighorn, Fremont, Montoya—are not all Richmondian as commonly identified. The latter formations are mostly Trentonian with some Blackriveran beds at the base and Cincinnatian strata, probably Edenian and Maysvillian as well as Richmondian, at the top. This largely eliminates the prominent gap on the Ordovician correlation chart (Twenhofel et al., 1954) that shows lower and middle Cincinnatian strata missing north and west of the Cincinnati Arch but a complete Cincinnatian sequence on top of the arch.

Our correlations suggest that the position of the Trentonian-Blackriveran boundary has been placed, particularly in recent years, too low in Pennsylvania, Kentucky, and states farther south. The suggested continuity of Pamelia, Lincolnshire, Murfreesboro, Dutchtown, and McLish strata would return to the Blackriveran Stage the sequences on which Cooper (1956) based two new stages between the Chazyan and Blackriveran. St. Peter, Dutchtown, Joachim, and Glenwood strata are represented in the Pamelia of New York and, therefore, are assigned to the Blackriveran rather than the Chazyan.

Changes in correlations, changes of rank to permit finer subdivision, and changes in classification practice have resulted in extensive modification of the existing classification of Champlainian rocks in Illinois. In the revised rock-stratigraphic classification presented here, four groups are recognized. The Everton Group, at the base, previously had been considered a formation. The new Ancell Group includes St. Peter, Dutchtown, and Joachim strata in southern Illinois and St. Peter and Glenwood strata in northern Illinois. The Platteville Group includes the strata previously included in the Platteville Formation in northern Illinois (except for type Spechts Ferry strata) and strata previously included in the Plattin and the upper part of the Joachim in southern Illinois. The Galena Group includes the strata previously classified as Spechts Ferry, Decorah, and Galena in northern Illinois and the Decorah and Kimmswick of southern Illinois. The groups are divided into a number of subgroups, formations, and members.

The Everton Group is thought to be equivalent to the Chazy Group of New York. The Ancell and Platteville Groups are equivalent to the Black River Group of New York, and the Galena Group is equivalent to the Trenton Group of New York, excluding Collingwood and Gloucester strata.

The Chazyan rocks, previously treated as a series in Illinois, are changed to a stage in the Champlainian Series. The name Canadian Series is accepted for the Lower Ordovician rocks, and the Prairie du Chien Series is made a provincial group of the Upper Mississippi Valley. In the Upper Ordovician (Cincinnatian) Series, the Maquoketa is made a group with five formations.

INTRODUCTION

The Champlainian Series forms the surface bedrock of a large area in northern Illinois, crops out in three limited areas in southwestern Illinois, and underlies the entire Illinois Basin (fig. 1). During the past 15 to 20 years an intensive study of these strata has been made in connection with quadrangle mapping, prospecting for lead and zinc deposits, and evaluating limestone and dolomite resources. The economic objectives have required accurate identification of stratigraphic position for both structural determinations and studies of lateral variations. As the existing classification was part lithologic, part faunal, and generally too gross for effective use, the need for a more detailed lithologic differentiation was apparent.

Although the Champlainian rocks of Illinois have received most attention, regional knowledge was needed to establish an Illinois classification that would be in harmony with the stratigraphy of adjacent states and of the New York section, commonly considered the standard of reference. Accordingly, detailed studies were made of selected exposures in Colorado, Indiana, Iowa, Kentucky, Michigan, Minnesota, Missouri, New York, Ontario, Tennessee, and Virginia (fig. 26).

Many individual lithologic units of the Mississippi Valley were recognized in other regions, and their continuity indicates that Champlainian sedimentation was amazingly uniform over wide areas. The persistence of relatively thin units is similar to that long recognized in the Pennsylvanian System, differing only in that the change in lithology between successive units is less conspicuous than that of the Pennsylvanian.

Regional changes in facies in the Champlainian generally are gradual, and most of the lithologic units can be followed from one gross facies into another. Where lithologic units are extensively missing, their absence generally results from regional diastems or unconformities rather than from lateral gradation. Changes in sedimentation between successive units generally are sharp and appear to have extended rapidly throughout the region. The contacts between most of the lithologic units are parallel to thin beds of bentonite and are essentially time planes.

The purpose of this report is to summarize the revised classification for the Champlainian Series in Illinois (fig. 2). Changes also are made in the classifications of both the overlying and underlying Ordovician series, but those sequences are not fully described.

J. S. Templeton led the study of the Platteville, Ancell, and Everton Groups and H. B. Willman the study of the Galena Group. The fossil identifications and discussions of the faunas are by Templeton. The authors have worked jointly on all aspects of the classification and the regional correlations.

As part of this general study of the Champlainian strata of Illinois, the late Paul Herbert, Jr., studied the Decorah strata in outcrop and subsurface between Decorah, Iowa, and southern Illinois. He submitted a doctoral thesis, the "Stratigraphy of the Decorah Formation in Western Illinois," to the University of Chicago in 1949. Data on the Spechts Ferry, Kings Lake, Guttenberg, and Ion strata in Illinois are taken from his thesis. He also took part in the preliminary studies of the higher Galena strata. The authors of this report are responsible for the

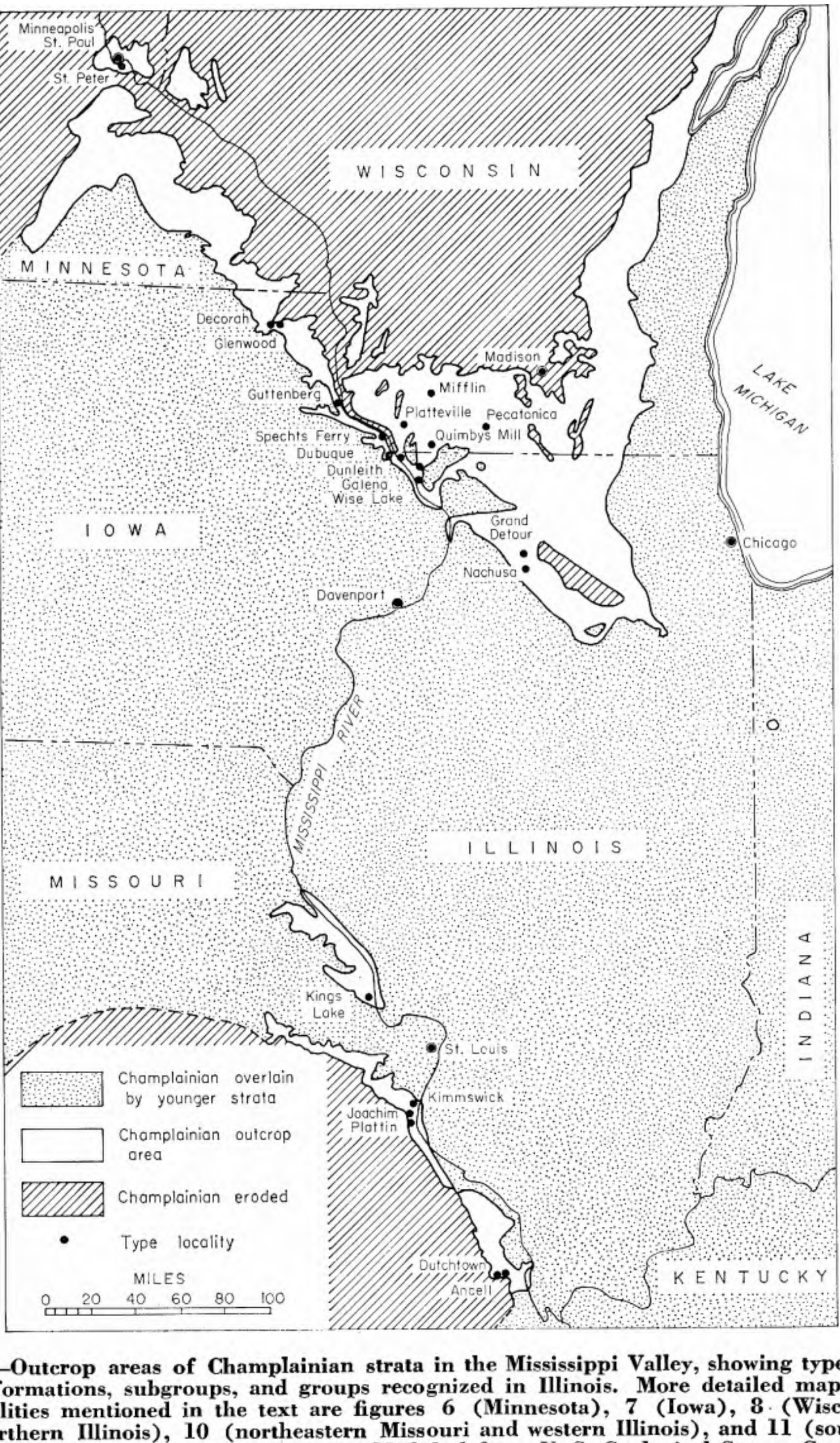

FIG. 1.—Outcrop areas of Champlainian strata in the Mississippi Valley, showing type localities of formations, subgroups, and groups recognized in Illinois. More detailed maps showing localities mentioned in the text are figures 6 (Minnesota), 7 (Iowa), 8 (Wisconsin), 9 (northern Illinois), 10 (northeastern Missouri and western Illinois), and 11 (southeastern Missouri and southwestern Illinois). Modified from U. S. Geological Survey Geologic Map of the United States.

SER.	STAGE	MEGA-GROUP	GROUP	SUB-GROUP	FORMATION	MEMBER	
CINCINNATIAN	Richmondian		Maquoketa		Neda		
					Brainard		
					Fort Atkinson		
	Maysvillian				Scales *	Clermont Elgin	Orchard Creek Thebes
	Edenian	Ottawa			Cape *1		
CHAMPLAINIAN	Trentonian		Galena		Dubuque		
				Kimmswick	Wise Lake *2	Stewartville Sinsinawa *2	
					Dunleith *2	Wyota *2 Wall *2 Sherwood *2 Rivoli *2 Mortimer *2 Fairplay *2 Eagle Point *2 Beecher *2 St. James *2 Buckhorn *2	New London * Moredock *
				Decorah	Guttenberg	Glenhaven *2 Garnavillo *2	
					Kings Lake *3	Tyson * Mincke *	
					Spechts Ferry	Glencoe * Castlewood *	
	Black-riveran		Platteville	Plattin	Quimbys Mill	Strawbridge *2 Shullsburg *2 Hazel Green *2	
					Nachusa *2	Everett *2 Elm *2 Eldena *2	
					Grand Detour *	Forreston *2 Victory *2 Hely *2 Clement *2 Stillman *2 Walgreen *2 Dement *2	
					Mifflin	Briton *2 Hazelwood *2 Establishment *2 Brickeys *2 Blomeyer *4	
					Pecatonica	Oglesby *2 Medusa *2 New Glarus *2 Dane *2 Chana *2 Hennepin *2	
↓	↓	↓					

				NORTH		SOUTH	
SER.	STAGE	MEGA-GROUP	GROUP	FORMATION	MEMBER	FORMATION	MEMBER
↑ CHAMPLAINIAN	↑ Black-riveran	↑ Ottawa	Ancell *	Glenwood	Harmony Hill *2	Joachim	Metz * Matson * Defiance * Boles * Augusta * Abernathy *
					Loughridge *2 (Nokomis *)		
					Daysville *2 (Nokomis *)		
					Kingdom *2 (Nokomis *)	Dutchtown	Sharpsboro * Gordonville
				St. Peter	Starved Rock * Tonti * Kress	St. Peter	Starved Rock* Tonti * Kress
	Chazyan	Knox	Everton	(absent)			
CANADIAN			Prairie du Chien (North)	Shakopee		Powell	
						Cotter	
						Jefferson City	
				New Richmond		Roubidoux	
				Oneota		Gasconade	
						Van Buren	
		↓		Gunter		Gunter	

* New name
1 Name formally introduced in this report, but cited by Gutstadt (1958 a)
2 Name formally introduced in this report, but used in guidebook (Templeton and Willman, 1952) and cited in several publications.
3 Name from manuscript of Paul Herbert, Jr. (1949)
4 Called Boarman in guidebook. Boarman is abandoned.

FIG. 2.—Classification of the Ordovician System in Illinois.

classification and the regional correlations of the Decorah equivalents, except for the differentiation and naming of the Kings Lake Formation.

The present report was essentially completed when Dr. Templeton died on April 21, 1953. In the final revision of the report no major changes in interpretations have been introduced. However, certain changes in the classification to be used in Illinois have been made to conform to a new stratigraphic policy (Willman et al., 1958), and references to many of the more important recent publications have been added. A few names have been added to the sequences compiled for the various areas visited outside of Illinois, but no changes either in the sequences or regional correlations have been necessary.

The major additions relate to two publications that deal primarily with regional correlation problems. The Ordovician correlation chart, prepared by a committee of the National Research Council, with W. H. Twenhofel as chairman (Twenhofel et al., 1954), contains an introduction by Carl O. Dunbar clearly summarizing many of the problems, a critical discussion of British-American correlations by Harry B. Whittington, and annotated contributions from numerous regional specialists. The chart can be assumed to express a broad cross section of opinion on correlations, but, in view of the numerous compromises that are necessary to produce such a compilation, it seems only fair to credit the authors of the individual columns for the nomenclature of their respective sequences but not to hold them entirely responsible for the correlations with other regions. For this reason the correlations are all referred to Twenhofel et al.

The second major study of regional correlations is that of G. A. Cooper (1956), which is based primarily on brachiopod faunas from all the Champlainian strata except the upper Trentonian.

The correlations in these two reports differ from each other perhaps as much as from ours. As the three correlations represent somewhat different approaches, a detailed comparison has been made. The Cooper and Twenhofel correlations have been added to several of our charts to call attention to the differing viewpoints.

Many of the stratigraphic names and some of the regional correlations introduced in this study were used in a mimeographed guidebook prepared for the 16th annual field conference of the Tri-State Geological Society at Dixon, Illinois, in 1952 (Templeton and Willman, 1952). We did not regard the guidebook as an official publication, and it contained a statement that the new names were not formally introduced. However, several of the names have been used in a number of publications. The entire list of names was included in *Geologic Names of North America Introduced in 1936-1955* (U. S. Geological Survey Bulletin 1056-A) and in *Index to the Geologic Names of North America* (U. S. Geological Survey Bulletin 1056-B). Because of the frequent references to guidebooks, it has become necessary to recognize them as publications, and many of them, in fact, are excellent sources of recent information. However, in the future, the Illinois State Geological Survey will not use new stratigraphic names in guidebooks because of the limited distribution of guidebooks and because they generally are not available in libraries.

In our opinion the names in the Tri-State guidebook were not defined adequately by present-day standards. As their validity, therefore, is open to question, we suggest that the present report be considered the formal introduction of these names. However, for the convenience of those who may disagree, the names used in the guidebook and listed in the U. S. Geological Survey indexes are indicated in figure 2. As anticipated, it has been necessary to change a few names before they were formally introduced.

Acknowledgments

We are indebted to John C. Frye, Chief, M. M. Leighton, Chief Emeritus, and Arthur Bevan, Principal Geologist Emeritus, of the Illinois State Geological Survey for encouragement and support of this project. D. H. Swann, Charles Collinson, George E. Ekblaw, and J. E. Lamar of the Survey staff gave valuable criticism and advice during the progress of the study. The important contribution of Paul Herbert, Jr., has been noted. Herbert D. Glass and William F. Bradley of the Survey staff have made differential thermal analyses and x-ray studies of many Champlainian bentonites and of the clay fractions of several Champlainian formations. Critical reading of the manuscript by Elwood Atherton, T. C. Buschbach, Charles Collinson, Charles A. Ross, June R. P. Ross, D. H. Swann, and M. L. Thompson was particularly helpful.

Discussions of stratigraphic and faunal problems with G. Marshall Kay, Columbia University, and with G. O. Raasch and L. E. Workman, former Survey staff members, have been most helpful. Early in the study, field conferences were held with Allen F. Agnew, Allen V. Heyl, Jr., and C. H. Behre, Jr., of the U. S. Geological Survey, on problems of the Galena Group; with C. A. Bays, consulting geologist and former Illinois Survey staff member, on Platteville-Galena problems; and with E. R. Larson, University of Nevada, on the Plattin Formation of Missouri.

Much helpful information was derived from an Illinois Geological Survey manuscript on the Glenwood Formation by the late Stanley G. Elder. K. Spiroff, Michigan College of Mining and Technology, guided us to Ordovician exposures at Limestone Mountain in northern Michigan. The aid of the Geologic Names Committee of the United States Geological Survey in checking stratigraphic names also is gratefully acknowledged.

METHODS OF CORRELATION

Much of the Champlainian sequence in Illinois consists of hundreds of feet of limestone and dolomite that is so uniform in lithology that it has been differentiated only into thick formations, such as the Galena, Platteville, Plattin, and Joachim. Lithologic differentiation within these units has been lacking or of local application. Accurate correlations have been difficult in a large part of the Upper Mississippi Valley where the best exposures commonly are only 25 to 50 feet high, and where formational boundaries are not exposed in large areas. Our problem was to find traceable characteristics that would permit accurate identification of the position of many limited and scattered exposures.

The correlations presented in this study are based on conventional methods of field study—the matching of detailed lithologic and faunal sequences combined with the tracing of key beds. In some parts of the sequence lithologic units can be recognized readily. In other parts identifications became apparent only after detailed graphic strips on a scale of a quarter of an inch or half an inch to the foot were drawn and compared. If correlations still were not sufficiently definite, the sections were revisited and studied in greater detail and any intervening exposures were carefully examined. In some cases the procedure was repeated many times. Generally it was possible, by finer and finer "splitting" of units, to establish almost bed-by-bed correlation between exposures. As correlation proceeded, the lithologic units and faunal zones that have regional continuity were recognized and the directions of facies change were established.

Insoluble residues, heavy minerals, clay minerals, and etched surfaces were studied, but such data generally are not required. The insoluble residues seldom reveal differences that cannot be observed by study of the textures and residues exposed on moderately weathered surfaces. Some units are indistinct on fresh rock faces, and for such exposures microscopic examination of the textures of closely spaced samples may be helpful. Most units can be recognized in well cutttings, and subsurface tracing is especially valuable if samples have been collected accurately at closely spaced intervals.

Thin sections also have been found useful in differentiating and correlating stratigraphic units in this sequence (Ziemba, 1955; Carozzi, 1956; Wanless et al., 1957), but we did not use them because field characteristics provided an adequate basis for differentiation.

In part of the predominantly carbonate sections in the Silurian System of Illinois thin units differentiated by slight variations in lithology also have extensive lateral continuity. However, regional tracing is not effective in beds in which the lateral change is great and exposures are too far apart. It has its limitations in thick sequences of detrital limestones in which lenticular relations locally are prominent. Sequences traceable regionally disappear in the immediate vicinity of reefs where lateral changes are great. However, in both situations the tracing of minor units yields much information about conditions of sedimentation, sources of sediments, and the relative ages of reefs, bars, and other features.

The supposition that profound and numerous lateral changes in facies exist in the Champlainian sequence generally has discouraged attempts to trace minor lithologic units and to make long-range lithologic correlations, particularly in regions of scattered outcrops such as the Middle West. Such ideas appear to be based principally on miscorrelations but also may be due to variations related to intermittent movement of local structures. The predominantly lithologic method used in this study is effective only because of great uniformity of sequences, gradual changes in facies, and the continuity of many distinctive units. Our results suggest that by intensive matching of lithologic sequences, in both wells and outcrops, much more precise determinations of stratigraphic position should be possible throughout much of the Paleozoic section in the interior stable region and into the marginal parts of the geosynclines.

Lithologic Criteria

To determine criteria important for correlation in dolomite and limestone sequences, study was made of differences in content of clay, silt, sand, and chert, in color, size of crystals or grains, porosity, character of fracture, thickness and nature of bedding, and in the character, number, and thickness of shale partings.

The most important influence on gross carbonate lithology is the content of disseminated clay—the degree of argillaceousness. In general, argillaceous units are finer grained, denser, less dolomitic, and thinner bedded. Strongly argillaceous or shaly facies generally are noncherty, and moderately argillaceous facies usually are more cherty than pure carbonate units. Argillaceous units commonly have a lighter colored, smoother, weathered face, and a fauna differing from that of purer beds. Silty carbonate units generally are similar to argillaceous units except that many are very light colored, are more massive when weathered, and the silt stands out on the weathered surfaces. Weathered faces were studied carefully because they usually show minor changes in argillaceous or siliceous content more clearly than do insoluble residues.

Features that may continue for long distances are bentonites, intraformational conglomerates, calcarenites, chert bands, oolites, pyritic and carbonaceous markings, coquinas, fucoidal layers, prominent bedding-breaks, laminations, cross-bedding, wavy bedding, scour surfaces, corrosion surfaces, unconformities, and beds characterized by phosphatic nodules, worm borings, spores, unicellular algae, and algal domes.

Scour surfaces are undulatory bedding surfaces that cut into the underlying bed and commonly have a relief of a few inches. Corrosion surfaces are deeply pitted bedding-breaks. Both represent minor diastems, but the scour surfaces are caused by current scour and the corrosion surfaces are believed to be caused by solution on the sea floor.

The origin of corrosion surfaces has been discussed by Weiss (1954a; 1957, p. 1052; 1958). He considers them solution features of the intertidal zone. Some are traceable for hundreds of miles, and their wide distribution is an objection to restricting them to the intertidal zone, as is the fact that some of them occur in pure, medium- to thick-bedded limestone and dolomite that does not suggest shallow-water deposition. In places several of these surfaces occur in zones only a few feet thick. We prefer the name corrosion surface for the individual feature rather than corrosion zone used by Weiss and others.

The usefulness of bentonites for regional correlation has been questioned (Miller and Fuller, 1954, p. 130) on the grounds that the ash falls forming the bentonites may be from different volcanoes, that the periods of volcanic activity may not be contemporaneous, and that the distribution of the ash at different times may not necessarily be similar. However, the presence of bentonites as much as an inch thick as far from the potential sources in the Appalachian region as Minnesota and northern Michigan attests to the wide distribution of individual ash falls. The equivalence of these distant deposits to the thicker bentonites of the southwestern Virginia region seems well established by both lithologic and faunal identifications of the enclosing rocks, without reliance on the bentonites themselves.

The greater abundance of bentonites in the geosynclinal region may reflect preservation of minor, more restricted ash falls. On the other hand, bentonites are much more abundant in the Mississippi Valley than generally realized. In addition to the more prominent bentonites in northern Illinois, a 2-inch bed of green shale in the Spechts Ferry Formation locally has three bentonite streaks, each an eighth of an inch or less thick, and a 4-foot interval in the basal Galena in one quarry has seven thin layers of whitish plastic clay, probably all bentonite. If the ash falls come from different volcanoes, there is perhaps some hope of differentiating them by mineralogical characteristics, but the problem is difficult because the original material is greatly altered and actual glass shards are rare, if present, in most deposits in the Mississippi Valley.

In the correlation of sandstones, differences in the clay, silt, and accessory mineral content, in the size, sorting, and rounding of grains, and in the character of the bedding, as well as physical breaks, have proved most useful.

Faunal Criteria

Although no systematic examination of fossils was attempted, detailed studies were made of Platteville faunas in northern Illinois, and all faunal lists available through 1952 have been reviewed.

The fossil names used in this report are those generally accepted in 1952. We have made reference to some recent changes, particularly where attention should be directed to a difference of opinion on identification or classification that affects suggested correlations. A few discontinued fossil names that may be more familiar to many than the present ones are enclosed in brackets. The name *Dalmanella* is used in place of *Resserella,* which is no longer valid for Ordovician species (Cooper, 1956, p. 956), or *Paucicrura,* which is valid but is unfamiliar and not in general use.

Relatively few Champlainian fossils have been found valuable in either local or regional correlations of formations and members. In general, only a profuse species or a characteristic assemblage has proved useful. Studies of the Platteville fauna of northern Illinois indicate that approximately half the species are undescribed. Even for described species the precise vertical range, the effect of environment on range and distribution, and the evolutionary sequence within the genus are not well known. Many species are long ranging and show no variation from bottom to top of even as large a unit as a group. Preliminary results suggest that few if any genera evolved with sufficient rapidity to provide index fossils for the relatively thin lithologic units differentiated in this study.

Regional correlations are complicated by the lateral migration of species and by major differences in the contemporary faunas of different areas. In several instances changes in environment have had a greater apparent effect on the fauna than on the type of sediments. Insufficient paleontologic work has been done in the contact zone of such contemporary faunas to establish detailed correlations.

Ecologic control of long-ranging forms in a given area may produce a faunal succession that is more apparent than real. For example, in the Mississippi Valley the brachiopod genera *Pionodema, Sowerbyella,* and *Dalmanella* are virtually confined, respectively, to Spechts Ferry, Guttenberg, and Buckhorn—St. James (Ion) strata. In Kentucky, Tennessee, and Virginia, however, all three genera are abundant in Curdsville (Spechts Ferry) beds, and *Dalmanella* generally is abundant in both Guttenberg and Buckhorn-St. James equivalents.

Our attempt at regional correlation is based on the belief that accurate tracing of Champlainian lithologies promises closer correlation than can be established at present by fossils. The apparent lack of fossils in great thicknesses of section, the poor preservation of fossils in many units, and the great expenditure of time and high degree of specialization required for modern faunal studies limit our use of fossils in correlation. However, where there is extreme facies change between widely separated exposures, certain species insensitive to such changes may offer the only tool for establishing accurate correlations. This report emphasizes the need for more paleontologic study and, in fact, lays a preliminary groundwork for more effective comparison of faunas.

CLASSIFICATION

The previous Illinois classification of the Champlainian Series (fig. 3) was unsatisfactory from several points of view. The formations and members were too thick and too generalized to be suitable for detailed studies of stratigraphy and mineral resources, and for areal and structural mapping. Many of the units either violated natural lithologic grouping, represented faunal zones alone, or were based on errors in correlation. The classification used different names for the same units in the northern and southern parts of the state, which greatly exaggerated the differences between the sequences in these areas. The classification also failed to correlate readily with classifications in other regions.

The major object of the present study was to develop a rock-stratigraphic classification based on field characteristics and consistent with the degree of differentiation recognized regionally. A framework was needed for the

PREVIOUS CLASSIFICATION IN NORTHERN ILLINOIS			PRESENT CLASSIFICATION						PREV. CLASSIFICATION IN S. ILLINOIS	
SER.	FORMATION	MEMBER	SER.	STAGE	MEGA-GRP.	GROUP	SUB-GRP.	FORMATION	SER.	FORMATION
Mohawkian	Galena	Dubuque	Champlainian	Trentonian	Ottawa	Galena		Dubuque		//////
		Stewartville					Kimmswick	Wise Lake	Mohawkian	Kimmswick
		Prosser						Dunleith		
	Decorah	Ion								
		Guttenberg					Decorah	Guttenberg		Decorah
	Platteville	//////						Kings Lake		
		Spechts Ferry						Spechts Ferry		
				Blackriveran		Platteville	Plattin	Quimbys Mill		Plattin
		Magnolia						Nachusa		
								Grand Detour		
		Mifflin						Mifflin		
		Pecatonica						Pecatonica	Chazyan	
	Glenwood					Ancell		Glenwood / Joachim		Joachim
								Glenwood / Dutchtown		Dutchtown
Chazyan	St. Peter							St. Peter		St. Peter
		//////		Chazyan	Knox	Everton				Everton

FIG. 3.—Comparison of present with previous classification of the Champlainian Series of Illinois. Previous classification is complete; present classification omits members, which are shown in figure 2.

organization of the large and rapidly expanding amount of stratigraphic data. The introduction of a multiple system of stratigraphic classification (Willman et al., 1958) during the late stage of this study has resulted in a few modifications of the classification, particularly those needed to establish clearly the separation of rock- and time-stratigraphic units.

Rock-Stratigraphic Classification

The principal sedimentational feature upon which the revised rock-stratigraphic classification of the Platteville and Galena Groups rests is the cyclic difference in relative argillaceousness, the most persistent and easily recognized of all the criteria noted. It is a feasible basis for classification because each individual unit within a vertical sequence commonly tends to have a characteristic and fairly uniform argillaceous content, and for the most part the changes between contiguous units are sharp. Some units have a gradational contact, but even this generally is characteristic of the specific unit.

The distribution of the argillaceous content appears to indicate relatively uniform conditions of admixture of calcareous and terrigenous sediment throughout a considerable interval of time, followed by a relatively sharp change in these conditions for a short interval represented by the contacts between the units. These variations in argillaceous content, along with regional facies gradations, seem to be related to recurring minor uplifts of land areas bordering the interior seas. Changes in sea level and climate may be major factors in controlling the argillaceous content, but the presence of diastems, evidence of volcanic activity, coarse clastics, and repeated movements along local structural axes all point more directly at diastrophic control, with the effects of climate and depths of seas being corollary.

Because the formations are the fundamental units of rock-stratigraphic classification, and the only units of which a complete sequence is required, maximum attention is given to the selection of formational units. If a unit merits formation rank in one area, we apply the same name to the unit as far as its boundaries can be traced by field methods, even though its gross lithology may change notably. Because of this emphasis on continuity, some units are projected into areas where they are not as distinctive from adjacent units as they are in their type locality. However, when strong and sharply defined facies changes occur and the tracing of formational contacts is uncertain, a different formational classification is established.

The formations recognized in this study are sufficiently distinct from adjacent units to be readily identified by a field stratigrapher. They are thick enough over a considerable area to be practical units for geologic mapping and economic and engineering studies. Nearly all exceed 25 feet in maximum thickness. The thinnest formations are several times thicker in nearby states.

Most of the formations have widely traceable members. We have considered that any subdivision of a formation important enough to be named should be ranked as a member. Most of the members recognized in this study have submembers of wide extent, and even subsubmembers, some of which are important key beds, but we have refrained from naming them in the hope that names will not be necessary.

The bentonites present a special problem and eventually may need formal geographic names as beds. At present they and certain other key beds are identified by position in a member, rather than by the number system used in some states.

The classification of formations into groups is intended to show some similarity in lithology among formations. In a few places in the sequence it has seemed desirable to introduce subgroups to show lithologic similarity on a lesser scale.

Although a complete sequence of formation names is necessary, other units are recognized only as needed. However, if any members are named in a formation, we have found that in most cases a complete sequence of member names is desirable for both field and report descriptions. In a few cases a member of one formation is recognized as a member in another formation in a different

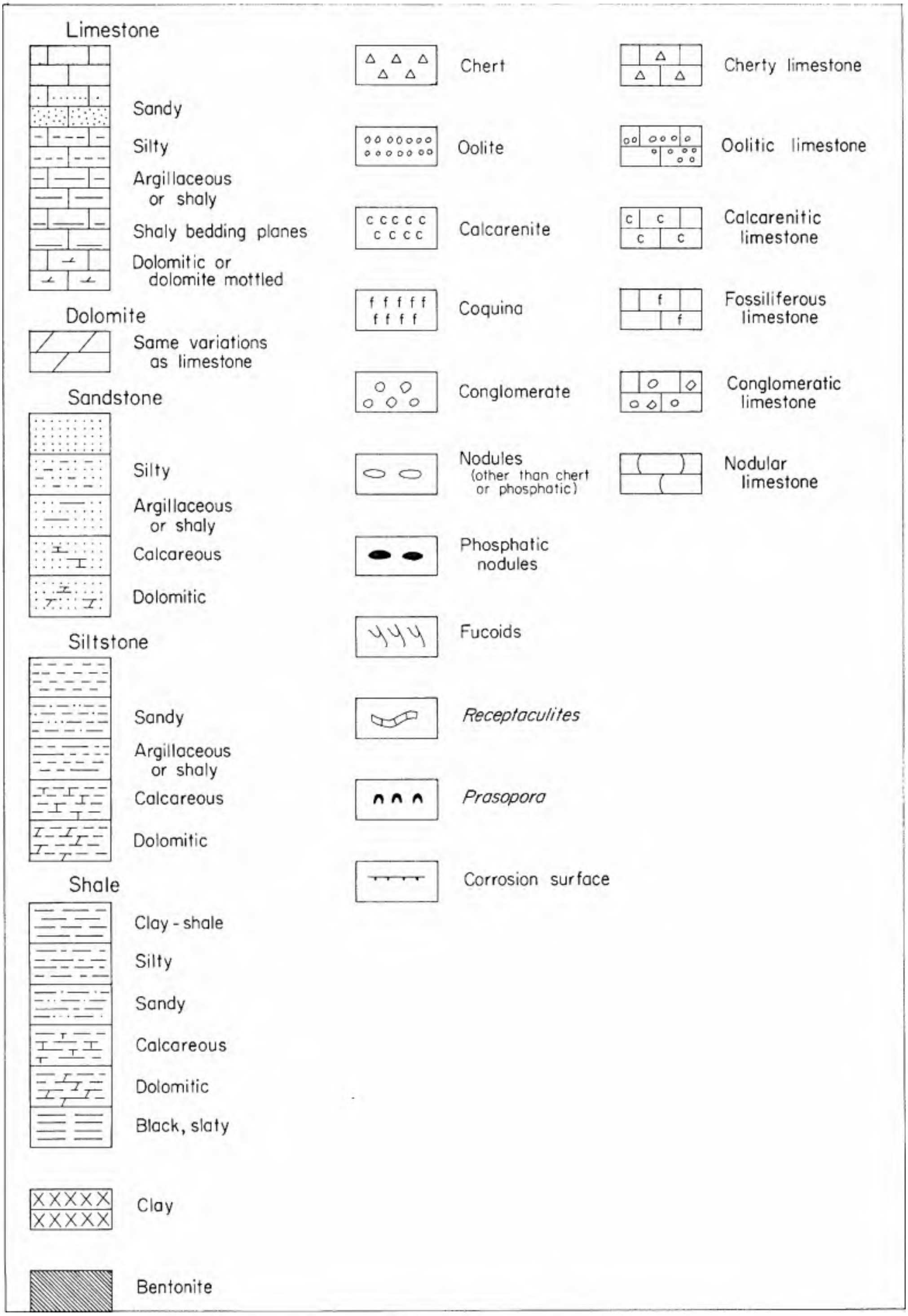

FIG. 4.—Patterns and symbols used in illustrations.

area. Although the ranking of a unit may change in different areas, we avoid the practice within Illinois.

Time-Stratigraphic Classification

The only time-stratigraphic subdivisions of the Champlainian Series recognized in this report are the Chazyan (oldest), Blackriveran, and Trentonian Stages. The regional extent of bentonites within certain members strongly suggests that in the Champlainian Series the formations and members are essentially time units over a wide area. Identification of the rock-stratigraphic sequence, therefore, essentially establishes an age relationship. As time-stratigraphic units smaller than stages would largely parallel the rock-stratigraphic classification and would have to be based on lithologic criteria, they are not needed.

Within the Mississippi Valley the positions of the stage boundaries are traced more effectively by lithologic than by faunal criteria. However, the stages are established on faunal zonation, and the basis for placement of boundary lines should be faunal.

Biostratigraphic Classification

A formal biostratigraphic classification of Champlainian strata is not attempted in this report. The classical zonation of the Minnesota sequence (Sardeson, 1897), based principally on bryozoans, preceded an effective lithologic differentiation and has been widely used. Several faunal assemblages are well known and are usually referred to by the name of the lithologic unit, for instance the Stewartville fauna. The disadvantage of this practice is well illustrated by the Stewartville, which has been redefined in some areas to include a considerable part of the underlying sequence previously included in the Prosser and containing a Prosser fauna. To avoid such confusion the naming of faunas for rock units has been replaced by the use of fossil names for biostratigraphic units. Biostratigraphic classification probably will develop over a period of years. In the transition period, to avoid the appearance of approving the naming of faunas by rock units, we refer to the "fauna of the Stewartville Dolomite." Certain abundance zones, such as the *Pionodema, Dalmanella, Prasopora,* and Lower, Middle, and Upper *Receptaculites* Zones, are mentioned frequently. Although the *Receptaculites* zones appear to be good examples of peak zones, and the "Stewartville fauna" is an assemblage zone, the entire problem of zone designation needs further study, and the term zone is used here without specific assignment to type of zone.

Selection of Names

An attempt has been made to retain long-established names, and when changes consist only of minor shifting of boundaries without violation of the concept upon which the unit was differentiated, redefinition has seemed desirable. When the changes consist of differentiation of new units, or major shifts in the boundaries of old units, new names have been applied. In such cases, redefinition is undesirable because (1) it causes confusion with the previous literature; (2) new classifications commonly are accepted in adjacent areas only after long study, and confusion results from contemporaneous use of names having different meanings; and (3) it implies an over-assurance of permanence that is seldom justified. It is essential to recognize the almost unlimited opportunities for discovery of new evidence bearing on these problems. It may be found that some units differentiated in the past have greater significance than they are thought to have at present, and in such cases the old names can be re-established if not hampered by endless redefinition.

FIELD TERMINOLOGY

Many of the common terms used in field descriptions have had various uses, and a brief statement of the usage in this study follows. Entirely consistent usage of rock terms is not to be expected, but many samples have been checked in the laboratory as control for field usage. Patterns and symbols for various descriptive terms used in the illustrations in this report are shown in figure 4.

The term *lithographic* is applied to limestone or dolomite that has no crystallinity visible to the naked eye. Such rock is dense and commonly has a glassy appearance and a conchoidal fracture. The term is synonymous with the *cryptocrystalline limestone, vaughanite, calcilutite,* and *sub-lithographic* of other writers. Lithographic dolomite is rare.

Calcarenite describes a granular detrital limestone, the fragments of which are mostly in the sand-size grade.

The term *chalky* is applied to very fine-grained, very finely porous limestone or dolomite that resembles chalk or unglazed porcelain.

The terms *fine grained, medium grained,* and so forth, referring to carbonate textures, are intended to have approximately the same size meaning as the equivalent terms in the scale for sand-size clastic rocks.

Pure and *impure* are somewhat objectionable terms but are convenient because no adequate substitute has been found. We cannot assume that the absence of limiting adjectives —silty, sandy, and so forth—will be interpreted to indicate a limestone that is relatively free from noncarbonate materials. Nor is it always practical to apply the specific adjectives defining the type of noncarbonate material present. *Pure* and *impure* are applied most frequently to limestones, dolomites, and sandstones, and are used without precise limitations, like most other field terms. They refer to the presence and amount of finely divided constituents that more or less uniformly dilute the major named components of the rock. They do not refer to well segregated, interbedded, or nodular minor constituents, such as shale or chert. Limestone and dolomite called *pure* contain less than 5 percent (and generally less than 3 percent) of finely divided constituents insoluble in hydrochloric acid. Sandstones called *pure* generally contain less than 10 percent of carbonates, silt, and clay combined, and less than 3 percent clay.

The clastic rocks are classified by grain size, on the basis of the Udden-Wentworth (N.R.C.) scale. The name assigned indicates the grain size in which the median diameter, determined by hand lens examination, falls. The term *claystone* is used only for massive indurated clays which are uncommon. The well bedded indurated clays and silty clays are called shale.

The term *bentonite* is applied to distinctive beds of white to light gray, occasionally yellow or orange, plastic clay. It is used as a broad genetic term for clays that are thought to be derived from volcanic ash. Other names, *metabentonite, potash bentonite, K-bentonite,* and *Ordovician bentonite,* apply to these clays (Allen, 1932; Weaver, 1953). They consist of a mixed-lattice clay mineral and thus differ from the type bentonite of Wyoming that consists largely of montmorillonite. Many samples, including some from all horizons where bentonite is reported, have been checked in Survey laboratories, mainly by R. E. Grim, H. D. Glass, and W. F. Bradley. Exposures of bentonite are too abundant to have analyses made of all occurrences described, but the physical characteristics are distinctive and identifications have been consistently confirmed in the laboratory.

In places the bentonites contain, or are replaced by, beds and lenses of a hard, pink, fine-grained rock identified by x-rays as potash feldspar. The pink beds are believed to have formed from bentonite and are accepted as indicating the presence of bentonite. Weiss (1954b) noted feldspathized shales in Minnesota.

A band of chert nodules is persistent in the bed immediately below a few bentonites, but is much less common than in areas where bentonites are thicker.

The bentonites commonly overlie smooth bedding surfaces that frequently are persistent and recognizable in localities where bentonite is absent. Locally, solution residues or other clays washed into open bedding surfaces resemble bentonites, but they lack lateral continuity. However, some clays may be misidentified as bentonites, and probably many thin bentonites and bentonite mixed with shale or carbonate sediment have been overlooked.

The bedding of sedimentary rocks is described as follows:

Very thin bedded	less than 1 inch thick
Thin bedded	from 1 to 3 inches thick
Medium bedded	more than 3 inches but less than 12 inches thick
Thick bedded	from 1 to 3 feet thick
Very thick bedded	over 3 feet thick

Laminations are abrupt vertical changes in color, texture, or composition that are less than a quarter of an inch apart and that may or may not be accompanied by a bedding break.

Massive is applied to any lithologic unit that has no internal bedding breaks, regardless of the thickness of the unit. Thus a 2-inch limestone layer might be described as massive to distinguish it from adjacent units that are well bedded or laminated.

Unconformity and *diastem* are both used to denote breaks in the sedimentary record. *Unconformity* is used only for those breaks that are believed to result from subaerial exposure. However, we may have breaks produced by extensive marine planation, and if so we do not differentiate them. We suspect that marine planation may be more important in the development of overlaps related directly to the major uplifts than is now recognized.

Diastem is applied to those breaks in the sedimentary record where beds are missing due to lack of sedimentation rather than to erosion. They differ from unconformities in that no withdrawal of the sea is indicated. The recognition of a diastem frequently is based on regional relations, but in many places diastems are marked by lag concentrates that may be rich in phosphatic debris. Minor diastems include bedding-plane surfaces along which a few inches of beds are locally missing because of current scour or because of solution before deposition of the overlying beds. Because of their abundance and minor importance these are not designated diastems in our descriptions. The term is more useful when confined to breaks of more than local importance and to breaks where the absence of members or major parts of members can be demonstrated.

GEOLOGIC SECTIONS AND CORRELATIONS

Summary descriptions of 35 geologic sections which are the type sections of units differentiated and named in this study are given at the end of the report. Figure 41 is an index to these sections. In order to include more than 100 geologic sections of the Champlainian strata, many skeleton descriptions are given, omitting lithologic details. Skeleton sections are practical only because the lithologic units are so persistent that the repetition of detailed descriptions is not needed. Experience has shown that stratigraphers will have no difficulty in identifying the units of the skeleton sections in the field by their general character, thickness, and relation to the top or bottom of the exposure.

In the systematic descriptions that follow, correlations with other states in the Mississippi Valley are discussed with the Illinois sequence. Correlations with the standard section of New York State are mentioned under the description of each formation or member and are discussed more fully under *New York* and *Ontario* in the section *Regional Correlations*. With a few exceptions, correlations with states in other regions are given only under *Regional Correlations*.

Time Stratigraphy of the

ORDOVICIAN SYSTEM

Lapworth, 1879

The Ordovician System in Illinois has long been divided into four series, the Prairie du Chien, Chazyan, Mohawkian, and Cincinnatian (Willman and Payne, 1942, p. 51). However, a three-fold subdivision of the Ordovician (fig. 5), combining the Chazyan and Mohawkian into one series, has received general acceptance, and it more accurately depicts the major time units in the Illinois sequence. Therefore, the Ordovician rocks of Illinois are herein divided into three series for which the names Canadian (oldest), Champlainian, and Cincinnatian Series are accepted.

The use of the names Lower, Middle, and Upper Ordovician Series is discontinued

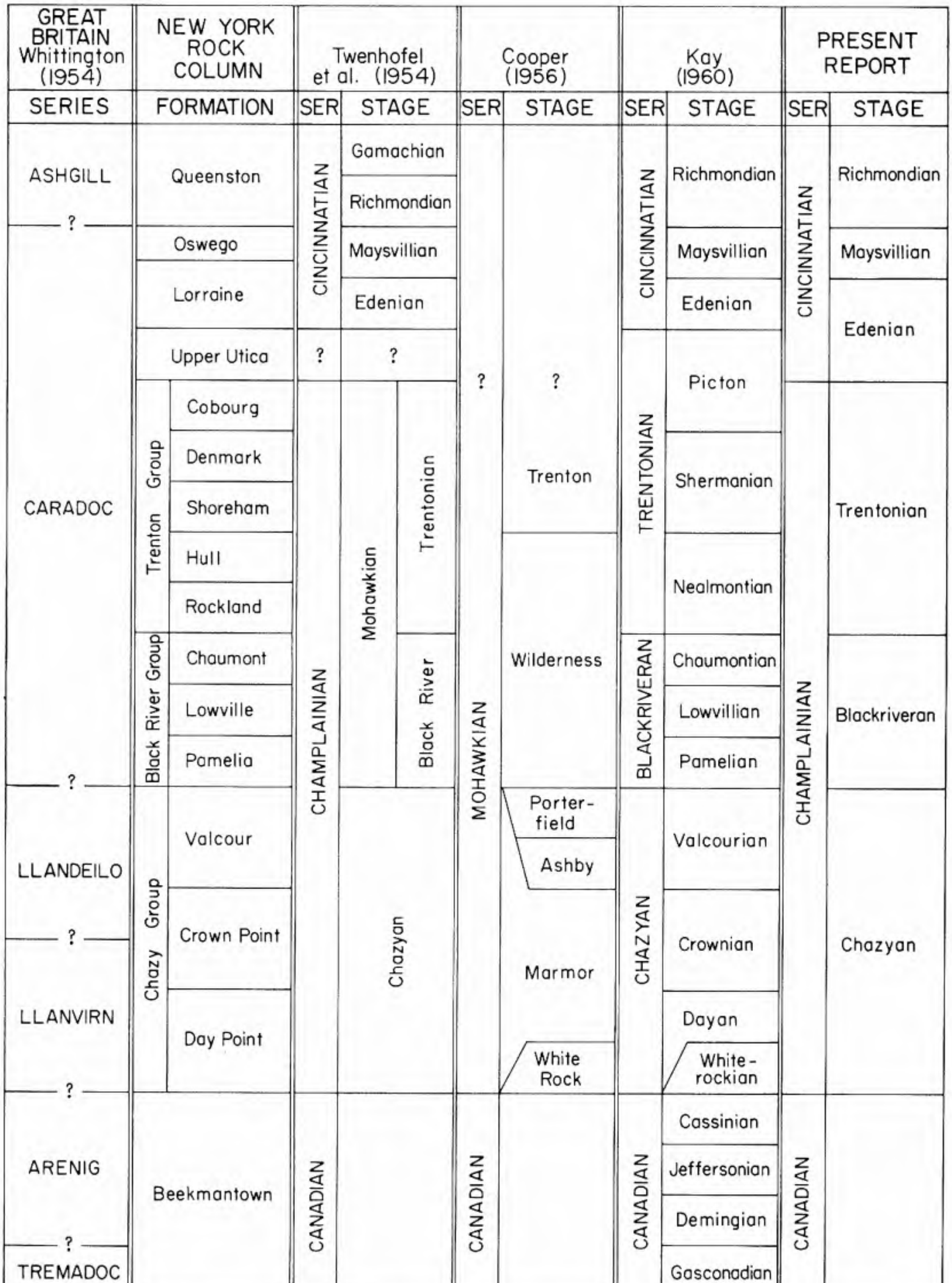

FIG. 5.—Time-stratigraphic classifications of the Ordovician System. (White Rock should be Whiterock.)

except where reference is made to previous usage, or the usage of other authors.

The series classification in the Ordovician in Great Britain (Jones, 1936), based largely on graptolite zones, presently has wide usage. The graptolite zones are used as stages in a three-fold classification that is at least approximately equivalent to that used in this country. The various series classifications used in Europe have been described by Jaanusson (1960). Whittington (*in* Twenhofel et al., 1954) discussed the relations between the European and North American zonation. Berry (1960) suggested a correlation of the graptolite zones with the brachiopod zones of Cooper (1956). Graptolites are too scarce in our dominantly carbonate sequences to be useful for age classification. Until the series based on graptolites are correlated with more common fossils, or a better zonation based on other fossils is produced, it will be difficult to attain world-wide uniformity in series nomenclature.

Kay (1958, 1960) proposed the Chazyan, Blackriveran, and Trentonian be elevated to series rank, but these units do not seem to be equivalent to units ranked as series in other systems.

Although the emphasis in this study has been primarily on the Champlainian strata, the need for revision of the classification in both the Canadian and Cincinnatian Series has become apparent, and certain changes are introduced here. However, systematic description of all the units recognized is confined to the Champlainian, and only new or reclassified units are described in the Canadian and Cincinnatian Series.

Canadian Series

Dana, 1874

In Illinois the lower series of the Ordovician System has been called Prairie du Chien (Bain, 1906, p. 18) and successively classified as a formation, group, and series. As uniformity in usage of series names is particularly desirable, the term Canadian (Dana, 1874, p. 214; Ulrich, 1911, p. 647-680; Wilmarth, 1925, p. 87-88), which has received wide approval for this series (Schuchert, 1943, p. 34-38; Dunbar, 1949, p. 157, 163-165; Moore, 1949, p. 117-118; Twenhofel et al., 1954; Kay, 1960), is accepted. The present usage of Canadian puts the base of the Ordovician at the base of the Gunter Sandstone and differs from the usage of Ulrich who drew the contact between his Canadian System and his underlying Ozarkian System at the base of the Roubidoux (New Richmond) Sandstone in the Mississippi Valley.

The name Beekmantown (Clarke and Schuchert, 1899), or Beekmantownian, also is used for the lower series of the Ordovician (Grabau, 1909; Wilmarth, 1938, p. 145-148; Kay, 1948, fig. 2). However, Canadian has priority as a general name for the lower Ordovician and has been more widely accepted as a series name. Beekmantown is useful as a formation or group name (Wilmarth, 1938, p. 145; Moore, 1949, fig. 84, p. 118).

Flower (1957) tentatively subdivided the Canadian Series into four stages based largely on cephalopod zones. This classification was accepted by Kay (1960), as shown in figure 3, but additional faunal studies are needed to establish the boundaries of the stages in the Illinois sequence.

As the Prairie du Chien includes only the lower part of the Canadian Series, it is returned to its former use as a provincial group name for the Gunter, Oneota, New Richmond, and Shakopee Formations in the Upper Mississippi Valley. The Prairie du Chien is a dominantly dolomitic group. The sandy and argillaceous New Richmond and Gunter Formations cannot always be differentiated, and a rock-stratigraphic name is needed for the entire unit. In large areas where the Prairie du Chien Group cannot be differentiated from the underlying dolomite formations of upper Cambrian age, the entire sequence from the base of the St. Peter Sandstone to the top of the Mt. Simon and Lamotte Sandstones is recognized as the Knox Megagroup (Swann and Willman, 1961). In some areas the Everton is excluded from the Knox.

Champlainian Series
Schuchert and Barrell, 1914

In Illinois the Champlainian Series, named for Lake Champlain, New York, includes strata that unconformably overlie Canadian dolomites and, throughout most of the state, unconformably underlie Cincinnatian shales and limestones (fig. 2). The Champlainian Series in Illinois contains the Everton, Ancell, Platteville, and Galena Groups, in ascending order. The sequence composed of the dominantly carbonate formations in the upper part of the Ancell Group, the Platteville Group, and the Galena Group is recognized as the Ottawa Limestone Megagroup (Swann and Willman, 1961). These strata overlie the St. Peter Sandstone and generally underlie shale of the Maquoketa Group, but in places limestones at the base of the Maquoketa also are included in the megagroup.

The terms Champlainian (Schuchert and Barrell, 1914, p. 16, 25) and Mohawkian (Clarke and Schuchert, 1899, p. 876-877) are both in current use as names for the middle series of Ordovician rocks. The choice of names depends largely on the age assignment of the Chazy Group in New York. The Mohawkian type area does not include the Chazy Group, and the name Mohawkian originally included only Black River and Trenton strata. We prefer the term Champlainian because it does include the Chazy Group. Although Chazyan strata have been placed in the Canadian (Lower Ordovician) Series (Wilmarth, 1938, p. 408), their faunal affinities are with the Middle Ordovician (Raymond, 1906, p. 562), and most stratigraphers regard them as the basal strata of the Middle Ordovician Series (Schuchert, 1943, p. 39-42; Kay, 1948, fig. 2; Dunbar, 1949, p. 166-167; Moore, 1949, p. 118, fig. 84; Oxley, 1951, p. 94; Twenhofel et al., 1954). Cooper (1956) extended Mohawkian to include the Chazyan rocks.

In Illinois both Everton and St. Peter strata previously have been placed in the Chazy "Series," (fig. 3) but the present studies suggest that only the Everton beds are of Chazyan age. In the Mississippi Valley the assignment of Chazyan equivalents to the Champlainian is supported by the presence of a major unconformity between Canadian and Everton strata.

The Champlainian Series is subdivided into the Chazyan (oldest), Blackriveran, and Trentonian Stages (fig. 5). The stages are based on the type sequences of the Chazy, Black River, and Trenton Groups in New York. The same classification is recommended by Twenhofel et al. (1954), except that they object to giving an adjectival ending to Black River, and they retain, without explanation, the term Mohawkian as a stage, embracing the Black River and Trentonian Stages.

Cooper (1956, p. 7-9, and p. 130, chart 1) proposed a classification that retains few of the previously used boundaries for stages, removes the type localities from New York to widely scattered localities, none the same, and introduces almost entirely new names (fig. 5). Cooper accepted Mohawkian for the series name and Trenton for the uppermost stage. He raised the base of the Trenton from the base of the Rockland Formation to the top of the Hull Formation. This redefinition of Trenton is potentially a source of much confusion, and a new name is needed if the classification is accepted. The Trenton Group is not likely to be changed from its present limits to fit the redefined time-stratigraphic unit. The change in boundary is the major reason given by Cooper for the introduction of Wilderness to replace Black River as a stage name.

As noted later in this report *(Regional Correlations—Oklahoma, Tennessee, Virginia)* correlation of McLish, Dutchtown, Murfreesboro, and Lincolnshire with the Pamelia puts in the Blackriveran most of the strata for which Cooper introduces two stages, Porterfield and Ashby, between the Blackriveran and Chazyan. The preliminary nature of our regional correlations, particularly in Oklahoma and Virginia, should be emphasized. Nevertheless, it is difficult to discount many features in the lithologic matching of the sequences. The faunal correlations seem to us to be based on such limited data that they should perhaps be considered equally tentative. However, the stages proposed by Cooper (1956) are defined too inadequately in terms of reference sections and faunal zonation to be used in Illinois at this time.

Kay (1960) elevated the Chazyan, Blackriveran, and Trentonian to series and proposed a stage classification (fig. 5) based largely on the major formational units of the New York sequence. The one name derived from Pennsylvania, Nealmontian, is based on a correlation that seems questionable (see *Regional Correlations—Pennsylvania)*. Ranking these units as stages gives them a higher rank than comparable units have in other systems. We agree that the units on which the stages are based can be traced widely by lithologic criteria and have regional time value, but we doubt that faunal zonation at present is adequate to differentiate these units consistently.

A major point of divergence in the classification is at the top of the Trentonian—the persistent question about the age of the Upper Utica Shale (Deer River and Atwater Creek) of the New York sequence. Twenhofel et al. (1954) assigned these strata to an interval of questionable age between the Champlainian and Cincinnatian. Kay assigned these strata to the Trentonian and in 1960 included them with the Cobourg Limestone in his Picton Stage. We believe that the Upper Utica Shale, via the Collingwood-Gloucester, Bills Creek, and basal Maquoketa, is equivalent to the basal shale of the Eden Group, at the base of the type Cincinnatian (see *Regional Correlations—New York, Michigan, Kentucky,* and *Ontario)*. Kay correlated these strata with the Dubuque (uppermost Galena) Dolomite. Because we consider the Dubuque equivalent to the Hillier Member at the top of the Cobourg Limestone, we place the top of the Trentonian at the top of the Cobourg Limestone, which is the top of the Trenton Limestone, as used by Twenhofel et al. (1954).

Cincinnatian Series

Meek and Worthen, 1865

The Cincinnatian Series, named for exposures in the Cincinnati area, is the uppermost series of the Ordovician System. In Illinois it includes all the strata assigned to the Maquoketa Group. Cincinnatian is the most generally accepted of the Ordovician series names, although its use also has varied (Weiss and Norman, 1960). The position of the basal boundary, the time plane separating the Cincinnatian from the Champlainian, is commonly accepted as being at the base of the Eden Shale. Its position in the Champlainian type area is discussed subsequently under the heading *Champlainian Series*. The upper boundary is the contact with rocks of Silurian age, which in Illinois are generally Edgewood or Kankakee-Sexton Creek (Brassfield) strata of the Alexandrian Series.

The presence of many elements of the type Cincinnatian sequence in the Maquoketa Group is described together with new Maquoketa rock-stratigraphic units, following the description of the rock-stratigraphic classification of the Champlainian. The time-stratigraphic classification based on the Cincinnati sequence (Twenhofel et al., 1954) is accepted (fig. 3), but the lithologic units more closely resemble the Iowa sequence and the Iowa names are accepted for the rock-stratigraphic classification. Largely on the basis of lithologic tracing of a few units and the stratigraphic position of others, we assign the Cape Limestone, the Thebes Sandstone, and Orchard Creek Shale Members of the Scales Formation, and the lower black, dark brown, and gray shales of the Elgin Member of the Scales Formation to the Edenian Stage. The upper lighter colored shale with numerous limestone beds in the Elgin Member is assigned to the Maysvillian Stage. The overlying Clermont Member of the Scales Formation, the Fort Atkinson Limestone, the Brainard Shale, and the Neda Formation are assigned to the Richmondian Stage.

The fauna of the Maquoketa Group in Illinois has not been studied in enough detail to match the faunal zonation in the Cincinnati region. However, the similarity of the faunas of the Waynesville and Fort Atkinson Limestones has been noted (Savage, 1924). Sweet et al. (1959) have correlated Eden and Maysville strata with lower Maquoketa strata by conodonts.

Rock Stratigraphy of the
CHAMPLAINIAN SERIES
Schuchert and Barrell, 1914

In Illinois the Champlainian Series includes strata that unconformably overlie dolomites of Canadian age and, throughout most of the state, unconformably underlie shale and limestone of Cincinnatian age. The Champlainian Series in Illinois contains the Knox and Ottawa Megagroups, and the Everton, Ancell, Platteville, and Galena Groups, in ascending order (fig. 2).

In most of southern Illinois the Everton Group is largely dolomite and is the uppermost part of the Knox Megagroup (Swann and Willman, 1961), but along the extreme western margin of southern Illinois bordering the Ozarks, sandstone units become prominent in the Everton and it is excluded from the Knox. The dominantly sandy units of the Ancell Group are not recognized as a megagroup, but the carbonate formations composing the upper Ancell, Platteville, and Galena Groups are assigned to the Ottawa Megagroup.

Champlainian strata are exposed in the Mississippi Valley in 2 major areas (fig. 1):

1) A northern outcrop area that curves around the southern part of the Wisconsin Arch. Outcrops occur in southeastern Minnesota (fig. 6), northeastern Iowa (fig. 7), southwestern Wisconsin (fig. 8), and northwestern and central northern Illinois (fig. 9).

2) A southern outcrop area in which exposures occur along the Mississippi Valley where it crosses the Lincoln Anticline in Ralls, Pike, and Lincoln Counties, northeastern Missouri, and Calhoun County, Illinois; in the lower Missouri Valley along the north flank of the Ozark Dome (fig. 10); and in the Mississippi Valley along the east flank of the dome south to Thebes, Illinois (fig. 11). In the latter region exposures occur in Illinois only at Valmeyer, Monroe County, and near Thebes.

EVERTON GROUP
Ulrich, 1907

Everton strata were named for the town of Everton, Boone County, northern Arkansas (Ulrich, *in* Purdue, 1907, p. 251-252). Although the Everton was defined as a formation, surface and subsurface data in Missouri and Illinois indicate that it is divisible into two or more units of formational rank, naming of which is withheld pending study of relations to named subdivisions in Arkansas (see *Regional Correlations*). The major divisions (Dake, 1921, p. 15-20; Weller and St. Clair, 1928, p. 91-95) are a lower sandstone unit that grades southward into sandy dolomite and an upper dolomite unit. Fine-grained sandstone overlying the dolomite unit was placed tentatively in the Everton (McQueen, 1937, p. 9, 23-24), but now is believed to be St. Peter. Classification of the Everton as a group is supported by its character in the type area of northern Arkansas, where it consists of three dolomite or limestone units separated by two sandstone units, and is as much as 400 feet thick (Croneis, 1930, p. 23-26; Giles, 1930, p. 113-157, table 2; McKnight, 1935, p. 28-41; Glick and Frezon, 1953).

Distribution.—Everton strata crop out around the flanks of the Ozark Dome in northern Arkansas and eastern Missouri, but are overlapped by younger formations around the remainder of the dome. They thin rapidly northward and eastward, and are missing beyond Knox County, northeastern Missouri (Grohskopf et al., 1939, p. 58-59) and St. Clair County, southwestern Illinois.

Thickness.—The group is over 500 feet thick in southeastern Missouri (McQueen, 1939, p. 67), more than 475 feet thick in a well at Cape Girardeau, Missouri (McQueen, 1937, p. 9), and from 100 to 125 feet thick in wells in Monroe County, Illinois.

Lithology.—The sandstone at the base of the Everton resembles the St. Peter Sandstone, is pure to ferruginous in the north, and becomes dolomite-cemented to the south. It is white to red-brown, fine to coarse grained, but chiefly medium grained, friable to hard, and thin bedded to massive. Some layers are conglomeratic with dolomite fragments or pellets. Locally the sandstone contains thin layers of dolomite or green shale, and in places chert fragments from Canadian strata have been incorporated at the base. Some of the shale layers are waxy and may be bentonitic. The sand grains commonly are better rounded and frosted than those in the underlying Canadian Series and are coarser than those in the overlying St. Peter Sandstone. They probably were derived from dominantly coarse-grained Cambrian sandstones.

The overlying dolomite is gray, chalky to finely crystalline, thin to thick bedded, and is partly argillaceous, sandy, conglomeratic, and shaly. Chert nodules are present in places but are not common. The dolomite contains some shale or sandstone layers and algal reef- structures composed of *Cryptozoon*. Although the dolomite is similar to the underlying upper dolomites of the Canadian Series, it lacks the siliceous oolites and banded or oolitic chert typical of Canadian strata.

The character of the Everton Group is well shown in a bluff just northeast of the village of Rockview, Scott County, Missouri (N line NW SE SE 5, 29N-13E, Morley Quad.), where 40 feet of dolomite overlies 21 feet of dolomitic sandstone.

Fauna.—In Missouri, Everton strata contain algae, worm-borings, mollusks, and ostracodes, most of which are rare, poorly preserved, specifically unidentifiable and not diagnostic. In Arkansas, where the Jasper Limestone appears to be the top formation of the Everton Group, bryozoans, *Lingula,* and trilobites also are present (Purdue and Miser, 1916, p. 6, 8; McKnight, 1935, p. 39-40).

Stratigraphic Relations.—The unconformity between the Everton and the underlying Powell Dolomite (Dake, 1921, p. 15, 41; Weller and St. Clair, 1928, p. 89-95) is continuous with the major unconformity between the Shakopee Dolomite and the St. Peter Sandstone in northern Illinois (Willman and Payne, 1942, p. 61, 193), where the Shakopee is of Jefferson City-Cotter age and where Powell and Everton strata are missing (Workman and Bell, 1948, p. 2059-2060).

An unconformity between Everton and the overlying St. Peter beds is indicated (1) by their sharp contact and by variations in thickness and lithologic sequence (Weller and St. Clair, 1928, p. 95); (2) by northward truncation of the dolomite unit of the Everton (Dake, 1921, p. 16-17, 21-23); (3) by the presence of an angular unconformity between Everton and St. Peter strata in a core from a well near Waterloo, Monroe County, Illinois (Mississippi River Fuel A-2 Kolmer, sec. 2, 2S-10W, Waterloo Quad.), and (4) by the local occurrence of red residual clay suggestive of pre-St. Peter weathering, as at the Everton-St. Peter contact in the bluff 2 miles west of Dutchtown, Missouri (SE SE NE 22 projected, 30N-12E, Cape Girardeau Quad.). This unconformity appears to be of considerably lesser magnitude than the one at the base of the Everton Group.

Correlation.—Subsurface tracing eastward to Virginia, as well as the fauna of the Jasper Limestone, in Arkansas, suggest that the Everton Group is of Chazyan age (see *Regional Correlations—Arkansas* and *Tennessee*). The correlation of the two Everton units found in Illinois with the five units present in Arkansas is not known.

ANCELL GROUP (new)

The Ancell Group (fig. 12) is named for the village of Ancell, Scott County, southeastern Missouri, near which its contacts with the Everton Group below and the Platteville Group above are well exposed. The type exposures are (1) in the north bluff of the lowland southwest of Cape Girardeau, between Everton outcrops 2 miles west of Dutchtown and Pecatonica outcrops at Rock Levee (Cape Girardeau Quad.), and (2) in the south bluff of the same lowland between Ancell and Rockview (Morley Quad.). These exposures are discussed in greater detail under the St. Peter, Dutchtown, and Joachim Formations. Because the beds have

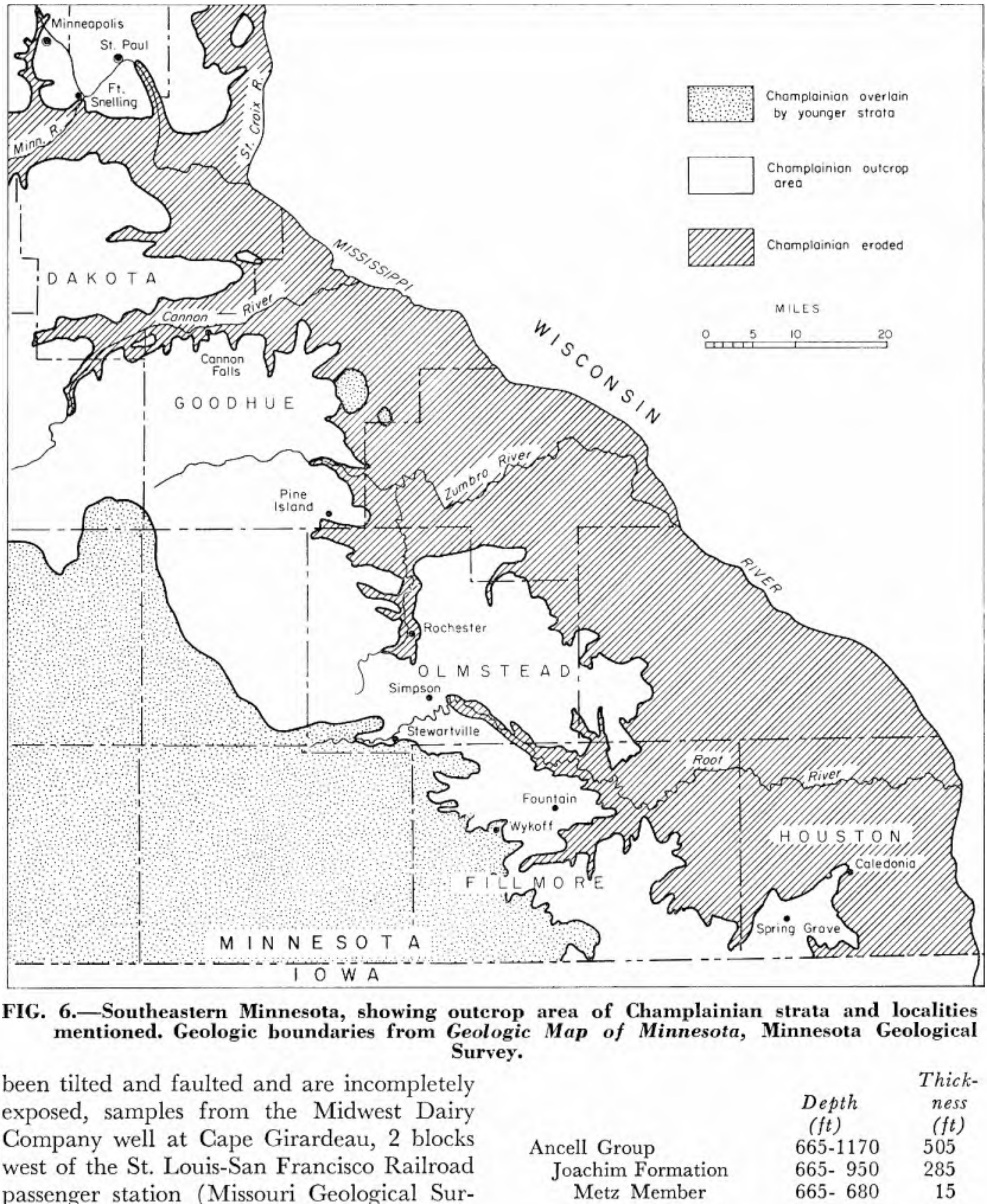

FIG. 6.—Southeastern Minnesota, showing outcrop area of Champlainian strata and localities mentioned. Geologic boundaries from *Geologic Map of Minnesota*, Minnesota Geological Survey.

been tilted and faulted and are incompletely exposed, samples from the Midwest Dairy Company well at Cape Girardeau, 2 blocks west of the St. Louis-San Francisco Railroad passenger station (Missouri Geological Survey Sample Set 6150, Illinois Geological Survey sample set 5248*) supplement the type section. The summary log of the lower portion of this well is as follows:

	Depth (ft)	*Thickness (ft)*
Ancell Group	665-1170	505
Joachim Formation	665- 950	285
Metz Member	665- 680	15
Matson Member	680- 710	30
Defiance Member	710- 750	40
Boles Member	750- 775	25
Augusta Member	775- 869	94
Abernathy Member	869- 950	81
Dutchtown Formation	950-1105	155
Sharpsboro Member	950-1055	105
Gordonville Member	1055-1105	50
St. Peter Formation	1105-1170	65
Everton Group	1170-1200 T.D.	30+

* Hereafter sample set is abbreviated to SS, and all sample set numbers are those of the Illinois Geological Survey, except where noted otherwise.

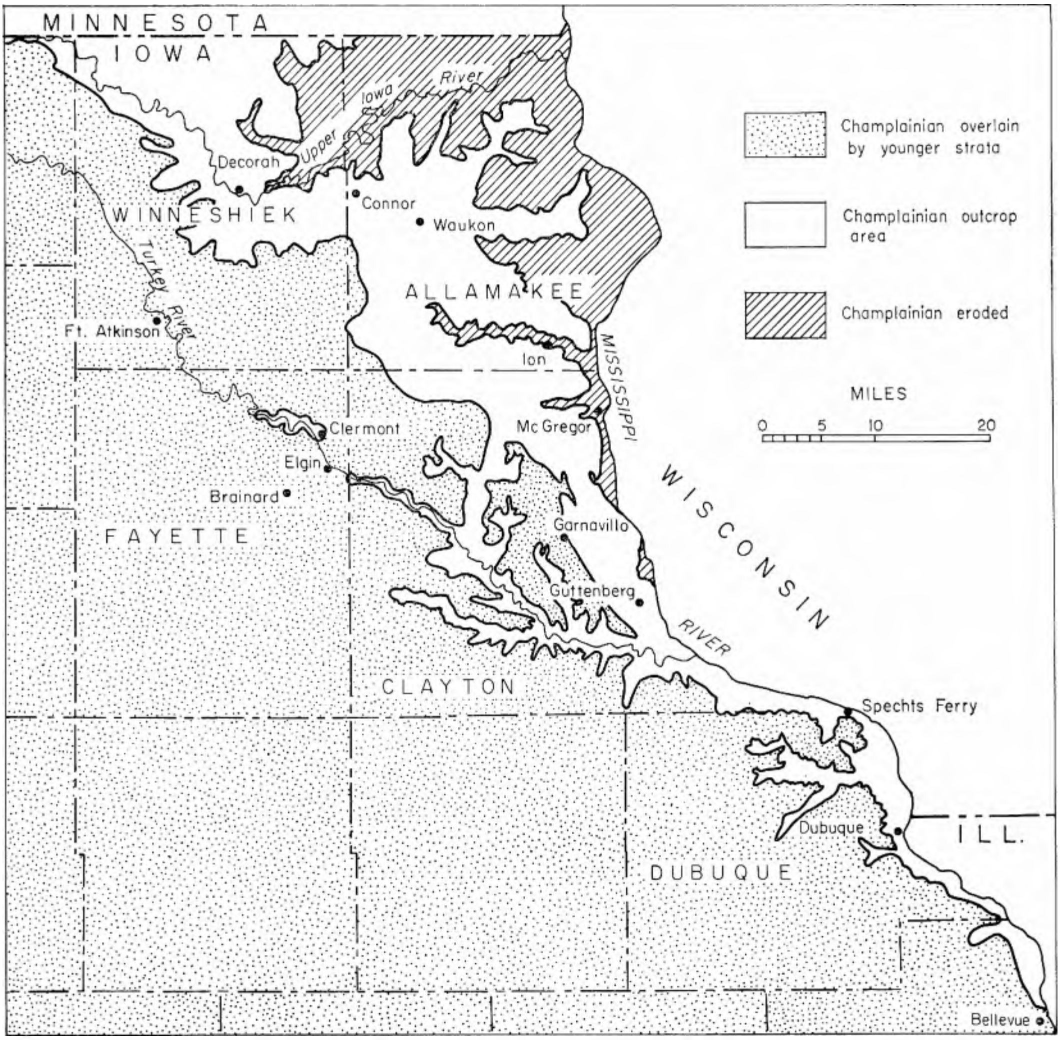

FIG. 7.—Northeastern Iowa, showing outcrop area of Champlainian strata and localities mentioned. Geologic boundaries from *Geologic Map of Iowa,* Iowa Geological Survey.

Ancell strata are considered a group for the following reasons.

1) The sequence consists of sandstones and impure dolomites and limestones, most of which wedge out in various directions and consequently are irregularly distributed.

2) The sequence differs in many lithologic details from the underlying Everton Group and contrasts sharply with the overlying less clastic, much more continuous strata of the Platteville Group.

3) The Ancell Group is bound by unconformities or diastems.

4) Strata of Ancell lithology are present throughout much of the eastern United States. In New York the Pamelia Formation, which is sufficiently distinct from the overlying Lowville Formation to be considered part of a separate group, the Hatterian (Kay, 1948, p. 1400-1409), is equivalent to the Ancell Group.

Distribution and Thickness.—Elements of the northern Illinois sequence are found from Minneapolis, Minnesota, to Scott County, central western Illinois, and from eastern

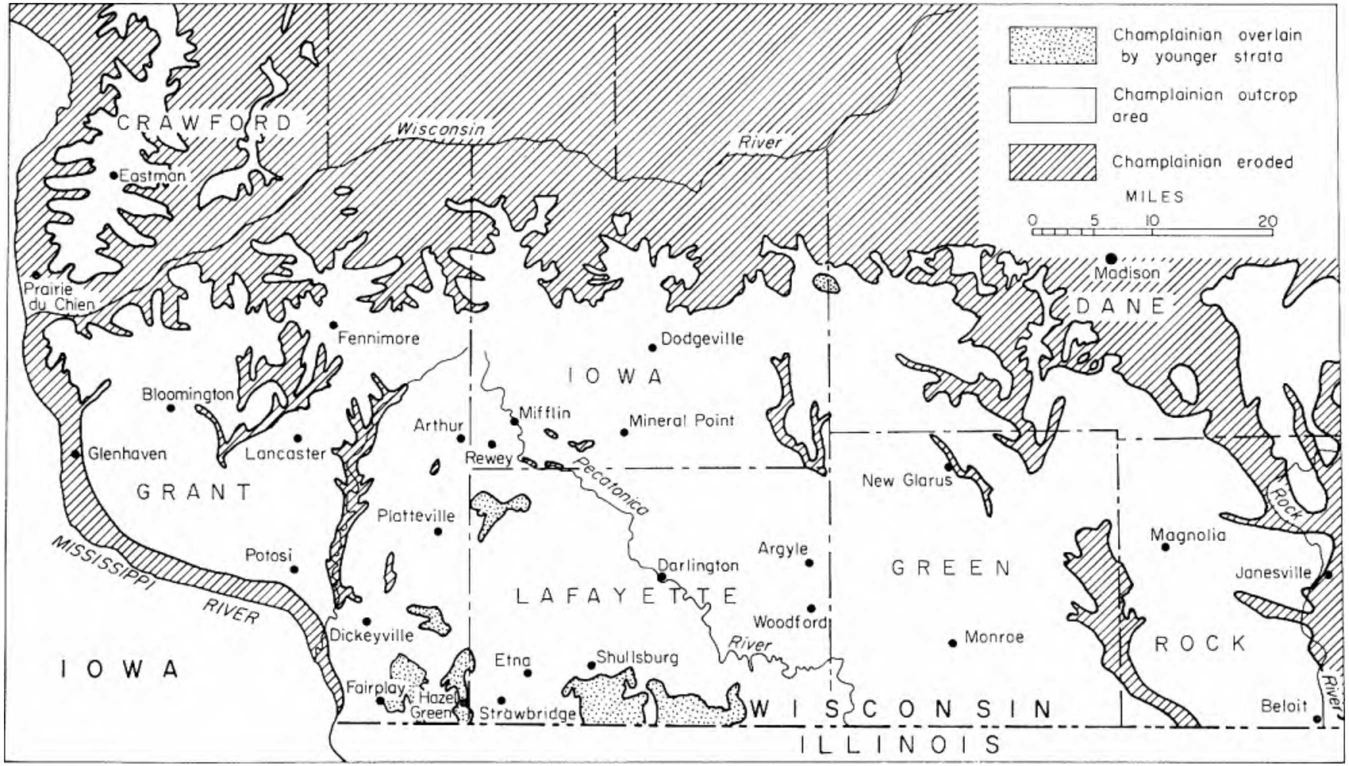

FIG. 8.—Southwestern Wisconsin, showing outcrop area of Champlainian strata and localities mentioned. Geologic boundaries from *Geologic Map of Wisconsin,* Wisconsin Geological and Natural History Survey.

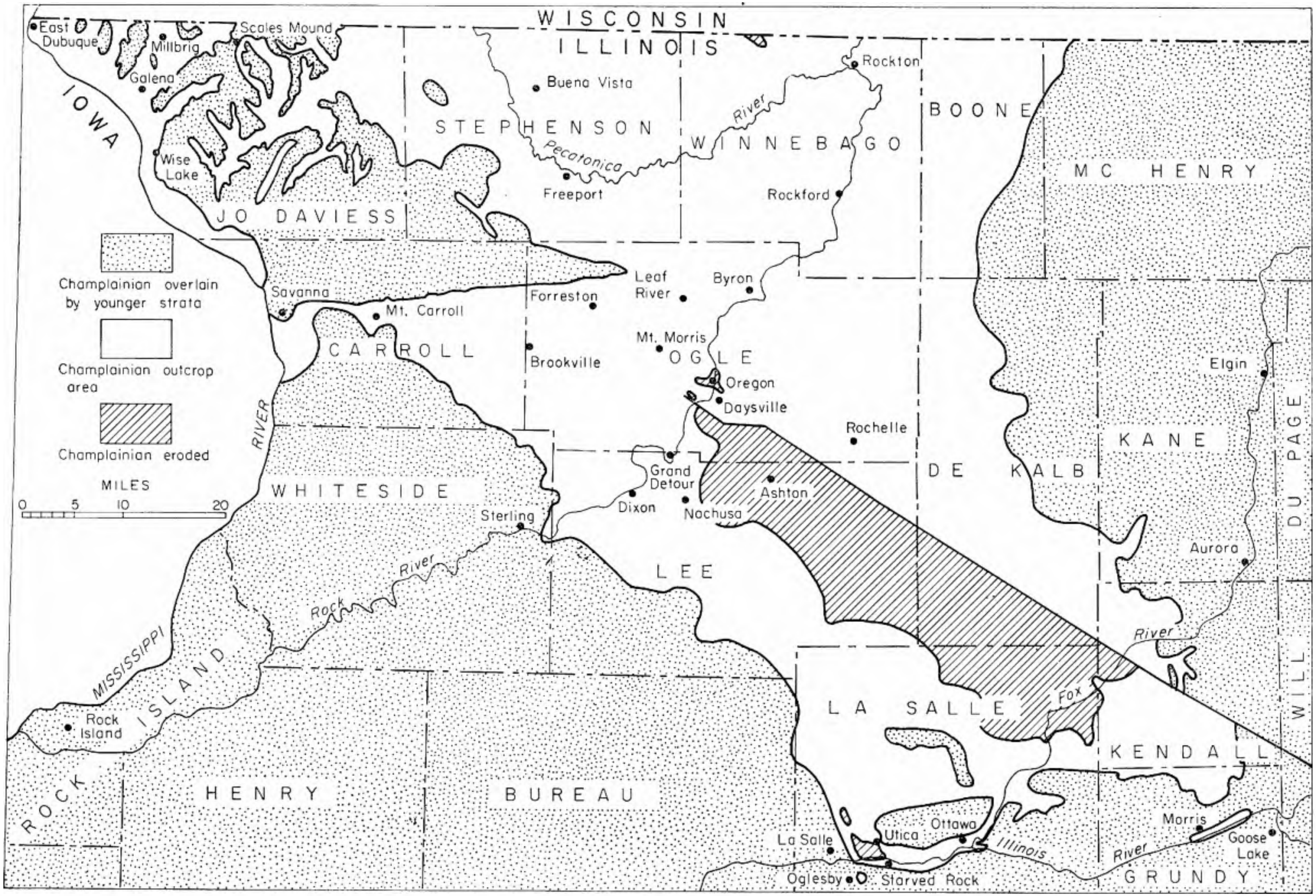

FIG. 9.—Northern Illinois, showing outcrop area of Champlainian strata and localities mentioned. Modified from *Geologic Map of Illinois*, Illinois Geological Survey.

FIG. 10.—Northeastern Missouri and western Illinois, showing outcrop area of Champlainian strata and localities mentioned. Geologic boundaries from geologic maps of Missouri and Illinois published by Missouri Geological Survey and Water Resources and by Illinois Geological Survey.

Nebraska to southern Michigan and possibly to northeastern Ohio. Part of the northern sequence also occurs at Limestone Mountain, Houghton County, upper Michigan. Elements of the southern Illinois sequence extend from southeastern Missouri to northwestern Indiana and eastward to Virginia and New York. The sequences are separated by a broad, irregular belt running from western to northeastern Illinois, within which only the St. Peter Sandstone is present (fig. 13).

Although locally absent in Wisconsin, the Ancell Group is 165 feet thick at Minneapolis, Minnesota, 505 feet thick at Cape Girardeau, Missouri, and a maximum of 640 feet thick at Rochelle, Ogle County, Illinois (Rochelle City No. 6, NE SW NE 25, 40N-1E, Rochelle Quad., SS-7767, 140-780′).

Fauna.—Conodonts, scolecodonts, worm-borings, linguloid brachiopods, gastropods, pelecypods, and ostracodes are found locally in restricted units. Corals, orthid brachiopods,

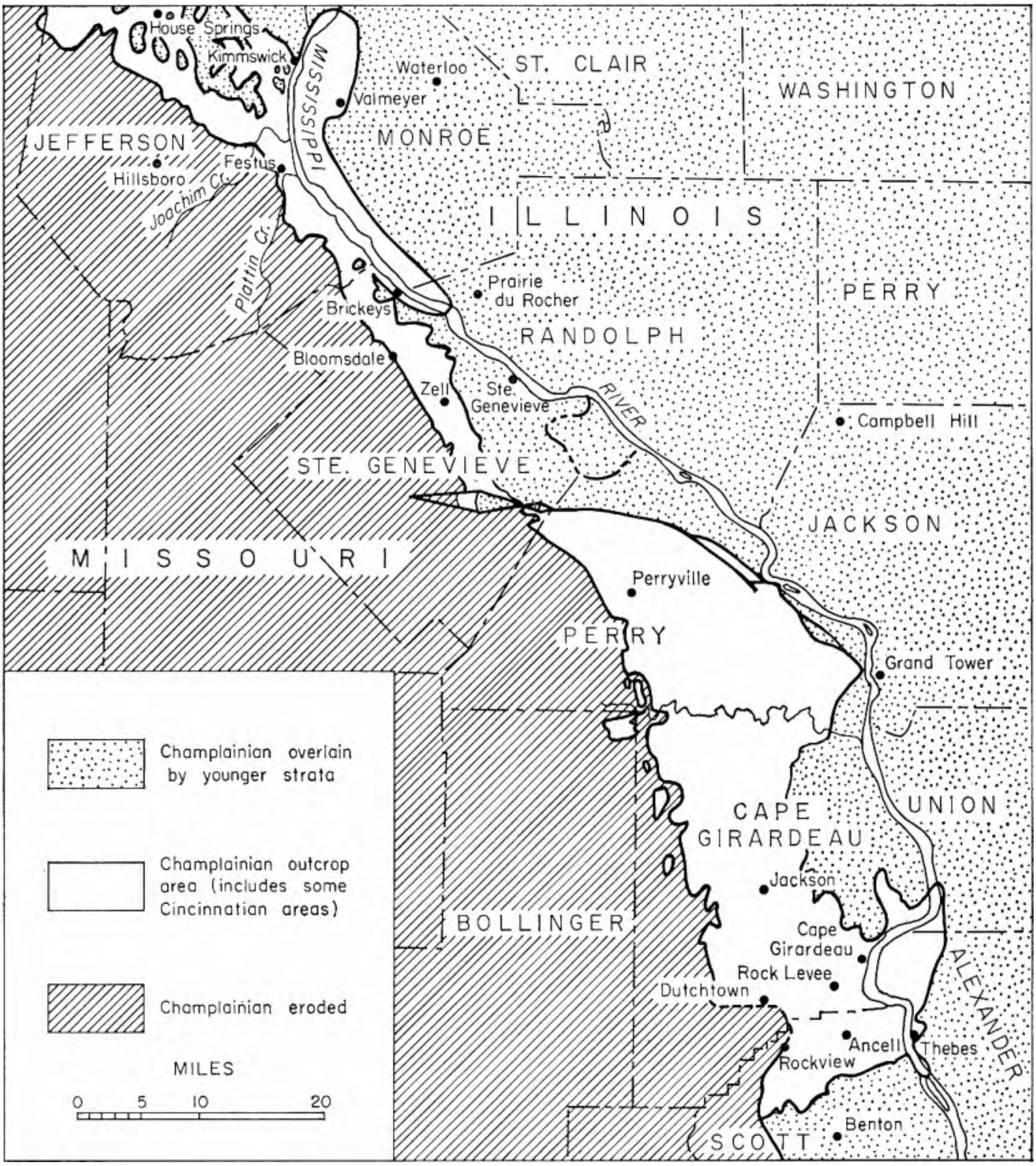

FIG. 11.—Southeastern Missouri and southwestern Illinois, showing outcrop area of Champlainian strata and localities mentioned. Geologic boundaries from geologic maps of Missouri and Illinois published by Missouri Geological Survey and Water Resources and by Illinois Geological Survey.

trilobites, and ostracodes were recovered from the Joachim Formation at one locality in Missouri. However, most Ancell strata probably were deposited either in brackish or in very saline water and do not contain a normal marine fauna.

Correlation.—In Illinois the St. Peter, Dutchtown, and Joachim Formations have been correlated previously with Chazyan strata and the Glenwood Formation with lowermost Mohawkian strata. Their fauna suggests Blackriveran age, and regional trac-

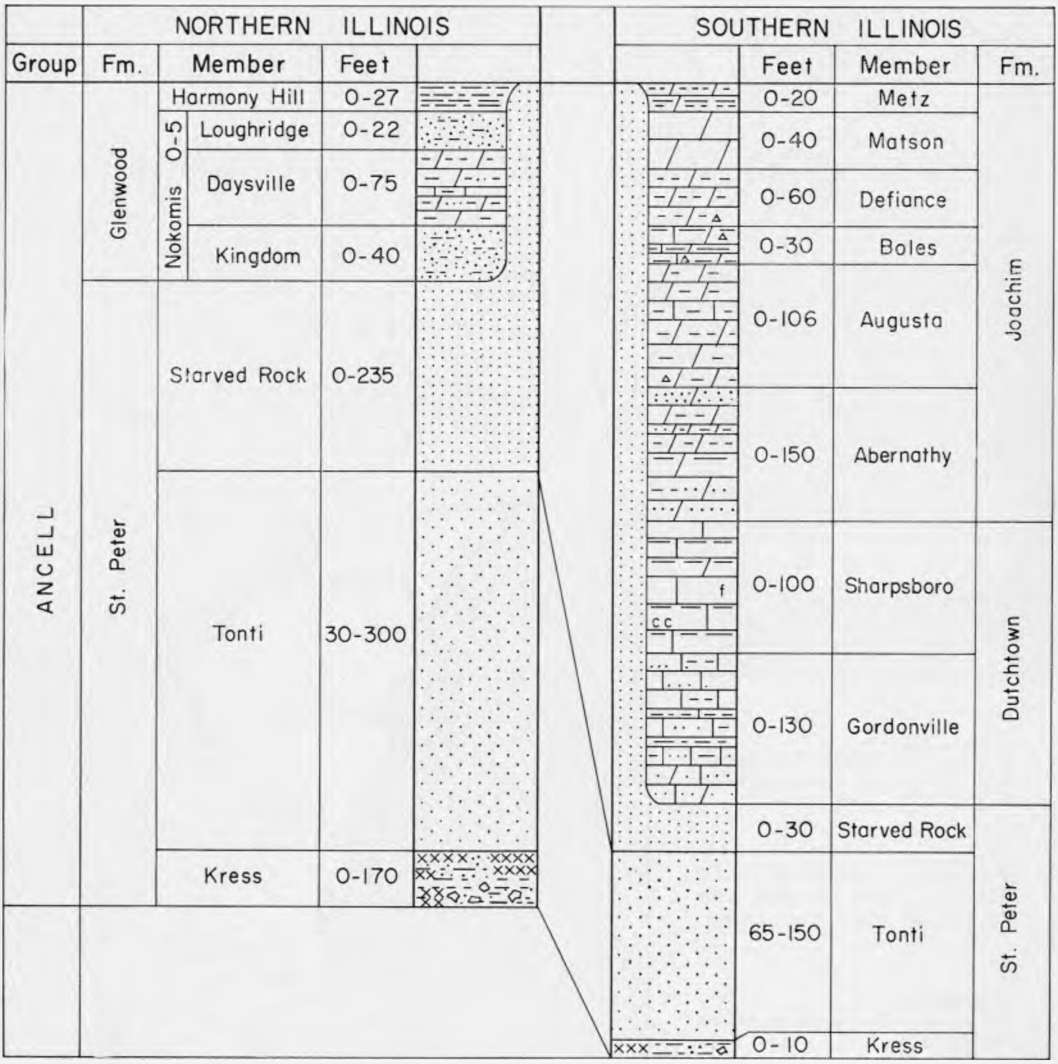

FIG. 12.—Classification of the Ancell Group in Illinois.

ing indicates that Ancell strata are equivalent to the Pamelia Formation of New York, the lowest formation in the Black River Group.

Stratigraphic Relations.—The Ancell Group is unconformable on the Everton Group or older beds and is separated from the overlying Platteville Group by a diastem or unconformity. Within the Ancell Group the various formations and members have more complex relations than do the units of other parts of the Champlainian Series.

Interpretation of the members of the Glenwood Formation as lenticular rock units with only minor facies gradations between them is supported by several observations:

1) The contacts between the members generally are sharp.

2) The Daysville-Loughridge contact locally is erosional.

3) Although scores of outcrops were studied, graduation or interfingering between the members is evident in only one exposure.

4) As the source of the Glenwood clastics probably lay to the north, the widespread presence of the Daysville Dolomite on the north side of the clastic members is difficult to explain if the members are facies.

5) The origin of apparently isolated outliers of the Kingdom, Loughridge, and Harmony Hill Members is difficult to explain by a facies interpretation.

6) Although the complete sequence is found only in Lee and Ogle Counties, northern Illinois, the members maintain the same relative stratigraphic position and character over a wide area.

Evidence that favors a facies relation between the Glenwood members and between the Glenwood and the Starved Rock Member of the St. Peter Formation (fig. 13) includes:

1) Strata with Glenwood lithology have not been recognized in states southeast and east of Illinois, except in southern Michigan and possibly in northeastern Ohio (Cohee, 1945a; 1948, p. 1427), which suggests that the Glenwood sequence grades laterally into beds of different lithology.

2) South of Lee County, northern Illinois, the Harmony Hill, Loughridge, and Daysville Members are replaced abruptly by the Starved Rock Sandstone Member of the St. Peter, but northward the Harmony Hill, Loughridge, and Kingdom Members wedge out rapidly and are replaced by the Daysville Dolomite.

3) Just before the argillaceous Kingdom Sandstone disappears east of LaSalle County, north-central Illinois, and south of Scott County, western Illinois, it develops Starved Rock texture in whole or in part and shows a decrease in silt and clay content.

4) The very fine grain size of the sandstone in the upper Kingdom and lower Loughridge in the area where all four Glenwood members are present suggests transition into the impure dolomite of the Daysville. In eastern Carroll County, Illinois, the Daysville differs from these strata only in being dolomitic.

5) Daysville and Starved Rock strata interfinger in wells at Elgin, northeastern Illinois. The abundance of disseminated sand and of layers of pure well sorted sand in the Daysville near its southern margin also suggests gradation into the Starved Rock.

6) Interfingering of the Loughridge and Starved Rock Sandstones is evident in well cuttings in southern Lee County, Illinois.

7) The lower part of the Harmony Hill Member consists of sandy shale or very argillaceous sandstone, and at Dixon, Lee County,

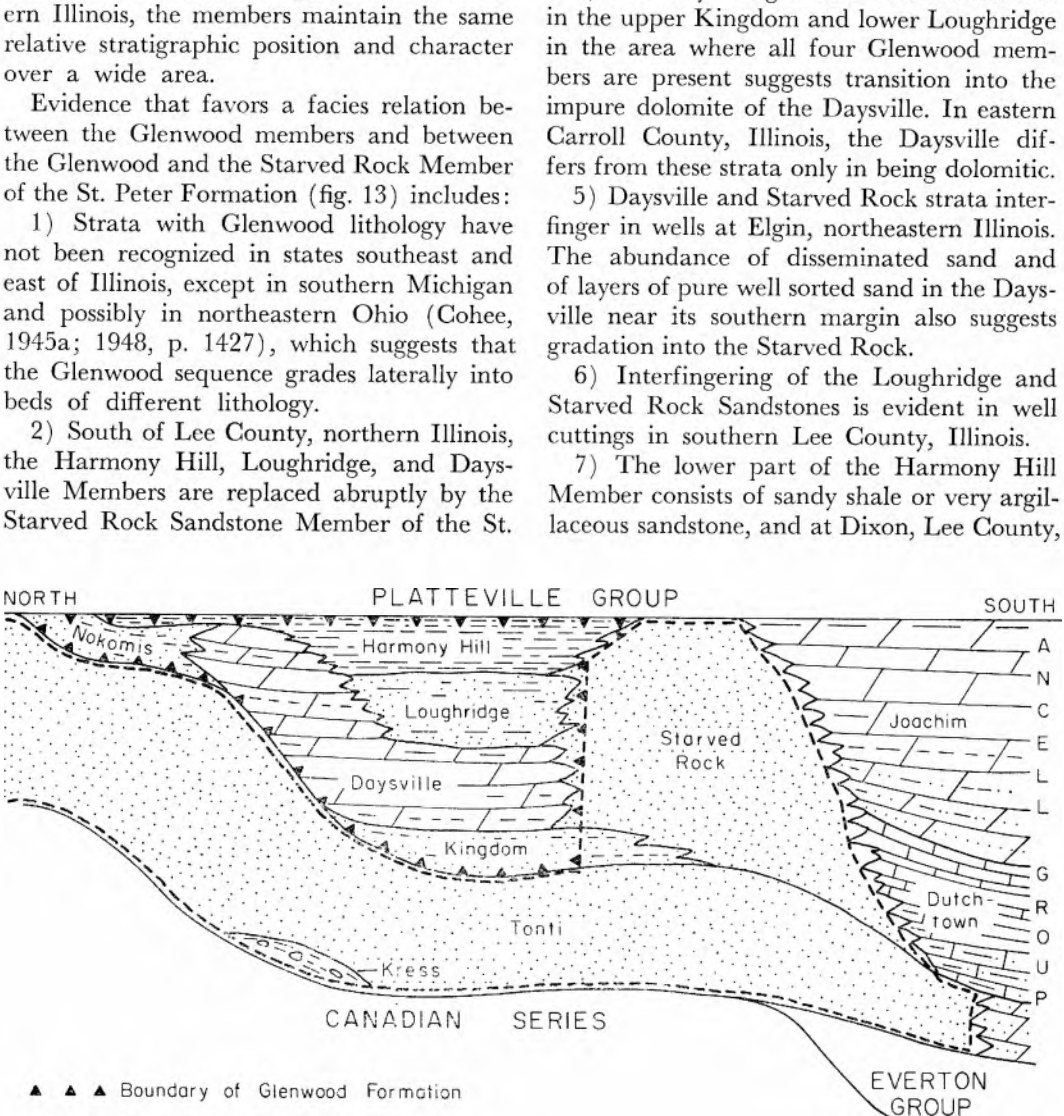

FIG. 13.—Diagrammatic sketch showing relations of units in the Ancell Group in the Mississippi Valley.

Illinois, the entire member grades to very argillaceous sandstone just before it is replaced southward by Loughridge Sandstone.

We believe that the evidence clearly favors a facies interpretation. Gradation from one Glenwood facies to another evidently is abrupt.

In part of southern Illinois and southeastern Missouri, the Starved Rock Sandstone, thinning rapidly southward, is overlain by the Dutchtown Limestone and the Joachim Dolomite, which thin rapidly northward. Facies relations between the St. Peter Sandstone and the Joachim dolomite and limestone (Joachim and Dutchtown of this report) were suggested by Ulrich (1911, p. 480), and have been discussed in many reports. As noted by Dake (1921, p. 26), the intermixing of sand and dolomite or limestone at the contacts of the formations can be explained either by conformable transition or by the reworking of the underlying sand in an advancing sea.

Although the Starved Rock–Dutchtown contact is sharp in the limited exposures and well cuttings, the following data suggest that a facies relation exists between them:

1) In wells in Alexander and Pulaski Counties, Illinois, and in the Midwest Dairy Company well at Cape Girardeau, Missouri, the Dutchtown contains only a little disseminated sand and has little or no interbedded sandstone. In a well near Grand Tower, southwestern Jackson County, Illinois (Baysinger No. 1, SW SW SW 32, 10S-3W, Alto Pass Quad., SS-4777, 2155-2295′ T. D.), the Dutchtown contains much disseminated medium sand and has numerous beds of partly dolomitic medium-grained sandstone, particularly in the lower part. In a well near Campbell Hill, northwestern Jackson County, Illinois (Leiner No. 1, NE NW SW 20, 7S-4W, Campbell Hill Quad., SS-2536), Dutchtown beds are absent and their stratigraphic position is occupied by the Starved Rock Sandstone.

2) The Starved Rock and the Dutchtown have a reciprocal thickness relation.

3) The facies relation between the Starved Rock and the Joachim requires that the Dutchtown also be a facies of the Starved Rock unless the Dutchtown is equivalent to a hiatus in the Starved Rock, a possibility for which there is no evidence.

4) The Starved Rock Sandstone is known only in Illinois, Iowa, and Missouri, whereas Dutchtown and Joachim equivalents are distributed throughout much of the eastern United States.

The existence of a facies relation between the Starved Rock and Joachim is suggested by the following evidence:

1) Reciprocal thickness relations. The Starved Rock thins southward as the overlying Joachim strata thicken.

2) Interfingering of the two formations. In a number of Illinois wells between Hancock and Jackson Counties the upper part of the Starved Rock Sandstone contains layers cemented by Joachim-type dolomite. Both in the southern outcrop belt and in wells to the east, the lower portion of the Joachim Formation contains beds of partly dolomitic, medium-grained sandstone of the Starved Rock type.

3) The presence of green sandy siltstone and of green argillaceous sandstone with Glenwood texture in basal Joachim beds underlain by Starved Rock Sandstone. In northern Illinois such siltstone and sandstone beds are best developed in the zone of gradation between the Starved Rock Sandstone and the Daysville Dolomite.

4) The close lithologic similarity between the Joachim and the Daysville Dolomites.

Although the uppermost Ancell units appear to have complex facies relations among themselves and with the Starved Rock Sandstone, there is no evidence that they are in any part contemporaneous with the underlying Tonti Sandstone Member of the St. Peter Sandstone. The widespread continuity of Platteville formations and members opposes the concept that transgressive relations exist between Glenwood or St. Peter strata and the overlying Platteville strata (DuBois, 1945, p. 32; Dapples, 1955, p. 447).

Other Names

Ancell strata have been included in the Big Buffalo Series of Arkansas (Ulrich, 1911) and the Buffalo Group of Missouri (Buehler, 1922), but in both cases the Everton is included at the base (fig. 14). These names, therefore, are not suitable for the Ancell Group.

The name Foley Limestone (Keyes, 1898, p. 59, 61; misspelled "Folley") is synonymous with and antedated by the term Joachim.

The name Stones River formerly was applied to upper Joachim, Pecatonica, and basal Mifflin strata at Cape Girardeau in the belief that these beds were pre-Blackriveran in age (McQueen, 1939, p. 63-64; Ulrich, 1939; Grohskopf, 1948, p. 361). However, as the Stones River Group of Tennessee embraces Everton (Chazyan) to Platteville (Blackriveran) strata, the name is not suitable for the Cape Girardeau exposures.

The name Rock Levee (Grohskopf, 1948) has been applied to beds between an oolite in the lower part of the Platteville Group and a chert band in the middle of the Joachim Formation, and the name Joachim restricted to strata beneath the chert band. The name Rock Levee is not adopted here for the following reasons:

1) Although the chert and oolite beds are persistent and useful key beds, several other chert bands and oolitic beds are locally present in this part of the sequence. Both of the key beds disappear northeastward in the Illinois subsurface. Therefore, the Rock Levee Formation cannot be differentiated consistently in some areas and cannot be recognized in others.

2) In southern Illinois and in Cape Girardeau and Perry Counties, Missouri, the Rock Levee Formation embraces three lithologic types (upper Joachim, Pecatonica, and lower Mifflin), crosses a regional diastem at the top of the Pecatonica Formation, and has boundaries unaccompanied by significant lithologic or faunal changes.

St. Peter Sandstone

Owen, 1847; modified by Calvin, 1906, and Bevan, 1926

The St. Peter Sandstone was named for St. Peter's River, now called the Minnesota River. The type section is in the bluffs along the river at Fort Snelling on the southeast edge of Minneapolis, Minnesota (Owen, 1847, p. 169-170; Stauffer, 1934, p. 352-355). In Illinois the entire formation is well exposed in the north bluffs of the Illinois Valley where it crosses the LaSalle Anticline in LaSalle County. The section from the top follows: *Pennsylvanian clay, coal, and shale 20′+; St. Peter Sandstone 160′ (Starved Rock 80′, Tonti 70′, Kress 10′); Shakopee Dolomite 50′+*. The contact of the St. Peter with the overlying Pennsylvanian strata is exposed at Split Rock (NW SW NE 13, 33N-1E, LaSalle Quad.). The contact with the underlying Shakopee is exposed half a mile east near the mouth of Pecumsaugan Creek.

Definition.—The St. Peter Sandstone originally included all beds between the Shakopee Dolomite and the Platteville Limestone. It was redefined to exclude the Glenwood Shale (Calvin, 1906). Later all of the shale, sandstone, and dolomite intervening between typical St. Peter and Platteville strata in northern Illinois were removed from the St. Peter Formation and called Glenwood (Bevan, 1925a, p. 189-190; 1925b; 1926).

Members.—The St. Peter Sandstone is subdivided into three members, the Kress Member (at the base), the Tonti Sandstone Member, and the Starved Rock Sandstone Member.

In the Chicago region a coarse chert conglomerate or rubble commonly is present at the base of the St. Peter Sandstone and is named the Kress Member (Buschbach, in press). Similar deposits occur at this position throughout the area of the St. Peter Sandstone, but generally are much less common and in places are dominantly clay or green and red shale mixed with sand and chert fragments. As the various types of deposits found at this position are mixed in places and generally are not separable, the name Kress is extended to cover all the deposits closely associated with the St. Peter but underlying the typical, pure sandstone.

From north-central Illinois to southeastern Missouri, the St. Peter Sandstone above the Kress Member consists of a lower fine-grained unit and an upper medium-grained unit (McQueen, 1937, p. 23-24; Willman and

THIS REPORT S. ILLINOIS Grp.	Sub-grp.	Formation	Winslow 1894 SE. Mo.	Keyes 1898 NE. Mo.	Ulrich, *in* Buckley & Buehler 1904 St. Louis, Mo. & vicinity	Ulrich 1911 NE. and SE. Mo.		Krey 1924 NE. Mo. Calhoun Co., Ill.	Weller, S., and St. Clair 1928 SE. Missouri		Mc Queen 1937 SE. Missouri		Weller, J.M., & McQueen SE. Mo. SW. Ill.	Ulrich 1939 SE. Mo.	
GALENA	Kimmswick	Wise Lake		Mc Cune			Mc Cune	Kimmswick							
		Dunleith	*Recep-taculites*	Bryant	Kimmswick		Upper Prosser / Kimmswick		Mohawkian	Kimmswick	Black River	Kimmswick	Kimmswick	Black River	Kimmswick
	Decorah	Guttenberg	Trenton		Plattin		Decorah	Plattin		Decorah		Decorah	Decorah		Plattin
		Kings Lake													
		Spechts Ferry													
PLATTEVILLE	Plattin	Quimbys Mill				Plattin	Bryant			Plattin		Plattin	Plattin		
		Nachusa													
		Grand Detour													
		Mifflin													
		Pecatonica					Upper Stones River						Stones River	Chazyan	Murfrees-boro
ANCELL		Joachim	Joachim	Folley	Joachim		Joachim	Joachim	Big Buffalo	Joachim	Buffalo River	Joachim	Joachim	Buffalo River	St. Peter
		Dutchtown										Dutchtown	Dutchtown		
		St. Peter	Crystal City	Cap-au-Gres	Pacific (St. Peters)		St. Peter	St. Peter		St. Peter		St. Peter	St. Peter		
EVER-TON				Winfield ↓	Jefferson City ↓					Everton		Everton	Everton		

FIG. 14-A.—Development of the classification of the Champlainian Series in the southern outcrop area from 1894 to 1939. "Southeast Missouri and southwest Illinois" refers to the part of the outcrop area south of St. Louis, "Northeast Missouri" to area north of St. Louis, and "East Missouri" to entire outcrop area.

Weller, J.M. 1940	Branson 1944	DuBois 1945	Grohskopf 1948	Larson 1951	Rubey 1952	Cullison, *in* Twenhofel et al 1954	Cooper 1956	THIS REPORT S. ILLINOIS		
SW. Illinois	E. Missouri	SW. Illinois	SE. Missouri	SE. Missouri	Calhoun Co., Illinois	East Missouri	SE. Missouri	Formation	Sub-grp.	Grp.
	Kimmswick					Kimmswick		Wise Lake	Kimmswick	GALENA
Kimmswick		Galena (Kimmswick)	Kimmswick	Kimmswick	Middle: Kimmswick		Kimmswick	Dunleith		
"Decorah"	Plattin	"Decorah"	"Decorah"	Decorah	Decorah	"Decorah"	Barnhart	Guttenberg	Decorah	
								Kings Lake		
								Spechts Ferry		
Plattin		Plattin (Platteville)	Plattin	Plattin: Macy	Plattin	Plattin: Macy	Plattin: Macy	Quimbys Mill	Plattin	PLATTVILLE
								Nachusa		
				Hager		Hager	Hager	Grand Detour		
				Beckett		Beckett	Beckett	Mifflin		
				Bloomsdale		Bloomsdale	Bloomsdale			
"Stones River"			Rock Levee	Rock Levee		Rock Levee	Rock Levee	Pecatonica		
Joachim	Joachim	Joachim	Joachim	Joachim	Joachim	Joachim	Buffalo River: Joachim	Joachim		ANCELL
Dutchtown	Dutchtown	Dutchtown	Dutchtown	Dutchtown		Dutchtown	Dutchtown	Dutchtown		
St. Peter	St. Peter	St. Peter	St. Peter	St. Peter	Lower: St. Peter	St. Peter	St. Peter	St. Peter		
Everton	Everton				Cotter ?	Everton	Everton			EVERTON

FIG. 14-B.—Development of the classification of the Champlainian Series in the southern outcrop area from 1940 to date.

Payne, 1942, p. 73-76). In Missouri, McQueen tentatively assigned the fine-grained unit to the Everton Formation. However, subsurface studies in Illinois and tracing in outcrops northward to Minnesota show that the fine-grained sandstone is the St. Peter Sandstone of the type area. The medium-grained sandstone is younger than the type St. Peter Sandstone and is absent in the type St. Peter region. The medium-grained unit, from its area of maximum development in north-central Illinois, grades northward into the Glenwood Formation and southward into the Dutchtown and Joachim Formations (fig. 13).

The two units are classified herein as members of the St. Peter Sandstone. The lower fine-grained unit is named the Tonti Sandstone Member and the upper medium-grained unit the Starved Rock Sandstone Member. In the early stages of the study, the name St. Peter was restricted to the lower fine-grained sandstone in order to keep it equivalent to the type St. Peter, and the upper sandstone was called the Starved Rock Sandstone Formation. This alternative has been rejected because the two sandstones are not readily separated in some areas, particularly in subsurface, and because the entire sandstone sequence has been considered St. Peter Sandstone for many years. Much of the detailed information on the lithology of the St. Peter Sandstone has been based on samples from the silica sand pits in the Ottawa district, many of which are largely in the Starved Rock Sandstone. Beyond the region in which the Starved Rock-Tonti differentiation is recognized, the formational name St. Peter will continue to be used, even though only the Tonti Sandstone Member may be generally present.

Distribution.—The St. Peter Sandstone is present throughout the Mississippi Valley region except for a few places in southern Wisconsin and southern Michigan, where Glenwood or Platteville strata rest directly on Shakopee or older dolomites (Chamberlin, 1878, p. 268-286; Cohee, 1945a). The St. Peter wedges out northward in northeastern Wisconsin and eastward in central Indiana, but extends westward through Iowa to eastern Nebraska. South of Illinois it disappears by lateral gradation into sandy dolomite. The St. Peter crops out (1) around the flanks of the Wisconsin Arch in Minnesota and Wisconsin, (2) on anticlinal uplifts in northern and western Illinois and northeastern Missouri, (3) on the Kentland structure in northwestern Indiana, and (4) around the flanks of the Ozark Dome in eastern Missouri and northern Arkansas. Many of the geologic sections (fig. 41) show typical exposures of the St. Peter Sandstone. Other exposures referred to in this report are listed in the index.

Thickness.—The thickness of the St. Peter Sandstone in Illinois is very irregular because of the strong relief of the pre-St. Peter surface. It ranges in wells from as little as 21 feet at Prophetstown, Whiteside County, and 28 feet between New Bedford and Normandy, Bureau County, to 590 feet at Rochelle in Ogle County (Rochelle City No. 6, 190-780′). However, the thickness most commonly varies from 200 to 300 feet in northern Illinois and from 100 to 200 feet in central and southern Illinois. In extreme southern Illinois and southeastern Missouri, just north of the transition zone into dolomite, the St. Peter ranges from 65 to 130 feet thick.

Lithology.—The St. Peter Sandstone consists mainly of quartz sand which normally is pure, white, very fine to coarse grained (chiefly fine grained), very well sorted, friable, thick to very thick bedded, and locally cross-bedded. Most of the sand grains are well rounded and frosted, but the degree of rounding and frosting decreases with decrease in grain size, so that the very fine grains generally are angular and clear. The chief heavy minerals are tourmaline and zircon (Lamar, 1928, p. 59-62; Thiel, 1935, p. 592-599). Garnet is rare.

The St. Peter commonly contains less than 2 percent silt and 1 to 3 percent disseminated clay, mostly kaolinite. Locally in western Illinois the sandstone is very silty, and at Minneapolis, Minnesota, a 30-foot silt bed is reported within the formation (Stauffer, 1934, p. 354). Interbedded shale is rare in the St. Peter Sandstone in the Mississippi

Valley. The presence of a significant amount of shale in the St. Peter in southern Illinois, as shown by Dapples (1955, p. 452-455) is not supported by our studies and may be based on the presence of caved Chester shales.

Where the St. Peter Sandstone underlies the Glenwood Formation or the Platteville Group in the northern outcrop area (fig. 13) and the Joachim Dolomite in southeastern Missouri, the topmost bed commonly is streaked and mottled with green clay-glauconite. In Missouri other zones of glauconitic staining up to 5 feet thick are found as much as 11 feet below the top. Locally the glauconite has altered to jarosite. The presence of clay-glauconite may be related to the diastem or unconformity at the top of the St. Peter in these areas. The glauconite appears to be missing where the Starved Rock Member is present and where the Dutchtown Limestone overlies the Tonti Member. In the northern outcrop area iron oxides also partially impregnate the uppermost bed of the St. Peter in most outcrops overlain by Glenwood or Platteville strata, but they are absent in well cuttings. Impregnations and veins or iron oxide and silica also are common locally at other positions within the sandstone.

South and east of southern Illinois and western Kentucky, the St. Peter Sandstone interfingers with and grades into sandy, light gray to white, very fine-grained, dense dolomite. This carbonate facies appears to be widespread in the eastern United States and deserves a formational name (see *Regional Correlations*). However, we feel the unit should be named in an area where it is exposed, or at least is better developed than in Illinois.

Topographic Expression.—Although the St. Peter Sandstone is mainly unconsolidated when fresh, exposed faces soon become weakly cemented or "case-hardened" by the deposition of silica from ground water. Consequently the sandstone ordinarily forms cliffs or steep slopes between the underlying Canadian dolomites and overlying Ancell or Platteville strata.

Fauna.—A marine molluscan fauna is present in the St. Peter Sandstone (Tonti Member) in the Minneapolis-St. Paul area, Minnesota (Sardeson, 1896a, p. 64-88; 1916, p. 5-6; Stauffer and Thiel, 1941, p. 69). The species have not been reported from other formations but are mostly closely related to Platteville forms.

Hormotoma subangulata Ulrich and Scofield, *Liospira obtusa* Ulrich and Scofield, and several unidentifiable gastropods and brachiopods are abundant in a 4-foot zone of silty quartzitic sandstone lying about 4 feet below the top of the Starved Rock Sandstone Member in road ditches 2 miles east of Millersville, Cape Girardeau County, Missouri (NE NE SW 19, 32N-12E, Marble Hill Quad.) (Elder, 1936b, p. 90, 264-265, fig. 33). Adjacent outcrops of ferruginous, partly quartzitic, fine- to medium-grained, thin-bedded sandstone at or near the top of the Starved Rock Sandstone contain *Hormotoma, Lophospira oweni* Ulrich and Scofield, and abundant pelecypods, most of which belong to the genera *Ischyrodonta* and *Modiolopsis* (Dake, 1921, p. 26; McQueen, 1937, p. 21, localities 7, 9, 10). All the fossils occur as poorly preserved molds. These beds were considered basal Dutchtown by McQueen.

A molluscan fauna with Platteville affinities was recovered from sandstone that formerly was exposed in the McCray quarry at Kentland, Newton County, northwestern Indiana, but which now has been quarried away (Shrock, 1937, p. 484-485). Inasmuch as the sandstone was described as somewhat coarser grained than parts of the St. Peter, it may have belonged to the Starved Rock Sandstone Member. If so, the fossils from Missouri and Indiana may come from approximately the same stratigraphic position in the lower part of the Starved Rock, because in Indiana the sandstone is overlain by Joachim strata and in Missouri only a few feet of Dutchtown beds separate it from the Joachim Formation.

Stratigraphic Relations.—The St. Peter Sandstone rests unconformably on the Everton Group in southern Illinois. In central and northern Illinois, where Everton beds are missing, a major unconformity separates the St. Peter from the underlying strata which range from Shakopee (Cotter-Jefferson City) to Galesville in age. There is evidence of 100- to 200-foot relief at many places.

Some irregularities in the base of the St. Peter Sandstone are related to solution of the underlying carbonate formation (Buschbach, 1961). Some of the basal chert conglomerates or breccias probably are surficial residuum from solution before deposition of the sandstone. Others appear to result from solution-collapse during deposition of the sandstone. Locally, the very sharp thickening of the St. Peter appears to be complementary to thinning of relatively pure zones in the Oneota, well below the base of the St. Peter, suggesting a gross stylolitic relationship. Some structures in the basal St. Peter in Wisconsin appear to be related to a combination of solution and compaction (Flint, 1956).

In southern Wisconsin and northern Illinois a diastem or an unconformity separates the St. Peter from overlying Glenwood or Platteville strata. From north-central Illinois southward to southeastern Missouri, this break appears to be represented by the sharp contact between the Tonti Member and the overlying Starved Rock Member or Dutchtown Formation. In the southern outcrop area, from southern Calhoun County, Illinois, to northern Ste. Genevieve County, Missouri, lower Starved Rock strata appear to be absent, and the resulting break in sedimentation between the St. Peter Sandstone and the overlying Joachim Dolomite may account for the clay-glauconite zone at the top of the St. Peter.

Deposition.—The St. Peter Sandstone was derived chiefly from the erosion of preexisting sandstones, of which the Cambrian Galesville Sandstone may be a major source. The general absence of marine fossils suggests deposition in a sea that was fresh or brackish during most of St. Peter time.

The essentially contemporaneous deposition of the St. Peter as a sheet deposit over an area with a breadth of more than 500 miles seems improbable. In a recent regional study of the depositional history of the St. Peter Sandstone and the Simpson Group, Dapples (1955) suggested transportation of the sand southwestward from the Canadian Shield region and deposition along shorelines that progressively advanced north and northwestward across the area of St. Peter deposition. On the other hand, most of the sand lacks the cross-bedding that generally characterizes such a near-shore deposit and the even bedding and uniform grain size suggest deposition in relatively quiet water. The long-held concept, supported by Dapples, that St. Peter deposition continued throughout most of the Chazyan Stage and into the early Blackriveran and therefore is equivalent to great thicknesses of limestone and dolomite seems equally questionable.

The Tonti and Starved Rock Members of the St. Peter probably have different origins. The more widely distributed Tonti Sandstone is essentially the St. Peter Sandstone of earlier reports, except those reports on the Ottawa region of north-central Illinois. Our correlations suggest that it is the initial deposit of the Blackriveran Stage. It grades southward and eastward into dolomite and its derivation from northern source areas seems well established. Nothing about its relations suggests transgressive deposition differing greatly from deposition by other advances of the sea. Nevertheless, the deposition of a sheet sand by coalescing shorelines, much as described by Dapples (1955, p. 464-467), is a distinct possibility. We favor deposition mostly somewhat farther from shore, probably in deeper water, a more widespread area of deposition, and a much shorter time of deposition than was suggested by Dapples. The St. Peter probably is equivalent to one of the sandstones in the Simpson Group rather than to all of them (see *Regional Correlations—Oklahoma*).

The Starved Rock Member of the St. Peter Sandstone appears to be a broad barlike, off-shore deposit roughly at the position of Dapples' shoreline 2 (1955, p. 465). Because the Starved Rock Member appears to be essentially equivalent to Glenwood strata to the north and to Dutchtown and Joachim strata to the south, these strata are all younger than the Tonti Member and generally are separated from it by a well defined break. Consequently they are not involved in the possible transgressive pattern of the Tonti Member of the St. Peter.

Correlation.—The St. Peter Formation is believed to be a shoreward clastic facies of the light colored dolomite or limestone that constitutes the lower portion of the Murfreesboro Formation of Tennessee (fig. 36), the Five Oaks and Elway Formations in Virgina (fig. 39), and the basal portion of the Pamelia Formation of New York (fig. 30).

Kress Member

Buschbach (in press)

The Kress Member of the St. Peter Sandstone was named for Kress Creek, northwest of West Chicago, in DuPage County, near which a well of the Elgin, Joliet and Eastern Railroad encountered 64 feet of typical conglomerate (NW NE SE 32, 40N-9E, Wheaton Quad., SS-1169, 940-1004′) (Buschbach, in press).

The Kress Member is the basal shaly and conglomeratic zone of the St. Peter Sandstone referred to in many Illinois, Iowa, Minnesota, Missouri, and Wisconsin reports (Dake, 1921, p. 98; Thwaites, 1923, p. 540-542; Stauffer and Thiel, 1941, p. 65; Agnew, 1955, p. 1739; Buschbach, 1961; and others).

Distribution and Thickness.—The Kress Member is highly irregular in distribution. It appears to be present at least locally throughout the area of St. Peter Sandstone, but it is much more common and thicker in some regions than others. It is encountered in so many wells in part of the Chicago region (Buschbach, 1961) that it appears to be essentially a sheet deposit. Buschbach noted that it appears to be thickest, locally exceeding 100 feet thick, immediately north of the north-facing pre-St. Peter escarpment of Prairie du Chien dolomites that extends from the central part of Chicago slightly north of west across northern Illinois. It also is thick in deep channels, valleys, reentrants, or depressions in the escarpment.

Lithology.—The Kress Member in places is a coarse basal conglomerate consisting largely of a rubble-like deposit of irregular blocks of chert with a matrix of clay, sand, or chert. This material is residual from solution of the underlying cherty dolomites and sandstones and is concentrated in solution depressions or along valley channels. The conglomerate is rather poorly exposed at several places in the Oregon region (Willman and Templeton, 1951, p. 115, fig. 7, at O_{SP} west of fault breccia).

At many places in northern Illinois and southern Wisconsin residual clay on Canadian and Cambrian dolomites was reworked by the advancing St. Peter seas, forming alternating layers of red sandy clay and red argillaceous sandstone at the base of the St. Peter Formation. This red argillaceous unit reaches a maximum thickness of 170 feet in a well at Rochelle, Ogle County, northern Illinois. One or more layers of bentonite occur in red clay or white sandstone just above the base of the formation in Ogle County. Elsewhere the Kress consists of well bedded deposits of red and green shales, generally containing thin beds of sandstone. The clay and shale phase of the Kress is locally exposed in the Split Rock section (see *St. Peter Sandstone*), particularly along Pecumsaugan Creek, where it is 10 feet thick (Cady, 1919, p. 39), and at Utica along Illinois Highway 178 (SE SE NE 8, 33N-2E, LaSalle Quad.), where it is about 2 feet thick.

Stratigraphic Relations.—On the Kankakee Arch the St. Peter Sandstone overlaps the entire Prairie du Chien Group and part of the Cambrian sequence (Buschbach, 1961). In northern Illinois the Kress Member in places directly overlies the Shakopee, Oneota, Eminence, Potosi, and Franconia Formations.

Tonti Sandstone Member (new)

The Tonti Sandstone Member of the St. Peter Sandstone is here named for Tonti Canyon in Starved Rock State Park in LaSalle County, Illinois. The top of the sandstone is exposed at the mouth of the canyon, but the type section is in the Starved Rock section (geol. sec. 1) where its relation to the Starved Rock Sandstone is better exposed. The Tonti Sandstone is completely exposed in the Split Rock section (see *St. Peter Sandstone*) 4 miles northwest of Starved Rock. The Tonti Sandstone Member previously was called the lower fine-grained unit of the St. Peter Sandstone (Willman and Payne, 1942, p. 73-76).

Distribution.—The Tonti Sandstone is by far the most widely distributed member of the St. Peter Sandstone and is present throughout the entire area of the formation.

Thickness.—The Tonti Sandstone Member is commonly 100 to 200 feet thick in Illinois. In the area of strong development of the Starved Rock Sandstone Member, the two units commonly are about equal in thickness, but in the more extreme variations either unit may be as much as three-fourths or as little as one-fourth of the St. Peter Sandstone Formation.

Lithology.—The Tonti Sandstone consists chiefly of fine-grained, well sorted, friable sandstone. Beds that are principally medium to coarse grained occur locally at various stratigraphic positions, but they form only a minor constituent in a dominantly fine-grained member. In parts of western Illinois, much of the Tonti Sandstone is very silty. Because the Tonti extends much more widely than the Starved Rock, the description of the St. Peter as a whole largely applies to the Tonti.

Stratigraphic Relations.—The Tonti Sandstone conformably overlies the Kress Member and is separated from the Starved Rock Sandstone above by a sharp contact believed to be a diastem.

Starved Rock Sandstone Member (new)

The Starved Rock Sandstone Member of the St. Peter Sandstone is here named for Starved Rock in Starved Rock State Park, LaSalle County, north-central Illinois. The type section consists of exposures at Starved Rock, French Canyon, and Lovers' Leap (geol. sec. 1). In the type section the lower 14 feet 5 inches of the Starved Rock Sandstone contains silty beds with Glenwood lithology. These beds reflect the interfingering of the Kingdom and Starved Rock Sandstones at the southeastern margin of the Kingdom Sandstone (fig. 13). Most of the lower 7 feet 8 inches of this zone has Starved Rock lithology. The Kingdom tongues are thinner and only locally present farther east in the Ottawa outcrop area.

The Starved Rock Sandstone formerly was classified as the upper division of the St. Peter Sandstone in north-central Illinois (Willman and Payne, 1942, p. 73-76), and as the upper or St. Peter part of the St. Peter-Everton Sandstone in southeastern Missouri (McQueen, 1937, p. 9-11, 23-24; 1939, p. 67). Although included in the St. Peter Formation, it is now considered younger than type St. Peter Sandstone and equivalent to Glenwood beds in the St. Peter type area.

Distribution.—The Starved Rock Sandstone occupies a broad band with lobate boundaries extending from Cook County, northeastern Illinois, to Lee County, southeastern Iowa. Its northern limit can be traced in wells from northern Cook County to the vicinity of Rock Island, Rock Island County. Its southern limit is known from fewer wells, but extends approximately from southern Kankakee County to Pike County, western Illinois.

The Starved Rock Sandstone is missing from the southern outcrop area between Calhoun County, Illinois, and southern St. Genevieve County, Missouri, where the Joachim Dolomite, the carbonate facies of the upper part of the Starved Rock Sandstone, rests directly on the St. Peter Sandstone. However, a sandstone believed to be the Starved Rock is present in an area extending from southern Ste. Genevieve County to Cape Girardeau County, Missouri, in which area it appears to grade into lower Joachim and Dutchtown strata. It seems likely that the two areas of Starved Rock Sandstone are connected through the Illinois Basin.

Thickness.—The Starved Rock Sandstone normally is from 60 to 90 feet thick. In western Illinois the greatest thickness of Starved Rock above the Kingdom Sandstone is 104 feet in a well at Bushnell, McDonough County, although slightly greater thicknesses are encountered farther south in western Illinois where the Starved Rock is divided into two parts by a tongue of Kingdom Sandstone. The maximum known thickness of the Starved Rock is 235 feet in a well near Joliet, Will County, northeastern Illinois (Blockson Chemical Co., SE NE 30, 35N-10E, Wilmington Quad., SS-22912, 615-

850′), where it appears to fill a sag in the top of the Tonti Sandstone over a major sub-St. Peter valley or depression.

Lithology.—The Starved Rock Member consists of sandstone that closely resembles the underlying sandstone in the Tonti Member, but is consistently coarser grained. The dominant size grade is medium in western Illinois and medium, locally coarse, in northern Illinois (Willman and Payne, 1942, p. 73-76). In western Illinois and around the margins of the formation in north-central and northeastern Illinois the sandstone is partly silty, locally fine grained, and contains tongues of Glenwood sandstones, but it maintains its character as a coarse-grained unit. As a rule the Starved Rock Sandstone lacks the strong cross-bedding that is locally prominent in the underlying Tonti Sandstone.

Stratigraphic Relations.—Between McDonough and Scott Counties, western Illinois, and in southeastern Missouri the Starved Rock Sandstone rests on the Tonti Sandstone with a sharp contact, which suggests the presence of a minor diastem. North of McDonough County the Starved Rock conformably overlies the Kingdom Sandstone. The Starved Rock Sandstone grades northward into the Glenwood Formation and tongues of Starved Rock-type sandstone are found locally in the Loughridge Member and more rarely on top of the Harmony Hill Member. The Starved Rock Sandstone grades southward into the Joachim and Dutchtown Formations.

Sub-Platteville channels as much as 20 feet deep in the top of the Starved Rock in its type area indicate an unconformity probably related to uplift along the LaSalle Anticline (Willman and Payne, 1942, p. 62). Elsewhere the abruptness of the Starved Rock-Platteville contact suggests a diastem. The unconformity at the top of the Starved Rock appears to be continuous northward with the diastem at the top of the Glenwood Formation.

Source of Sand.—The Starved Rock Sandstone becomes finer grained southwestward, which suggests that the source of the sand apparently was to the northeast. Older coarse-grained sandstones, such as the Cambrian Eau Claire and Mt. Simon Formations, may have contributed more sand than they did during Tonti deposition.

Correlation.—The Starved Rock Sandstone is considered equivalent to Agnew's (1955, p. 1731-1734) "unnamed sandstone" (sometimes referred to as the "Re-Peter" Sandstone) which is as much as 100 feet thick in subsurface in southeastern Iowa and extreme western Illinois. We correlate the green shale separating the "Re-Peter" from the underlying "St. Peter" with the shaly facies of the Kingdom Sandstone, the basal beds of the Glenwood Formation. Agnew referred the shale to the Glenwood Shale, which is our New Harmony Member at the top of the Glenwood Formation. In western Illinois a green shale is present above the upper sand and we correlate it with the New Harmony Shale.

Glenwood Formation

Calvin, 1906; modified by Bevan, 1926

The Glenwood Formation was named for Glenwood Township, Winneshiek County, northeastern Iowa. The type section is a ravine exposure 3 miles northeast of Decorah (SE SW 6, 98N-7W, Decorah Quad.) (Calvin, 1906, p. 60-61, 74-76). Because this section is now covered, Elder (1936b, p. 60) suggested an excellent exposure less than half a mile away (head of ravine in NE SE SE 1, 98N-8W) as a reference section.

Definition.—The name Glenwood originally was applied only to the shale herein called Harmony Hill. Later the Glenwood was extended in Illinois and Minnesota to include certain underlying sandstone and dolomite beds because (1) the beds are more closely related in lithology to the Glenwood Shale than to St. Peter Sandstone beneath, (2) the beds are conformable with the shale and may be in part a facies of the shale, and (3) the beds are separated from the St. Peter by a diastem or unconformity (Bevan, 1925a, p. 189-190, 1925b, 1926; Elder, 1936a, 1936b; Thiel, 1935, 1937; Stauffer and Thiel, 1941, p. 73-77).

The Glenwood Formation is subdivided into the following members: Harmony Hill Shale Member (at top), Loughridge Sandstone Member, Daysville Dolomite Member, and Kingdom Sandstone Member. The Nokomis Sandstone Member locally occupies the position of the Loughridge, Daysville, and Kingdom Members and may be equivalent to all or part of them.

Elevation of the Glenwood to a subgroup was considered (Templeton and Willman, 1952; quoted in U. S. G. S. Bulls. 1056A and 1056B) because its subdivisions are as distinctive as most other Champlainian formations and because they have adequate maximum thickness for formations (Kingdom, 40 feet; Daysville, 75 feet; Loughridge, 22 feet; Harmony Hill, 27 feet; Nokomis, 11 feet). However, the maximum thickness is approached, mostly in subsurface, in only a few counties, and in most of the outcrop region the entire Glenwood is relatively thin, even for a formation. The units do not require ranking higher than member to permit subdivision. Consequently, the Glenwood is classified as a formation and the subdivisions as members.

The name Glenwood was restricted largely to the green shale (Harmony Hill Shale) and classified as a member of the Platteville Formation in some recent reports (Twenhofel et al., 1954; Agnew, 1955; Agnew et al., 1956).

Distribution.—The general distribution of the Glenwood Formation has been described (see *Ancell Group*). Glenwood strata are exposed only in the northern outcrop area. They are absent over much of the Wisconsin Arch in central southern Wisconsin and are missing at a few places in northern Illinois. Outcrops described in this report are listed in the index.

Thickness.—The Glenwood Formation is characterized by abrupt, irregular variations in thickness. The greatest thicknesses are found at the southern limits, just before it grades into the Starved Rock Sandstone Member of the St. Peter Sandstone. It commonly is not more than 20 feet thick but reaches a maximum of 150 feet at Galesburg, Knox County (Galesburg City well No. 1, NE 15, 11N-1E, Galesburg Quad., SS-33, 1090-1240′).

Lithology.—The distinctive lithologic features of the Glenwood Formation are (1) the texture of the sand, which is a bimodal mixture of very fine grains and medium or coarse grains, with relatively few fine grains, (2) abundant accessory garnets, (3) the high silt and clay content, (4) a clay fraction composed chiefly of illite and authigenic potash feldspar, (5) the chalky texture of the dolomite, (6) a green color or tint caused by disseminated illite, (7) lithologic units of irregular thickness and comparatively limited extent, and (8) the scarcity of cross-bedding which is common locally in the underlying St. Peter Sandstone. The distinctive bimodal texture of the sand is referred to as "Glenwood texture," in contrast to well sorted "St. Peter texture."

The Glenwood shale and sandstone commonly have been described as glauconitic. However, many recent analyses of Glenwood accessory minerals indicate that the green color apparently is imparted by illite and the high potash content by feldspar. Glauconitic uppermost St. Peter strata sometimes have been mistaken for one of the Glenwood sandstones.

Stratigraphic Relations.—The presence of an unconformity, probably of small magnitude, between the Glenwood and the underlying St. Peter Sandstone is indicated by the following:

1) The St. Peter-Glenwood contact shows 12 feet of relief within a horizontal distance of 150 feet in Iowa County, Wisconsin (roadcut in SW NW NW 20, 7N-3E, Richland Center Quad.) (Elder, 1936b, p. 70, fig. 25). The erratic distribution of the glauconitic uppermost St. Peter strata probably is the result of erosion. In wells at Mount Morris, Ogle County, Illinois, the uppermost Glenwood Harmony Hill Member rests directly on the St. Peter Sandstone, but short distances away older Glenwood members are present between the two.

2) Pebbles and angular fragments of St. Peter Sandstone are present in the basal beds

of the Kingdom and Daysville Members at many localities, such as the Daysville and Harmony Hill type sections.

3) Silica veinlets, joints, faults, and folds in the St. Peter Sandstone are truncated by Glenwood strata. Glenwood strata truncate a shallow syncline and joints in the St. Peter Sandstone in Rock County, Wisconsin (roadcut in SE NE NW 22, 2N-10E, Broadhead Quad.).

In much of central southern Wisconsin and at places in northern Illinois the Glenwood Formation is missing and the Pecatonica Dolomite, locally containing St. Peter debris, directly overlies the St. Peter Sandstone. An excellent example of such an unconformable St. Peter-Pecatonica contact is exposed in Green County, Wisconsin (southeast end of ridge in SE NE SW 13, 2N-6E, Monroe Quad.). Because no unconformity is known within the Glenwood-Pecatonica sequence, these relations are ascribed to a post-St. Peter, pre-Glenwood unconformity that continued through Glenwood time.

The presence of a diastem locally accompanied by minor erosion between the Glenwood and the overlying Platteville strata is suggested by the following:

1) A very abrupt lithologic and faunal change generally takes place at the Glenwood-Platteville contact. Clastics or impure dolomite give way to relatively pure dolomite, fine sand with Glenwood texture is replaced by coarser sand with St. Peter texture, and the sparse, restricted Glenwood fauna is succeeded by the relatively plentiful, diversified Platteville fauna. Where the Harmony Hill Shale underlies the Pecatonica Dolomite, the top of the shale is pyritic or ferruginous, and phosphatic pellets are common near the contact, especially in the dolomite.

2) Near Brookville and Leaf River, Ogle County, Illinois, the Pecatonica Formation is missing, and Mifflin strata directly overlie the Glenwood (ravine in NE SW NE 24, 25N-9E, Oregon Quad.).

3) In a few places the Pecatonica contains pebbles of Daysville Dolomite (railroad cut in NW NE NE 34, 2N-12E, Rock Co., Wis., Janesville Quad.), and at a few other localities the Daysville-Pecatonica contact is uneven (quarry in SW NW NE 20, 2N-8E, Green Co., Wis., Monroe Quad.).

Deposition.—The northern distribution, the variable lithology, and the general absence of a normal marine fauna suggest that Glenwood sediments were derived from two different terranes and were deposited in the brackish muddy waters of a shallow marine basin that was partly closed to the southeast by a bar of sand, the Starved Rock Sandstone.

The clay, silt, very fine sand, and accessory garnet probably came mainly from Precambrian schists in the Lake Superior region to the north and northwest (Bevan, 1926, p. 13; Elder, 1936b, p. 107). Little of this fine clastic fraction could have been obtained from the contemporaneous Starved Rock Sandstone because Glenwood and Starved Rock beds have different clay minerals and accessory minerals. In northern Illinois some of the medium to coarse sand may have been derived from Starved Rock Sandstone. Farther north, however, medium to coarse sand must have been available from exposures of Cambrian sandstones, because well developed Glenwood texture is found as far north as Minneapolis and the upper peninsula of Michigan.

The uniformity and wide distribution of the Glenwood texture suggest that the fine and the coarse clastics were mixed in rivers before discharge into the sea. The coarse clastics perhaps came from sand dunes that migrated into the lower courses of the rivers. The lack of sorting in the typical Glenwood sandstones implies strong currents and rapid distribution. The conglomeratic layers, the thin, irregular bedding, and the presence of local channeling and diastems within the Glenwood suggest that the water generally was very shallow and agitated, and that portions of the sea floor repeatedly emerged for short periods.

Kingdom Sandstone Member (new)

The Kingdom Sandstone Member of the Glenwood Formation is here named for the hamlet of Kingdom, Lee County, northern Illinois, which is 3 miles south of the type section, which is the Oak Ridge school section (geol. sec. 2) in Ogle County. In the area where the Kingdom extends beyond the other Glenwood members, it is recognized as a member of the St. Peter Sandstone (fig. 13).

Distribution.—The Kingdom Sandstone is found from Ogle County, northern Illinois, southward to Scott County, western Illinois. It also extends from Lee County, southeastern Iowa, northeastward to Will County, northeastern Illinois. North of the area outlined, the Kingdom Sandstone grades into the Daysville Dolomite or forms the lower part of the Nokomis Sandstone. South of the area outlined it grades into the Starved Rock Sandstone.

Thickness.—The Kingdom Sandstone most commonly is from 5 to 20 feet thick. However, it is 35 feet thick in a well at Joliet, Will County, and reaches a maximum thickness of 40 feet in a well at Rochelle, Ogle County.

Lithology.—The Kingdom Member consists of sandstone that is mostly silty, argillaceous, pyritic, and greenish gray, white, or pale green. It has bimodal Glenwood texture, is friable, and occurs in irregular beds from 2 to 36 inches thick. In Carroll, Lee, and Ogle Counties, Illinois, the upper part of the formation is very silty and argillaceous, gray-green, mainly very fine grained, and firm. It occurs in regular 1- to 3-inch beds. This upper unit represents a transitional facies between the Kingdom Sandstone and the Daysville Dolomite, and at Rochelle, just before the Kingdom merges eastward into the Daysville, it constitutes three-fourths of the Kingdom Member. The Kingdom contains some shale and siltstone partings, which are most common in the upper unit. The shale generally is green, but becomes gray in parts of northeastern Illinois.

As the Kingdom begins to grade laterally into the Starved Rock Sandstone it becomes partly or wholly fine to medium grained and well sorted, and has a clay fraction composed of kaolinite instead of illite and feldspar. In such cases the Kingdom closely resembles the St. Peter Sandstone, but is distinguished from it by its high content of pyrite and silt, and by the presence of green or gray shale partings.

Fauna.—Worm-borings of *Scolithus* type are abundant locally, and minute, dark red, unicellular algae or spores occur rarely, but no other fossils have been found.

Stratigraphic Relations.—In the northern outcrop area the Kingdom Sandstone unconformably overlies the Tonti Member of the St. Peter Sandstone. In wells between the northern outcrop area and northern McDonough County, the sharpness of the St. Peter-Kingdom contact suggests the presence of a diastem. Southward from northern McDonough County the Kingdom Sandstone overlies a tongue of the Starved Rock Sandstone that probably was deposited during the break in sedimentation between the Tonti and Kingdom Sandstones farther north. The relations of the Kingdom Sandstone to the Starved Rock and Daysville Members are gradational at the margins of the Kingdom and are conformable elsewhere. In northwestern Illinois the Kingdom merges with the lower part of the Nokomis Sandstone, beyond the limits of the Daysville Dolomite.

Daysville Dolomite Member (new)

The Daysville Dolomite Member of the Glenwood Formation is here named for the village of Daysville, Ogle County, northern Illinois, which lies 3 miles southwest of the type section (geol. sec. 3).

Distribution.—The Daysville Dolomite extends from northwestern Illinois eastward to Milwaukee, Wisconsin, and into southern Michigan (Cohee, 1945a, fig. 2). It is absent north and west of Green County, central southern Wisconsin, and in Iowa and Minnesota. It also is missing south of a lobate boundary extending from Galesburg, Knox County, to northermost Cook County, Illinois.

Thickness.—The Daysville Dolomite is thinnest along its northern and western margins and thickest along its southeastern margin. It is commonly about 45 feet thick in a belt extending from western DeKalb County, Illinois, to Racine County, southeastern Wisconsin. The Daysville reaches a maximum known thickness of 75 feet in wells at Elgin, Kane County, northeastern Illinois, where it grades abruptly southeastward into the Starved Rock Sandstone.

Lithology.—The Daysville Member consists largely of dolomite that is argillaceous, silty, sandy, greenish gray, white, or greenish buff, chalky to dense, and is in irregular beds from 1 to 12 inches thick. Layers of intraformational dolomite-pebble conglomerate are common. In many places part or all of the dolomite grades laterally into dolomite-cemented sandstone of the Glenwood type. Where the Daysville overlies the Tonti Member of the St. Peter Sandstone or borders the Starved Rock Member it generally contains interbedded layers of St. Peter-type sandstone, some of which are dolomite cemented. Worm-borings of the *Scolithus* type are the only fossils known.

Stratigraphic Relations.—Throughout most of its extent the Daysville Dolomite rests unconformably on the St. Peter Sandstone and is separated by a diastem from the overlying Platteville Group. However, in Carroll, Lee, Ogle, and Whiteside Counties, central northern Illinois, it overlies the Kingdom Sandstone and underlies Loughridge, or Harmony Hill strata. In places, a minor diastem accompanied by a slight amount of erosion separates the Daysville Dolomite from the succeeding Loughridge Sandstone.

Loughridge Sandstone Member (new)

The Loughridge Sandstone Member of the Glenwood Formation is here named for Loughridge school (pronounced Lo-ridge), Ogle County, northern Illinois, 5 miles northwest of the type section (geol. sec. 4).

Distribution.—The Loughridge Sandstone is confined to Carroll, Lee, Ogle, and Whiteside Counties, northern Illinois. It is the most areally restricted of the Glenwood members.

Thickness.—The Loughridge Sandstone thins out to the north as it grades into the Daysville Dolomite from the base upward. It thickens to the south and east and finally passes into the Starved Rock Sandstone. The maximum known thickness is 22 feet in a well at Dixon, Lee County.

Lithology.—The Loughridge Member is composed mainly of sandstone which is silty, argillaceous, pale green, white or brown, very fine or medium to coarse grained, friable, and thin bedded to massive; it is similar to the lower part of the Kingdom Sandstone. In places the lower part, from 1 to 4 feet thick, is very argillaceous and silty, gray-green, chiefly very fine grained, firm, and in thin, fairly regular beds, like the upper part of the Kingdom Sandstone. In southeastern Lee County, Illinois, in the zone of transition into the Starved Rock Sandstone, the Loughridge has pronounced bimodal Glenwood texture, but has a clay fraction composed of kaolinite. Scolecodonts are the only fossils.

Stratigraphic Relations.—The Loughridge Sandstone has a facies relation and a generally conformable contact with the underlying Daysville Dolomite, although locally a minor diastem separates the two units. The contact with the overlying Harmony Hill Shale is conformable and probably is accompanied by lateral gradation. In a few places the Loughridge directly underlies Platteville strata, from which it is separated by a diastem. The Loughridge Sandstone merges westward with the upper part of the Nokomis Sandstone and interfingers southeastward with the Starved Rock Sandstone.

Nokomis Sandstone Member (new)

The Nokomis Sandstone Member of the Glenwood Formation is here named for Lake Nokomis (formerly Amelia Lake) 1½ miles west of the type section in the bluff on the west side of the Mississippi River at Lock and Dam No. 1, in Minneapolis, Hennepin County, Minnesota (geol. sec. 5). (See also Stauffer and Thiel, 1941, p. 162.) The name Nokomis is applied to sandstone with Glenwood texture lying between the St. Peter Sandstone and the Harmony Hill Shale. It results from merger of the Kingdom Sandstone and the Loughridge Sandstone beyond the northern and western margin of the intervening Daysville Dolomite (fig. 13).

Distribution.—The Nokomis Sandstone is present in southeastern Minnesota, northeastern Iowa, southwestern Wisconsin, and northwestern Illinois. It occurs also in an outlier at Limestone Mountain, Houghton County, upper Michigan.

Thickness.—The Nokomis Sandstone is highly variable in thickness. It is missing in many places, and its maximum thickness is nearly 11 feet in the type section.

Lithology.—The Nokomis Member consists mainly of sandstone which is a silty, argillaceous, and generally bimodal mixture of very fine and medium to coarse grains. It is friable, greenish gray, white, or buff, and thin bedded to massive. However, at many exposures in southeastern Minnesota, northeastern Iowa, and southwestern Wisconsin the lower part of the Nokomis consists of argillaceous, silty, partly limonitic or pyritic, gray-white or brown sandstone. It is bimodal with very fine and coarse grains, but coarse grains predominate. It is thin bedded to massive, and the heavy minerals include garnet. The clay mineral in the matrix is largely kaolinite. In Minnesota the coarse-grained bed and the upper Nokomis strata have long been classed as the basal part of the Glenwood (Thiel, 1935, p. 572, 606; 1937, p. 120; Stauffer and Thiel, 1941, p. 74).

Thin interbeds of purplish gray silt are present in the upper foot of the Nokomis Sandstone at the type locality. Occasional streaks or thin layers of green shale are found in a few exposures.

Fauna.—The Nokomis Sandstone commonly contains *Scolithus* borings, conodonts, and scolecodonts. Megascopic fossils belonging to genera that also are found in the Platteville Group have been reported from the Nokomis at Minneapolis (Stauffer, 1935a, p. 128-129).

Stratigraphic Relations.—The Nokomis Sandstone rests unconformably on St. Peter Sandstone and in places contains St. Peter pebbles or truncates St. Peter structures. Generally it lies conformably beneath the Harmony Hill Shale, with which it probably has a facies relation, but locally it underlies the Pecatonica Formation, from which it is separated by a diastem. In northwestern Illinois the upper part of the Nokomis Sandstone grades eastward into the Loughridge Sandstone and the lower part grades southward into the Kingdom Sandstone.

Harmony Hill Shale Member (new)

The Harmony Hill Shale Member of the Glenwood Formation is here named for Harmony Hill school, Ogle County, northern Illinois, one mile northwest of the type section (geol. sec. 6).

Distribution.—The Harmony Hill Shale extends westward from Lee and Ogle Counties in northern Illinois to eastern Nebraska, and northward from Warren County, western Illinois to Minneapolis. It is absent in central southern and eastern Wisconsin, in part of northern Illinois, and in northeastern Illinois.

Thickness.—The Harmony Hill Shale commonly is from 1 to 5 feet thick, but ranges from a few inches to a maximum of 27 feet thick in southwestern Ogle County.

Lithology.—The Harmony Hill Member consists mainly of shale that is pyritic, partly silty and sandy, friable, and in very thin, laminated, regular beds. The color is generally gray-green, weathering buff or maroon, but is black at one locality in Ogle County. A thin layer of pyrite or iron oxide locally is present at the top, and in places the shale contains jarosite. Scattered phosphatic pellets are common near the top. Thin beds and lenses of silt or of argillaceous fine-grained sandstone occur in the shale at some exposures. The lower part, and in places the entire member, consists of strongly argillaceous, gray-green, mostly very fine-grained sandstone in thin, irregular beds.

Fauna.—Conodonts and scolecodonts normally are present in the Harmony Hill Shale. At Minneapolis the "Glenwood Shale" is said to carry megascopic fossils belonging to genera that also occur in the Platteville Group (Stauffer, 1933, 1935a), but it is considered more likely that the megascopic fauna came from beds herein regarded as basal Platteville. In Lee and Ogle Counties, northern Illinois, the Harmony Hill contains rare fragments of scolecodonts and *Lingula* (Elder, 1936b), and locally has minute, dark red, unicellular marine algae or spores.

Stratigraphic Relations.—The Harmony Hill Shale rests conformably on Loughridge, Daysville, Nokomis, or Starved Rock strata. In a few places it unconformably overlies the St. Peter Sandstone. It grades eastward into the Daysville Dolomite and southward into the Starved Rock Sandstone and in places appears to have a facies relation with the Loughridge Sandstone.

Dutchtown Limestone

McQueen, 1937

The Dutchtown Limestone was named for the village of Dutchtown, Cape Girardeau County, southeastern Missouri (McQueen, 1937, p. 12), near which the formation is exposed. It consists of limestone, dolomite, and dolomitic sandstone lying between the St. Peter and the Joachim Formations. It is separable from the dolomite facies of the St. Peter by its coarser sand grains and darker color. It is distinguished from the overlying Joachim Formation by its higher clay content, lower silt and sand content in the upper part, lack of anhydrite and gypsum, darker color, and higher proportion of limestone. It further contrasts with the Joachim Formation in lacking numerous mud-cracks, rill-marks, and ripple-marks, and in having a normal marine fauna.

In certain wells in southwestern Illinois, interbedding of Dutchtown and Joachim lithologies occurs near the boundary between the two formations, and makes selection of the contact difficult. In such instances cuttings from the Midwest Dairy Company well at Cape Girardeau (see *Ancell Group*) have been used as a standard of comparison, because there the Dutchtown-Joachim contact is sharp and the internal lithologic sequence within the two formations is well defined.

Members.—In the type area the Dutchtown Formation has been divided into three members (McQueen, 1937, p. 15-19). The lower member is chiefly silty, sandy, and dark gray limestone. It contains greenish gray shale partings and has beds of dolomite and dolomitic sandstone near the base. Fossiliferous sandstone placed in the basal portion of this member by McQueen (1937, p. 21, localities 7, 9, 10) is herein considered Starved Rock. The middle member, for which McQueen suggested the name Geiser Quarry Member, and the upper member are limestones that are less sandy than the lower member and are brown to black with partings of similarly colored shale and siltstone. The Geiser Quarry Member has local calcarenite layers and the upper member has less siltstone and finer disseminated sand than the other members. These differences do not seem to be persistent. In some wells in southern Illinois the two lithologies are interbedded throughout a considerable vertical interval. Therefore, it seems desirable to divide the Dutchtown Formation into two members. The lower member, herein named Gordonville, corresponds to the lower member of McQueen. The upper member, herein named Sharpsboro, is equivalent to the combined middle and upper members of McQueen.

Distribution.—Dutchtown strata are exposed only near the south end of the southern outcrop area. The formation extends from Cape Girardeau County north to Perry County (McQueen, 1937, pl. I; Grohskopf, 1948, fig. 2), and in southern Illinois it is found as far north as southern Jackson County and eastward across the state. Dutchtown strata reported north of southern Jackson County (DuBois, 1945, p. 27-28, pls. 1, 2) belong to the overlying Joachim Formation.

Thickness.—The maximum thickness of Dutchtown strata is 200 feet in Ballard County, Kentucky (Robinson-Puckett, Inc., No. 1 Clark, 22-H-5, SS-9540, 2820-3020′). In Missouri the Dutchtown is as much as 170 feet thick in a well at Cape Girardeau (McQueen, 1937, p. 14, table 1), but thins out rapidly northward.

Lithology.—The Dutchtown Formation consists mainly of limestone and dolomite that is argillaceous, partly silty and sandy, mostly black or dark shades of gray, blue, and brown, lithographic to fine grained, thin bedded, and shaly. It contains a few layers of calcareous siltstone and dolomitic sandstone, and has an abundance of disseminated dark organic particles. Although the Dutchtown Formation is mainly dark colored, it contains some layers of light gray, white, or light brown sandy dolomite or dolomitic sandstone near the base and near the top.

The profusion of organic particles, the local occurrence of asphalt (McQueen, 1937, p. 17-18), and the strongly fetid odor of freshly broken surfaces suggest that the Dutchtown may be a source rock for oil and gas.

Fauna.—Mollusks, ostracodes, and conodonts are common, with species of *Lophospira* most abundant (Cullison, 1938; Branson, 1944, p. 66-67). These species are not reported elsewhere, but many have definite affinities with forms from the upper part of the Murfreesboro Limestone of Tennessee, the lower part of the Peery Limestone of Virginia, and the lower part of the Pamelia Limestone of New York. *Cryptozoon* is common near the top of the Gordonville Member.

Stratigraphic Relations.—Southward from Cape Girardeau, southeastern Missouri (McQueen, 1937, p. 23-24), and in southernmost Illinois the Dutchtown rests on St. Peter Sandstone with a sharp contact that suggests a diastem. North of Cape Girardeau and southernmost Jackson County, Illinois, the Dutchtown appears to grade laterally from the base upward into the lower part of the Starved Rock Sandstone (fig. 13), and it disappears a short distance farther north. In southern Illinois the contact between the Dutchtown and the overlying Joachim Dolomite is conformable. In places it is also gradational and is characterized by interbedding of the two lithologic types. The conformability of the contact accords with the view that the Starved Rock Sandstone is the shoreward facies of the two formations. However, in Cape Girardeau County, Missouri, the variable thickness of the upper or Sharpsboro Member of the Dutchtown (McQueen, 1937, p. 24) and the sharp contact with the Joachim Formation suggest that a diastem accompanied by a minor amount of erosion intervenes between Dutchtown and Joachim strata. This diastem appears to result from minor uplift of the Ozark Dome.

Correlation.—On the basis of similarities in lithology, fauna, and stratigraphic position, the Dutchtown is correlated, via Tennessee and Virginia, with black limestone composing the upper part of the lower division of the Pamelia Formation in New York.

Gordonville Member (new)

The Gordonville Member of the Dutchtown Formation is here named for the village of Gordonville, Cape Girardeau County, Missouri, 4½ miles northwest of the type section, which is in the Geiser quarry on the north side of State Highway 75, 1¼ miles east of Dutchtown (SW NW NW 20 projected, 30N-13E, Cape Girardeau Quad.), where the sequence from the top is: *Ancell Group, Dutchtown 15′6″ (Sharpsboro 10′6″, Gordonville 5′).* (See also McQueen, 1937, p. 18.) An excellent exposure of uppermost Gordonville beds is located 5¼ miles southeastward in the Sals Creek diversion channel, about 1 mile west of Ancell (NE 1, 29N-13E, and NW 6, 29N-14E, Scott Co., Morley Quad.) (McQueen, 1937, p. 20, locality 4).

Distribution.—The Gordonville Member has been traced from Cape Girardeau in southeastern Missouri to Hardin County, southeastern Illinois, and to Ballard County, northwestern Kentucky. It does not extend as far north as higher Dutchtown strata.

Thickness.—At Cape Girardeau the Gordonville is 50 feet thick, (Midwest Dairy Company well, 1055-1105′) and a thickness of 65 feet is reported nearby (McQueen, 1937, p. 17). In Illinois the thickness ranges from over 45 feet in southernmost Jackson County to 97 feet in southern Pulaski County near Mound City. The maximum known thickness is 130 feet in Ballard County, Kentucky (Robinson-Puckett No. 1 Clark, 2890-3020′).

Lithology.—The Gordonville Member normally consists of dolomite with subordinate amounts of limestone, although in southernmost Jackson County, Illinois, close to the transition into the Starved Rock Sandstone, it is composed mainly of dolomite-cemented, medium-grained sandstone. The dolomite and limestone are mostly sandy, somewhat silty, greenish gray, brownish gray, or dark gray, lithographic to very fine grained and dense. A few layers are dark brown to black, and light gray, white, or light brown carbonates are common in the sandstone facies. Dark greenish gray to locally dark brown shale partings are present in several intervals.

Fauna.—Ostracodes are common in the limestone beds and conodonts are numerous in the shale partings. Abundant reef-like accumulations of the marine algae *Cryptozoon* are present in the exposure at the Sals Creek diversion channel (McQueen, 1937, p. 16, 18, 20). With these exceptions fossils are not common.

Sharpsboro Member (new)

The Sharpsboro Member is here named for Sharpsboro, a station on the St. Louis-San Francisco Railroad, in Cape Girardeau County, Missouri, 5½ miles southeast of the type section in the Geiser quarry, which also is the type section for the Gordonville Member. The Sharpsboro Member is equivalent to the middle and upper Dutchtown members of McQueen, who lists other exposures (1937, p. 19-21).

Distribution and Thickness.—The distribution of the Sharpsboro Member coincides with that of the Dutchtown Formation. The thickness ranges from 67 feet in a well near Mound City, Pulaski County, southernmost Illinois, to 105 feet in the Midwest Dairy Company well at Cape Girardeau, southeastern Missouri. The area of maximum thickness thus is somewhat farther west than that of the underlying Gordonville Member.

Lithology.—The Sharpsboro Member consists principally of argillaceous dark brown to black, lithographic to fine grained, dense limestone and dolomite that is somewhat silty and sandy at various intervals and is rarely oolitic. Some layers of lighter colored, medium-grained limestone and medium-grained calcarenite are present in the lower part in the type area. Partings of dark brown, calcareous or dolomitic shale are common. In Illinois, beds of light colored, sandy dolomite resembling the overlying Joachim Formation locally are present near the top.

In comparison with Gordonville strata beneath it, the Sharpsboro Member is more argillaceous and shaly, less silty and sandy, darker and browner in color, has a higher proportion of limestone, and is more fossiliferous. The abundant fauna from the Dutchtown is found chiefly in Sharpsboro beds.

Joachim Dolomite

Winslow, 1894; McQueen, 1937

The Joachim Dolomite is the uppermost formation of the Ancell Group in central and southern Illinois, overlying the Dutchtown Formation and underlying the Pecatonica Formation of the Platteville Group. It was named for Joachim Creek in Jefferson County, Missouri (Winslow, 1894), along the lower part of which it is partially exposed. It is the "First Magnesian Limestone" of early reports. As originally defined, the Joachim Dolomite included the dolomite strata overlying the St. Peter Sandstone and underlying the Plattin Limestone. Strata in this position thicken greatly southward from Joachim Creek, and in southeastern Missouri McQueen (1937) differentiated the lower dark colored beds (which do not extend as far north as Joachim Creek) as the Dutchtown Formation and thus restricted the Joachim Formation to the upper beds. The overlying Pecatonica Formation also is absent in the type Joachim area and in the nearby type Plattin area, but it separates Plattin and Joachim strata farther south. Pecatonica strata have not previously been differentiated in the southern outcrop area and have been included in either the Plattin or Joachim Formations, generally the latter.

As a major part of the Joachim Formation, as well as the Dutchtown and Pecatonica Formations, is not present in the Joachim Creek region, a better reference section is found in the Ancell type section—the bluffs and quarries on the north side of State Highway 74 east of Dutchtown in Cape Girardeau County, southeastern Missouri (between SE NW NE 20 and SW NE NE 22, 30N-13E, Cape Girardeau Quad.). The Joachim crops out in the bluffs for over 2.2 miles, and the composite section is 173 feet thick. The Joachim is not completely exposed, and its exposed thickness is reduced by faulting. Further details are given below under the description of members. The section is supplemented by the Midwest Dairy Company well at Cape Girardeau (see *Ancell Group*).

Members.—The Joachim Dolomite is divided into six members on the basis of differences in the content of shale, silt, and sand and differences in bedding. Beginning at the base, the member sequence is Abernathy (sandy, with sandstone at top), Augusta (thick bedded, silty), Boles (thin bedded and shaly), Defiance (thick bedded and silty), Matson (thick bedded and relatively pure), and Metz (thin bedded and silty). No facies relations have been observed between the members and most of them are persistent units throughout the area studied.

Distribution.—The Joachim Dolomite is exposed throughout the southern outcrop area. It has been traced in subsurface from Webster and Trigg Counties, Kentucky, through westernmost Kentucky and southern Illinois to Hancock County, western Illinois. It also has been followed from Adair County, northeastern Missouri (Grohskopf, 1948, fig. 2), to Champaign County, eastern Illinois, and to outcrops at Kentland, Newton County, northwestern Indiana. North of a line extending approximately from Hardin, Calhoun County, Illinois, to Champaign, Illinois, the Joachim begins to grade laterally into the Starved Rock Sandstone. The basal Abernathy Member does not extend north of Perry County, Missouri, but the other members have been traced from southernmost Illinois northward to the zone of gradation into the Starved Rock Sandstone. The upper two members are exposed at Kentland, Indiana. Outcrops of Joachim strata described in this report are listed in the index.

Thickness.—In the southern outcrop belt the Joachim Dolomite thickens southward from 65 feet in southern Calhoun County, Illinois, to 285 feet at Cape Girardeau, Missouri. This southward thickening is interrupted abruptly in southern St. Genevieve County, Missouri, where the formation (possibly including some lower Platteville beds) is said rarely to exceed 60 or 70 feet, apparently due to the absence of the higher Joachim beds (Weller and St. Clair, 1928, p. 100).

In subsurface the Joachim is thickest in extreme southern Illinois. It is 385 feet thick in Pulaski County (Hudson No. 1, SW SE 23, 16S-1W, Cairo Quad., SS-23,495, 2350-2708′), but across the state line in Ballard County, Kentucky, it is only 240 feet thick (Robinson-Puckett, Inc., No. 1 Clark, 22-H-5, SS-9540, 2350-2708′). Northward it thins to 258 feet in Jackson County, 238 feet in central Monroe County, 90 feet in Sangamon County, and 60 feet in Champaign County.

Lithology.—The Joachim grades from more or less silty dolomite in the northern part of the southern outcrop belt to interbedded dolomite and limestone in the southern part. The dolomites are of two principal types. The first type is silty, light gray, white or light buff, chalky, and thin to thick bedded. It has a semi-conchoidal fracture, a smooth, weathered face, and an insoluble residue commonly ranging from 7 to 22 percent. The second type is only slightly silty, light gray or light brown to dark brown, fine grained, mainly porous to finely vuggy, rarely dense, strongly laminated, and thick bedded. It has a rough, weathered face, and generally contains numerous algal domes. The second type has an insoluble residue commonly ranging from 3 to 5 percent.

The limestones are slightly silty to silty, gray to brown, lithographic, laminated, and thick bedded, with a conchoidal fracture and a whitish gray weathered face. The purer units contain many algal domes. The limestones strongly resemble beds in the Plattin but lack the dolomite mottling and the pitted weathered face of the latter.

A characteristic feature of the silty dolomites and silty limestones is the presence of mottling, laminae, streaks, and "penetration marks" composed of dark gray to black, argillaceous, carbonaceous, very pyritic silt. The "penetration marks" are very irregular, nearly vertical wedges that cut through horizontal laminae. They appear in some places to be coatings of the surfaces of mud-cracks but in other places their origin is uncertain.

Most Joachim carbonates are not argillaceous and contain only 1 or 2 percent of clay.

However, some beds of greenish gray argillaceous dolomite and limestone are present, particularly toward the base of the formation. Layers of intraformational conglomerate or breccia also are present, especially in the lower part. Large vugs filled with coarse calcite crystals occur at places in the dolomite and limestone.

Sandstones are confined to the lower part of the formation. They are cemented by white to buff silty dolomite, are mainly medium grained, generally thick bedded, and locally grade into intraformational conglomerates by the incorporation of silty dolomite fragments. The sand grains are well frosted, rounded, and sorted. A few thin sandstone layers are argillaceous, very silty and green, and have Glenwood texture. Gray-green siltstone that weathers buff and is partly dolomitic, argillaceous, or sandy constitutes most of the lower part of the formation in exposures along Sandy Creek, north of Hillsboro, Missouri, but elsewhere this siltstone is found only as thin, local beds.

Two types of shale are common in the Joachim Formation. The first is red-brown, weathering blue-gray to gray-green, is laminated, and is present in films, partings, or thin layers that ordinarily are less than 5 inches thick but have a wide areal extent. The second type is silty, partly dolomitic, gray-green, very thin bedded, and occurs in beds up to 2 feet thick that grade southeastward into argillaceous dolomite within short distances.

White, gray, or black chert is present in the form of nodular bands at several stratigraphic horizons within the Joachim Formation and is common in the Illinois Basin. Anhydrite and gypsum are found in most subsurface samples east of the southern outcrop area and may be equivalent to breccias in the outcrops.

Rapid local changes in facies from sandstone, siltstone, or shale to impure dolomite is common in the lower part of the Joachim Formation, and the entire sequence is subject to a slow regional facies change from dolomite in the north to limestone in the south. Otherwise Joachim strata show little lateral variation. Although individual units represent all gradations between pure, argillaceous, and silty dolomite or limestone, the contacts between different units are sharp. The various lithologic types are interbedded repeatedly and without sequence, although within each member one lithology predominates. The individual beds show much pinch and swell but have considerable lateral continuity and rarely lens out.

Topographic Expression.—In outcrops north of Perry County, Missouri, the Joachim Dolomite combines with the relatively thin overlying Brickeys and Establishment Members of the Mifflin Formation to form a talus-covered slope between cliffs composed of St. Peter Sandstone below and ledges of the Plattin Limestone above. The relatively pure and thick-bedded Matson Member makes a shoulder in this slope. Good natural exposures are rare. From Perry County southward an increase in the proportion of limestone and the thickness of the beds and a decrease in the amount of clastics make the Joachim more resistant to weathering so that its slope-forming character is lost.

Fauna.—Algal domes resembling *Cryptozoon* are common. Other fossils in the Joachim are confined to certain thin stratigraphic zones within which they may be abundant but have little variety. Ostracodes and conodonts (Branson and Mehl, 1933b) are, next to algae, the most common fossils. *Lingula* is found rarely. The only known approach to a normal marine fauna occurs in Matson Limestone near Zell, Ste. Genevieve County Missouri, where the beds contain *Tetradium,* brachiopods, trilobites, and ostracodes.

Stratigraphic Relations.—The possible diastem between the Dutchtown and Joachim Formations has been noted. North of Calhoun County, Illinois, the Joachim Dolomite grades laterally into the Starved Rock Sandstone. The Joachim-Pecatonica contact is exposed at Kentland, Indiana, and the abrupt change in character suggests a possible diastem. Where Pecatonica and basal Mifflin strata are absent, as in the northern part of the southern outcrop belt and in much of western Illinois, the Joachim is overlain unconformably by the Brickeys Member of the Mifflin Formation. Sharp contacts and local scour surfaces along the boundaries between the Joachim members suggests the presence of minor breaks in sedimentation at these horizons.

Deposition.—Joachim sediments are characterized by mud-cracks, ripple-marks, rill-marks, rain-drop impressions, undulatory scour surfaces, conglomeratic layers, and interbedding of thin strata of different lithology. These features suggest interrupted deposition in shallow water under fluctuating conditions. The presence of widely disseminated anhydrite and gypsum and of mud-cracks with downturned edges (Kindle, 1917, p. 140-142), together with the general absence of a normal marine fauna, point toward accumulation in a barred basin that was subject to evaporation and periodic marine influxes.

It appears that much of the silt and sand in the Joachim Formation may have been winnowed out of the Starved Rock sands and carried seaward into the region of carbonate sedimentation. Sand was mixed with carbonate mud throughout this region in early Joachim time, and the sandstone at the top of the Abernathy Member appears to represent a thin but very widespread tongue of the Starved Rock Sandstone. In later Joachim time the admixture of sand was largely confined to the zone of contact with the Starved Rock Sandstone.

Correlation.—The Joachim Dolomite is believed to be equivalent to the upper division of the Pamelia Formation in New York and Ontario (fig. 30).

Abernathy Member (new)

The Abernathy Member of the Joachim Formation is here named for the Abernathy school, 2 miles north of the type section in a bluff on the north side of Missouri State Highway 74, 1½ miles east of Dutchtown, Cape Girardeau County, Missouri (geol. sec. 7) (McQueen, 1939, p. 65-66; stop 29). The type section is cut by a north-trending fault with a downthrow of about 55 feet on the east side. A small exposure at road level on the west side of the fault shows 2 feet of Joachim (Abernathy) on 1 foot of Dutchtown (Gordonville). The type section is supplemented by the Midwest Dairy Company well at Cape Girardeau.

The Abernathy Member is fully exposed, although thin, in the banks of Apple Creek along the Cape Girardeau County-Perry County line, Missouri (from S½ NE NW NW 1 elongated, 33N-11E, northwest 1 mile to NW NE SE 34, 34N-11E, Perryville Quad.). The topmost 2½ feet is exposed in the south bank of Cinque Hommes Creek, beneath the bridge on Missouri State Highway 25, 2 miles southeast of the court house in Perryville, Perry County.

Distribution and Thickness. — Although absent north of Perry County, Missouri, the Abernathy Member is present southward at least as far as western Kentucky. It has been traced eastward in Illinois wells from northwest Jackson County to Hicks Dome, Hardin County. The Abernathy Member ranges from 25 feet thick in the Apple Creek outcrops noted above to 149 feet thick in a well near Mound City, Pulaski County, Illinois (Hudson No. 1, 2559-2708′). It is 60 feet thick at Perryville, Perry County, Missouri, and 95 feet thick in a well near Grand Tower, Jackson County, Illinois. A thickness of only 47 feet on Hicks Dome may indicate eastward thinning or upward movement of the dome during Abernathy time.

Lithology.—The Abernathy Member is composed mainly of silty, sandy, thick-bedded dolomite containing layers of dolomitic, medium-grained sandstone, a few beds of limestone, and some partings of dark red-brown shale. A small proportion of the dolomite is not sandy. At the top there is a distinctive and very persistent layer of St. Peter-type sandstone from 1½ to 14 feet thick, which forms an excellent key bed. It is commonly medium grained, but is fine grained in the exposures along Apple Creek. This sandstone constitutes the basal unit of McQueen's middle division of the Joachim Formation (McQueen, 1939, p. 65-66). The Abernathy Member normally is much lighter colored, less argillaceous, and more silty and sandy than the underlying Dutchtown Formation. It is more sandy than the overlying Augusta Member, contains a coarser grade of sand (chiefly medium grains instead of very fine to fine grains), and usually contains a greater number of shale partings, although it cannot be considered a shaly unit. As a rule the Abernathy also contains a higher proportion of dark brown dolomite or limestone than the Augusta. Chert is common just beneath the topmost sandstone of the Abernathy Member in wells in Jackson County, Illinois, and occurs at several lower horizons. No fossils have been found.

Stratigraphic Relations.—Stratigraphic relations with Dutchtown and Augusta beds have been described. The Abernathy Member is believed to grade westward into Starved Rock Sandstone along Apple Creek, Cape Girardeau and Perry Counties, Missouri, the transition taking place first in the lower Abernathy strata. A similar facies change probably takes place from south to north in central Illinois. In the southern outcrop belt and in adjacent parts of western Illinois the Abernathy Member is thought to thin out northward between Augusta beds and the Tonti Member of the St. Peter, because the Starved Rock Sandstone, as well as the Abernathy, is missing from most of that area.

Augusta Member (new)

The Augusta Member of the Joachim Formation is here named for the village of Augusta, which is 5 miles west of the type section in a cut on the Chicago, Rock Island and Pacific Railroad, at the foot of the bluffs along the southeast side of the Missouri River, a mile southwest of the hamlet of St. Albans, Franklin County, Missouri (geol. sec. 8). The upper 40 feet of the Augusta Member, capped by 23 feet of Boles strata, is also well exposed in the Ancell type section in Cape Girardeau County, Missouri (composite of bluff in SW NE NW 21 projected, quarry in SW NE NW 21, and bluff in S½ NE NE 21, 30N-13E, Cape Girardeau Quad.).

Thickness.—Where unaffected by gradation into the Starved Rock Sandstone the Augusta ranges from 16 feet thick in a well in southern Calhoun County, Illinois, to 106 feet thick near Mound City, Pulaski County, Illinois (Hudson No. 1, 2453-2559′). In exposures in Ste. Genevieve and Perry Counties, Missouri, the Augusta Member varies from 60 to 71 feet thick.

Lithology.—The Augusta Member consists principally of pure to silty, thick-bedded dolomite and limestone. It lacks the sandstone beds and disseminated medium sand grains of the underlying Abernathy Member and generally has fewer shale layers. Ordinarily it is distinctly thicker bedded and less shaly than the overlying Boles Member. However, the lower part of the member contains green shale layers up to 16 inches thick in exposures along Missouri State Highway 25 in Ste. Genevieve County, 2 miles south of Isle du Bois Creek (N½ SE NE 29, 39N-7E, Crystal City Quad.) and 1.3 miles north of Bloomsdale (SE SE SE 3, 38N-7E, Renault Quad.). In a roadcut 4.5 miles north of Hillsboro (see *Defiance Member*), the Augusta is 61 feet thick, and the lower 25 feet consists mainly of gray-green siltstone. In the southern outcrop area the lower part of the Augusta also contains several beds of both Glenwood-type sandstone and more or less dolomitic St. Peter-type sandstone. The sandstone beds are particularly prominent in the type area in the Missouri Valley. The layers of shale, siltstone, and Glenwood-type sandstone grade rapidly eastward and southward into dolomite.

Two layers of pure, brown, algal dolomite or limestone, separated by 4 to 6 feet of silty gray dolomite, are distinctive features of the upper part of the Augusta Member. The upper layer, lying from 2½ to 9 feet below the top of the member, is from 1 to 7 feet thick and the lower layer is from 1½ to 5 feet thick. In some places these pure layers are massive, but in others they exhibit thin to medium beds. Locally both layers are conglomeratic.

A nodular chert band occurs 1 foot 3 inches below the top of the member, 5 feet 8 inches above the floor of the quarry just west of St. Albans, Franklin County, Missouri (center N line NE 10, 44N-2E, Augusta Quad.) and chert is common in the member in wells in southwestern Illinois.

Fauna.—Algal domes generally are common in the pure layers described above and are numerous in the lower pure beds in the Ancell type section. Ostracodes are abundant in a 10-inch bed 9 feet above the base in the highway cut south of Isle du Bois Creek, noted above, and in a bed 11 feet above the base in the cut on Missouri State Highway 25 at Grindstaff Hill State Park in Jefferson County (NW NW NW 34, 40N-6E, Crystal City Quad.).

Stratigraphic Relations.—From Perry County, Missouri, southward, the Augusta Member overlies Abernathy strata, but north of Perry County it rests directly on the Tonti Member of the St. Peter Sandstone.

Boles Member (new)

The Boles Member of the Joachim Formation is here named for the hamlet of Boles, which is on the Missouri Pacific Railroad on the south side of the Missouri River and 6 miles southwest of the type section, a quarry in the bluffs on the north side of the river 1 mile southwest of Matson, St. Charles County, Missouri (geol. sec. 9).

Thickness.—The Boles Member is the thinnest but the most uniform of the Joachim members. The thickness shows no consistent variation in any direction, and in most outcrops is close to 20 feet. However, it ranges from 15 feet in several wells to 30 feet in the Ancell type section at Cape Girardeau, Missouri.

Lithology.—The Boles Member consists principally of thin to medium beds of silty, dense dolomite alternating with similar layers of pure, vuggy dolomite. In the Cape Girardeau section, however, the member is limestone. Closely spaced films, partings, and layers of dark red-brown to gray-green shale, as much as 5 inches thick but usually thinner, are a characteristic feature. One distinctive 4-inch shale lying 15 feet below the top of the member at Cape Girardeau is heavily mottled with bright yellow. The Boles Member contains at least seven discontinuous bands of nodular white to black chert. In Jefferson and St. Louis Counties, Missouri, a chert band within this member has been designated as the boundary between the Rock Levee and Joachim Formations (Grohskopf, 1948), but in a well in southern Jackson County, Illinois (Baysinger No. 1), the boundary was placed at a chert band that appears to be near the base of the Augusta Member. The Boles Member may be distinguished from adjacent members by its thin bedding, high shale content, and the usual presence of one or more chert bands, although no chert is present in the Ancell type section at Cape Girardeau. Distinctive "penetration marks" also are particularly common in this member. The numerous shale partings make the member especially conspicuous in a fresh face, such as is found in a quarry 1½ miles southeast of Perryville, Perry County, Missouri (NW NW NE 29 projected, 35N-11E, Perryville Quad.) where the sequence from the top downward is: *Joachim 62′6″ (Defiance 16′, Boles 19′6″, Augusta 27′).* A chert band, not present in the quarry, occurs 1½ feet below the top of the Boles Member in the highway cut and adjacent gully on the north side of Cinque Hommes Creek 0.35 mile east of the quarry, where the section in descending order is: *Joachim 67′ (Defiance 14′, Boles 19′6″, Augusta 33′6″).*

Defiance Member (new)

The Defiance Member of the Joachim Formation is here named for the village of Defiance, St. Charles County, Missouri, 3 miles northeast of the type section (geol. sec. 9), which is the same as for the Boles Member. Defiance strata also are well exposed (1) half a mile south of Glencoe, St. Louis County, Missouri, on the east side of County Highway B (SW SW NE 24, 44N-3E, Eureka Quad.) where the section from the top is: *Joachim 32′ (Defiance 17′ 9″, Boles, with four nodular chert bands, 14′ 3″);* and (2) in a cut on the west side of Missouri State Highway 21, 4.5 miles north of Hillsboro, Jefferson County (SE NE SE 2 projected, 41N-4E, Hillsboro Quad.), where the sequence is: *Platteville Group 125′; Ancell Group, Joachim 136′ (Metz 7′6″, Matson 30′, Defiance 22′, Boles 15′6″, Augusta 61′), St. Peter 21′.*

Thickness.—The Defiance Member ranges from 20 feet 6 inches thick in the Joachim alternate type section to 40 feet in the Midwest Dairy Company well at Cape Girardeau (see *Abernathy Member*). The thickness may reach 50 feet near Grand Tower, Jackson County, Illinois (Baysinger No. 1 well), where the sequence below 1850 feet is thought to be: *Joachim 305′ (Metz 20′, Matson 25′, Defiance 50′, Boles 15′, Augusta 100′, Abernathy 95′).* This interpretation is based on rearrangement of certain samples whose depth appears to have been mislabeled. A thickness of 58 feet was measured in a ravine just south of Isle du Bois Creek, in Ste. Genevieve County, Missouri (N½ NW 20, 39N-7E, Crystal City Quad.), but the section is only partially exposed, and the thickness may be exaggerated by faulting.

Lithology.—The Defiance Member is composed mostly of silty, party argillaceous, thick-bedded dolomite that has a smooth, white, weathered face. The basal unit, however, consists of only slightly silty, thick-bedded to massive dolomite from 4½ to 15 feet thick (generally from 5 to 10 feet thick) that has a rougher and browner face than the rest of the member. This unit contains closely spaced films of dark brown shale in the northern part of the outcrop area. Although the Defiance Member contains several beds of gray-green shale in the type area, including one 18- to 24-inch bed about 2 feet below the top, most of the shale grades southward into argillaceous, silty dolomite before reaching the exposure at Glencoe, St. Louis County (see *Matson Member*). The shale layers probably represent the outer margin of the contact facies with the Starved Rock Sandstone Member of the St. Peter. The argillaceous dolomite associated with the shale is characteristically mottled and streaked with dark, carbonaceous, pyritic material. A little chert occurs in the lower part of the Defiance in wells in Jackson County, southwestern Illinois, and a nodular band of white chert is present 8½ feet above the base of the member and 4 feet below the top of a quarry which is above and about ⅛-mile northeast of the highway cut near Bloomsdale, Missouri (see *Augusta Member*). In the Ancell type section, the Defiance Member consists of silty dolomite and limestone interbedded with pure limestone and is best exposed in the Arnold quarry (SW NW NE 22 projected, 30N-13E, Cape Girardeau Quad.), where the sequence from the top is: *Joachim 73′ (Matson 12′, Defiance 32′, Boles 29′).* The limestone facies seems chiefly confined to the Cape Girardeau area. Except for occasional algal domes, especially in the purer basal unit, fossils have not been observed in the Defiance Member.

Matson Member (new)

The Matson Member of the Joachim Formation is here named for the village of Matson, St. Charles County, Missouri, which is just east of the type section (geol. sec. 10). The Matson Member is well exposed in the Metz Member type section (geol. sec. 11) and also in a cut on the Missouri Pacific Railroad on the north side of the Meramec River just east of Glencoe, St. Louis County, Missouri (SE NW NW 19, 44N-4E, Manchester Quad.), where the section from the top is: *Platteville Group; Ancell Group, Joachim 51′ (Metz 16′, Matson 21′6″, Defiance 13′6″).* The southernmost exposure is in the bluff forming the eastern end of the Ancell type section, .3 mile east of the Arnold quarry (NW NE NE 22, 30N-13E, Cape Girardeau Quad.) where the succession from the top downward is: *Joachim 36′ (Matson 32′, Defiance 4′).*

Thickness.—South of the zone affected by lateral gradation into the Starved Rock Sandstone, the Matson Member ranges from 15 feet thick near Prairie du Rocher, Randolph County, Illinois (Nicholson No. 1, SW NW NW 12, 5S-9W, Renault Quad., SS-2974, 1685-1700′), to 43 feet thick near Campbell Hill, Jackson County, Illinois (Leiner No. 1, SS-2536, 3853-3896′). However, in the majority of outcrops and wells the thickness of the member is close to 30 feet.

Lithology.—The Matson Member consists mainly of relatively pure, gray to light brown, laminated, thick-bedded algal dolomite that grades southward into dark brown limestone having the same features. In the Metz type section a 17-inch unit 17 inches below the top of the Matson consists partly of fine-grained, faintly cross-bedded, detrital dolomite. Purity, massiveness, and relatively strong resistance to weathering distinguish the Matson from any other member of the Joachim, but during the early part of the present study in the St. Louis region it was confused with the Pecatonica Formation, which is similar in many respects but is absent in that region.

In the dolomite facies, the Matson has a weathered face that is darker and rougher than that of the adjacent members. The dolomite facies contains some relatively thin layers and lenses of silty, yellowish white, smooth-faced dolomite that generally are less than 2½ feet thick. Such silty lenses are conspicuous in the exposure at Glencoe mentioned above. Chert has not been observed in the Matson Member. A few thin layers of platy to slightly shaly dolomite or limestone are present locally.

Fauna.—Ostracodes are abundant in several beds in the basal 5½ feet of the Matson Member at the exposure north of Hillsboro (see *Defiance Member*), and are present in a thin-bedded reentrant about 10 feet below the top of the bluff that constitutes the eastern end of the Ancell type section. Algal domes as much as 3 feet in diameter and 2 feet high occur 13½ feet below the top of the bluff. The marine fauna referred to under *Joachim Formation* is found in 7 feet of dolomitic limestone, which constitutes the basal unit of the Matson Member, in a ravine just north of the village of Zell, Ste. Genevieve County, Missouri (geol. sec. 18).

Metz Member (new)

The Metz Member of the Joachim Formation is here named for Metz Lake on the floodplain of the Mississippi River, 5 miles north of the type locality, a quarry just north of West Point Creek and Landing, Calhoun County, Illinois (geol. sec. 11). The Metz Member crops out in a cut on the north side of Missouri State Highway 30 between House Springs and Cedar Hill, Jefferson County, Missouri (NE NW SE 18, 42N-4E, Hillsboro Quad.) where the sequence from the top is: *Platteville Group; Grand Detour, not measured, Mifflin 16′ (Establishment 3′, Brickeys 13′); Ancell Group, Joachim 27′6″ (Metz 11′, Matson 16′6″).* It also is exposed near Zell (geol. sec. 18) and near Bloomsdale (geol. sec. 17), both in Ste. Genevieve County, Missouri. All but about the basal 3 feet of the Metz is exposed in a quarry 0.8 miles east of Glencoe, St. Louis County, Missouri (see *Mifflin Formation, Brickeys Member*).

Thickness.—The Metz Member is commonly about 15 feet thick but ranges from 7½ or 8 feet thick at the Hillsboro section (see *Defiance Member*) and at the Brickeys type section to 20 feet thick in a well near Waterloo, Monroe County, Illinois (A-2 Kolmer, NW NE NW 2, 2S-10W, Waterloo Quad., SS-4425, 725-745′), and near Grand Tower, Jackson County, Illinois (Baysinger No. 1, SS-4777, 1850-1870′).

Lithology.—The Metz Member consists chiefly of silty, thin- to medium-bedded dolomite but contains subordinate beds of pure dolomite. In the Cape Girardeau area and adjacent parts of Illinois the member grades wholly or partly to silty limestone. Relatively thin units composed of argillaceous, silty, moderately shaly, thin-bedded dolomite or limestone generally are present at the top and bottom of the member. These argillaceous units range from 1½ to 3 feet thick and in places exhibit prominent mud-cracks on the bedding surfaces. A 6-inch bed of moderately silty oolitic dolomite occurs about 1 foot 9 inches below the top of the Metz Member in Ste. Genevieve County, Missouri. Scour surfaces having a relief of as much as 12 inches are common within the member. No chert has been observed and, with the exception of a few algal domes, no fossils have been found.

Stratigraphic Relations.—Southward from Perry County, Missouri, and Jackson County, Illinois, the Metz Member is overlain by the Pecatonica Formation. The abrupt lithologic change suggests the presence of a minor diastem, but no evidence of unconformity has been found. North of Perry and Jackson Counties the Pecatonica Formation and the basal Blomeyer Member of the succeeding Mifflin Formation wedge out, so that the Brickeys Member of the Mifflin rests directly upon Metz strata. As neither Metz nor Brickeys beds are missing in the area and neither show important variations in thickness, this hiatus apparently was not accompanied by erosion. However, a significant break in sedimentation is suggested by the common presence of a combined scour and solution surface at the top of the Metz. This surface is well exhibited in the quarry east of Glencoe, Missouri, mentioned above, where it has an undulatory relief of 6 inches and is pitted and ferruginous.

PLATTEVILLE GROUP

Bain, 1905; modified by Calvin, 1906, and in this report

The Platteville Limestone (fig. 15) was named by Bain (1905, p. 18-21) for Platteville, Grant County, southwestern Wisconsin, about 4 miles east of type exposures along the Little Platte River. Because Bain designated no specific type section, Kay (1931, p. 369, 371) proposed as the type a ravine exposure west of Platteville (SW NW NW 20, 3N-1W, Lancaster Quad.). A more accessible, better exposed section that more clearly shows the relations to adjacent groups is now available in a roadcut on the west side of U. S. Highway 151, 5 miles southwest of Platteville (SE SW SE 1, 2N-2W). This exposure shows the following sequence from the top: *Galena Group, Spechts Ferry 2′; Platteville Group, Quimbys Mill 5-12″, Nachusa 3′2″, Grand Detour 16′2″, Mifflin 11′3″, Pecatonica 22′; Ancell Group, Glenwood 4′, St. Peter.* (See also Agnew et al., 1956, p. 274.) Many Platteville members are missing in the exposure, but all the Platteville formations are present, and a more complete succession is not available in the type area.

Although previously classified as a formation, the Platteville is herein considered a group because (1) it is divisible into five widespread, distinctive, mappable units that merit formational rank, (2) it has a maximum thickness of 780 feet, and (3) equivalent strata elsewhere in eastern North America have group status.

Within the Platteville Group, a regional diastem or unconformity is present at the top of the Pecatonic Formation, and Pecatonica or older strata, if deposited, were entirely eroded in parts of Minnesota and Missouri and locally over anticlinal structures. Nevertheless, the Pecatonica is included within the group because in lithology and fauna it is much more like Platteville strata above than Ancell strata below.

Although the name "Trenton Limestone" was applied for many years to strata overlying St. Peter Sandstone and underlying massive Galena Dolomite (fig. 16), after the pre-Trenton age of most of these strata was recognized (Ulrich, *in* Winchell and Ulrich, 1895, p. l-li; 1897, p. lxxxvii-ci) the name Platteville was introduced as a replacement (Bain, 1905, p. 18-21). In terms of the present classification, the Platteville originally included beds from the base of the Harmony Hill Shale Member of the Glenwood Formation to, or nearly to, the top of the Guttenberg Formation. Later it was redefined to exclude Guttenberg strata, which were placed in the Galena Formation (Bain, 1906, p. 21). Calvin (1906, p. 60-61, 74-76, 81-82) excluded the beds now called Harmony Hill and Spechts Ferry from the Platteville Formation. Usage has since varied, but in Illinois, following Kay (1935a, p. 285-288; 1940a, p. 234), the Harmony Hill has been excluded from the Platteville, and the Spechts Ferry has been included. It is proposed here to return to the definition given by Calvin, which recognizes the more important physical changes and emphasizes the lithologic unity of the group.

The name "Trenton" is used in oil field terminology for the limestone underlying the Maquoketa Shale and is applied in some cases to the oil-producing upper part of the limestone and in others to all the limestone between the Maquoketa Shale and the St. Peter Sandstone. In the later usage it includes strata of both Trentonian and Blackriveran age. As currently used by drillers in the northwestern Illinois lead-zinc district, the name "Trenton" applies to the limestone below the "clay bed," that is, to the limestone below the Spechts Ferry Shale.

THIS REPORT						PREV. CLASS.		
						N. ILLINOIS		S. ILL.
Group	Sub-group	Formation	Member		Feet	Fm.	Member	Fm.
PLATTEVILLE	Plattin	Quimbys Mill 3-35'	Strawbridge		0-15	Platteville	↑ Spechts Ferry	Plattin
			Shullsburg		3-20			
			Hazel Green		0-10			
		Nachusa 0-75'	Everett		0-25		Magnolia	
			Elm		0-15			
			Eldena		0-40			
		Grand Detour 15-210'	Forreston		2-40			
			Victory		0-7			
			Hely		3-73			
			Clement		0-13			
			Stillman		5-65			
			Walgreen		0-12			
			Dement		9-20			
		Mifflin 10-120'	Briton		3-55		Mifflin	
			Hazelwood		1-50			
			Establishment		2-8			
			Brickeys		1-20			
			Blomeyer		0-15			
		Pecatonica 15-140'	Oglesby		0-15		Pecatonica	Joachim ↓
			Medusa		5-20			
			New Glarus		5-25			
			Dane		5-60			
			Chana		0-20			
			Hennepin		0-4			

FIG. 15.—Classification of the Platteville Group in Illinois.

Other names have been proposed for the approximate stratigraphic interval of the Platteville Group. The Beloit Formation (Sardeson, 1896b, p. 23-24, 361-363; 1907, p. 184-190), a name introduced as a replacement for "Trenton Limestone" in the Mississippi Valley, included beds from the top of the St. Peter Sandstone to the top of the St. James Member of the Dunleith Formation. Although it has priority over the name Platteville, is has not come into general use, and its revival would require greater redefinition than is now required for Platteville.

The Bryant Formation of eastern Missouri (Keyes, 1898, p. 59, 61), as originally defined, included the Plattin, Decorah, and all of the Kimmswick except the upper 50 feet, which was named McCune. However, Bryant was later interpreted by Keyes and others to have been intended for strata below the Kimmswick, with which meaning it includes strata from the base of the Mifflin Formation to the top of the Guttenberg Formation. Used in that sense, the name Bryant has priority over Plattin (Ulrich, *in* Buckley and Buehler, 1904, p. 111), which originally was proposed for the same stratigraphic interval, but Bryant has not been used. Subsequent exclusion of Decorah strata from the Plattin (Weller and St. Clair, 1928, p. 109-110) made the top of the Plattin Formation coincide approximately with the top of the Platteville as defined by Calvin (1906, p. 81-82).

As the Plattin Formation for many years had been considered equivalent to the Platteville Formation, DuBois (1945, p. 17, 23-25) proposed that the older name Plattin be used in Illinois except in the northern part of the state, where he applied the compound name Plattin (Platteville). However, Pecatonica strata have not been included in most applications of the term Plattin, and they are not present in the type area of the Plattin. Pecatonica strata also are excluded from the Plattin by recent definitions (Grohskopf, 1948, p. 354-359; Larson, 1951, p. 2043-2046; 2061-2066) which restrict the Plattin to beds above the oolite of the Mifflin Formation. Therefore, Plattin and Platteville are not synonymous names. The name Plattin is here rejected as a group name but is retained in the classification as a subgroup.

Distribution.—The Platteville Group is exposed throughout the northern and southern outcrop areas (fig. 1). In northeastern Missouri the group is overlapped by Galena strata (Grohskopf, 1948, fig. 2).

Thickness.—The Platteville Group ranges from as little as 10 feet thick in a well in Faribault County, southern Minnesota (Stauffer and Thiel, 1941, p. 142) to 780 feet in a well in Ballard County, northwestern Kentucky, opposite southernmost Illinois (Robinson-Puckett, Inc., No. 1 Clark, 22-H-5, SS-9540, 1800-2580′). In the northern outcrop area it is commonly between 30 and 135 feet thick, but it thickens southeastward and is 222 feet thick at Kentland, Indiana. In the southern outcrop area it ranges from 150 feet thick in Calhoun County, western Illinois, to 580 feet in Cape Girardeau County, southeastern Missouri (Midwest Dairy Company well at Cape Girardeau, SS-6150, 85-665′). In subsurface between the outcrop areas, it is only 21 feet thick in a local area of abnormal thinning in Hancock County, western Illinois, but it thickens eastward to 204 feet in Sangamon County, central Illinois. Regional southward thickening of the Platteville Group is mainly the result of thickening of members present in the northern outcrop area, but a few new members also are introduced.

Lithology.—The Platteville Group is characterized by three regional facies:

1) A thin, shaly facies in which blue-gray, lithographic, partly dolomitic, thin-bedded limestone with a bryozoan-brachiopod-arthropod fauna predominates. This facies embraces most of the group in southeastern Minnesota, northeastern Iowa, southwestern Wisconsin, and the eastern part of the upper peninsula of Michigan.

2) A thicker, less shaly facies containing similar limestone, but in which partly cherty dolomite with a coralline-molluscan fauna is common or dominant. This facies embraces northern Illinois, south-central and eastern Wisconsin, and the outlier at Limestone Mountain in the western part of the upper peninsula of Michigan. The Pecatonica For-

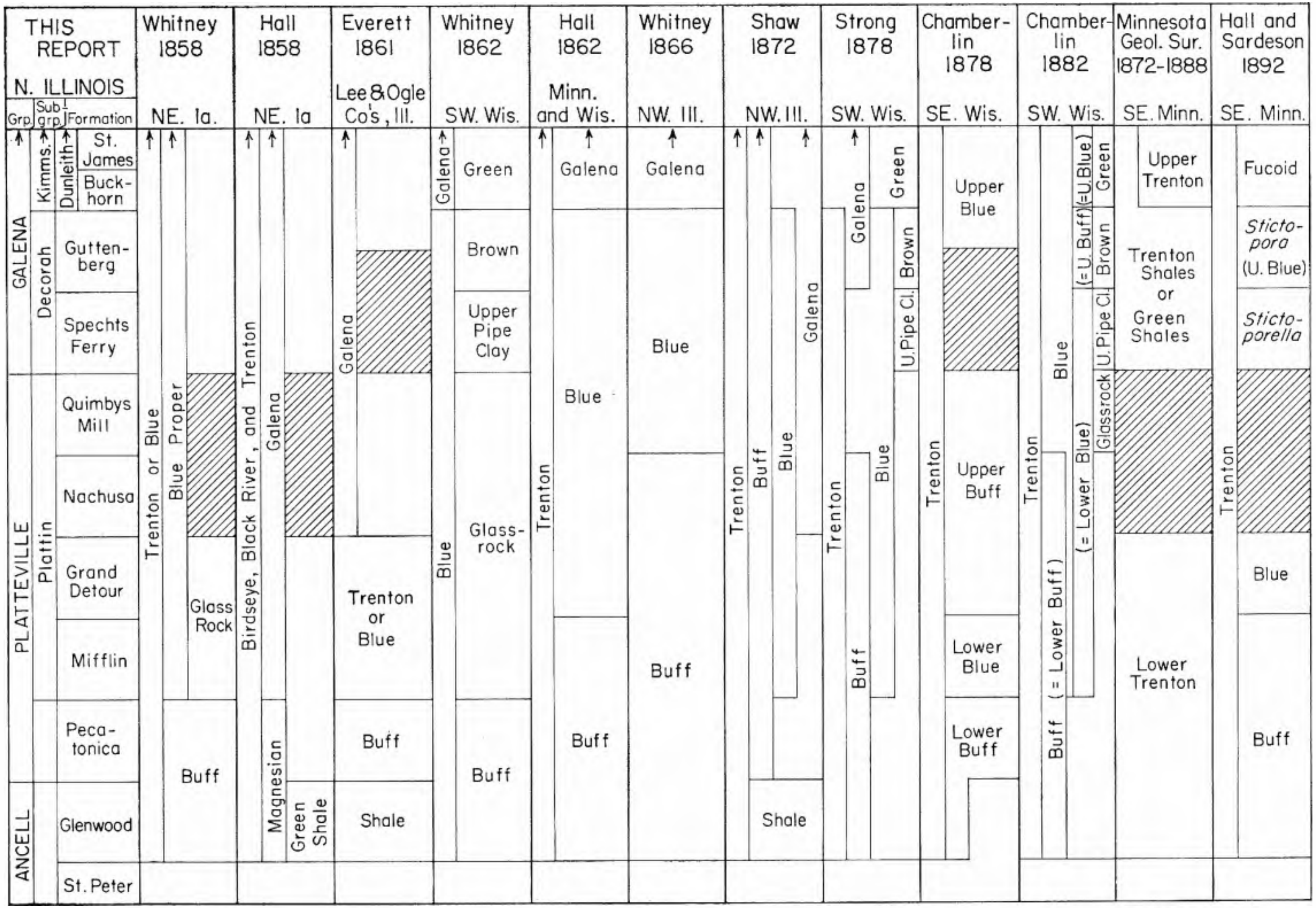

FIG. 16-A.—Development of the classification of the Platteville Group in the northern outcrop area from 1858 to 1892.

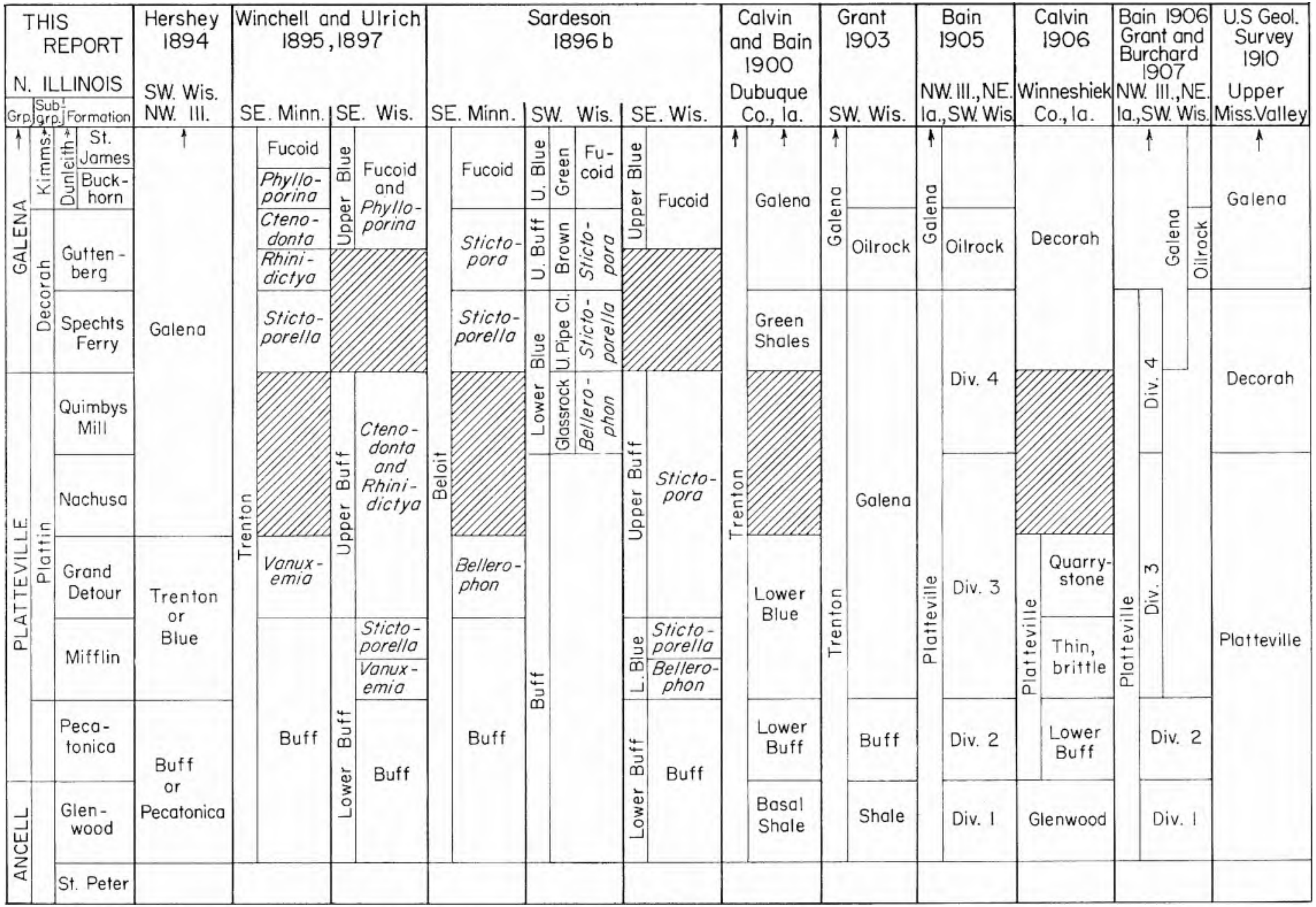

FIG. 16-B.—Development of the classification of the Platteville Group in the northern outcrop area from 1894 to 1910.

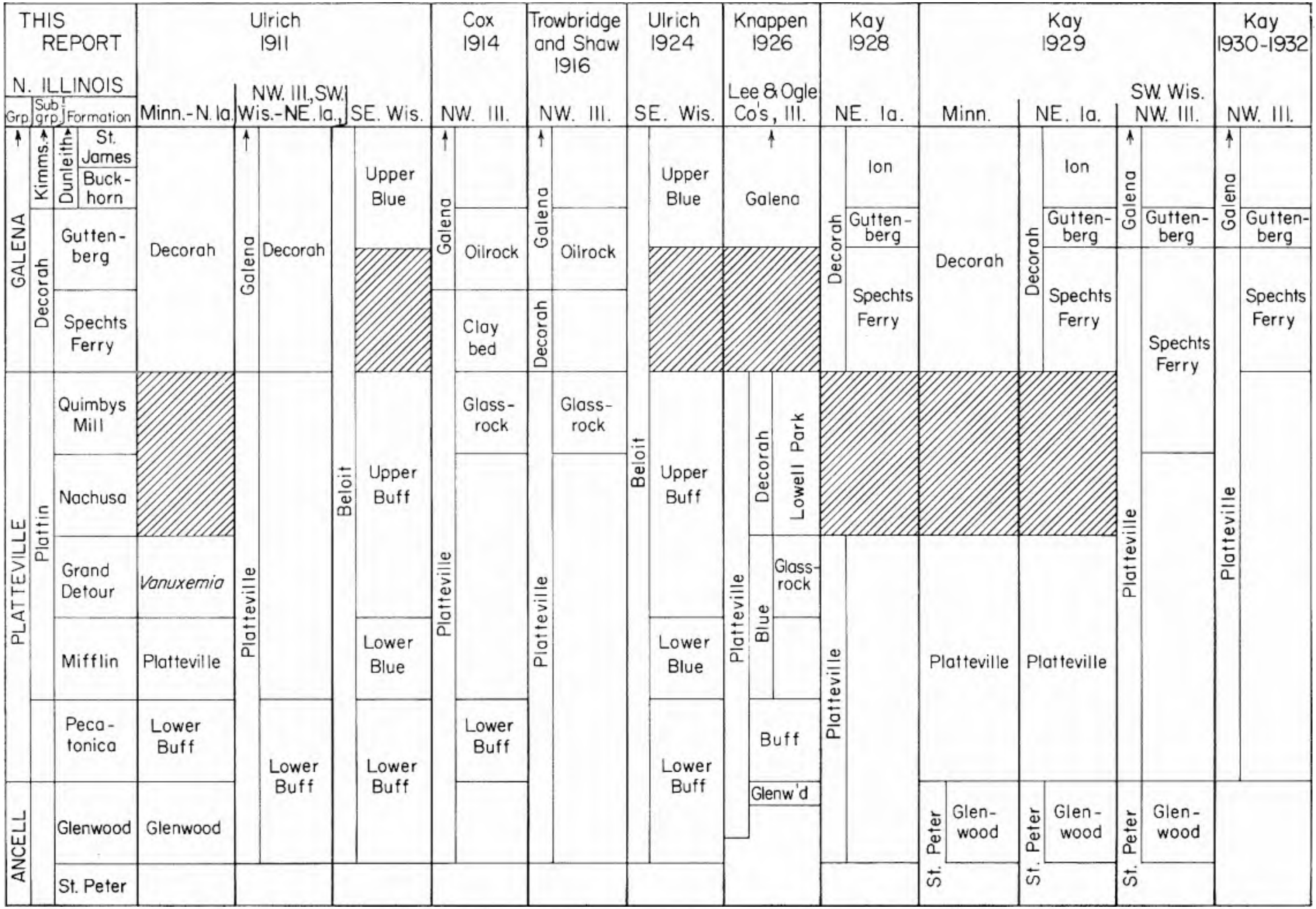

FIG. 16-C.—Development of the classification of the Platteville Group in the northern outcrop area from 1911 to 1932.

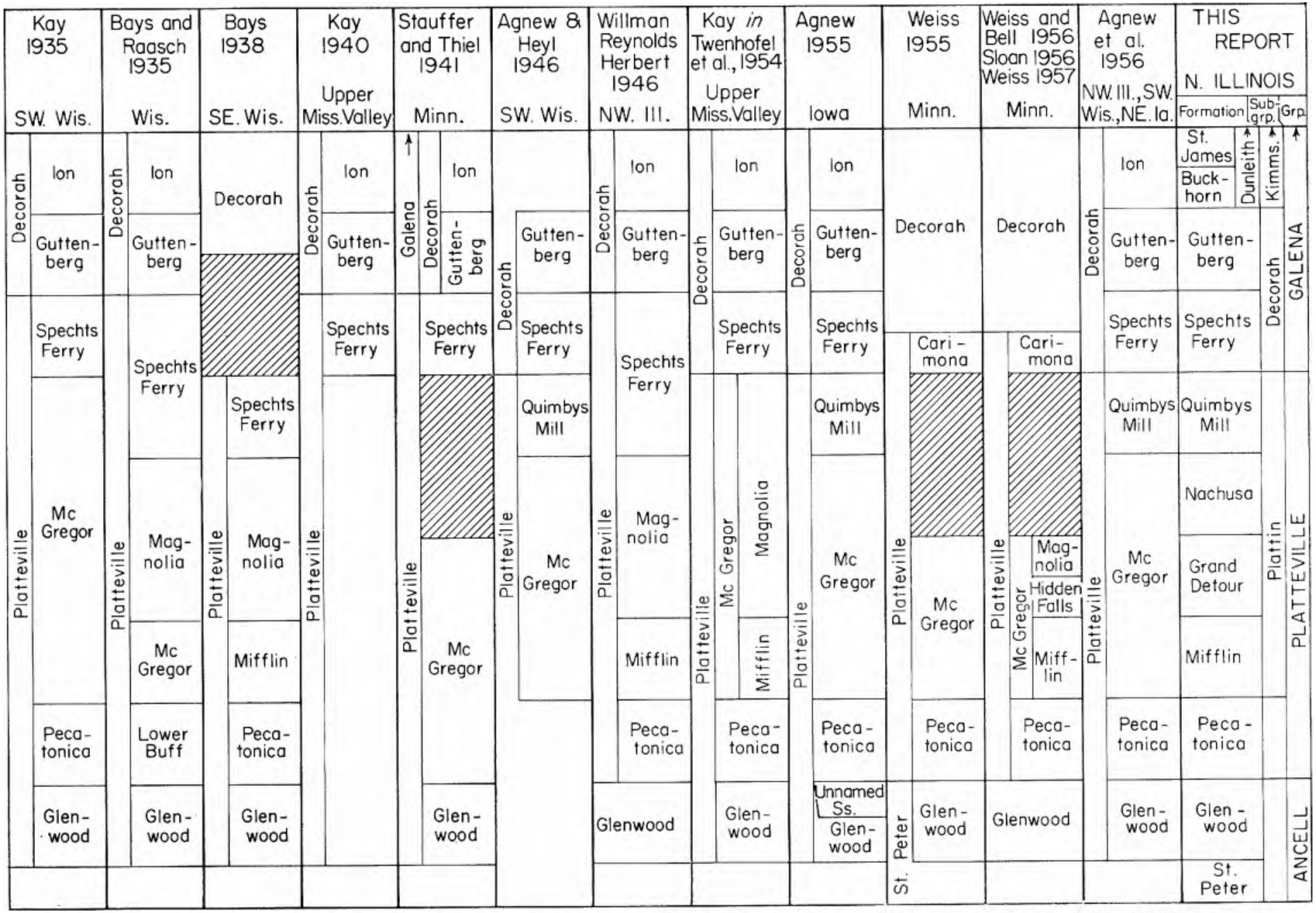

FIG. 16-D.—Development of the classification of the Platteville Group in the northern outcrop area from 1935 to date.

mation is present in this facies from southernmost Minnesota to northern Illinois.

3) A thick, relatively pure, slightly shaly facies that consists mainly of dark brown, lithographic, partly dolomitic, and thin- to thick-bedded limestone. It has a sparse brachiopod fauna. This facies extends from southeastern Missouri to northwestern Indiana.

The boundaries between the facies are irregular, gradational, and interfingering, and the facies changes are subordinate to the vertical lithologic changes that define the formations and members described below. The formations and members can be traced from one facies to another, and they extend from central Tennessee to the upper peninsula of Michigan and eastward to northern New York without important changes in lithology or fauna. Each unit is believed to have been deposited, under remarkably uniform conditions of sedimentation, at practically the same time over a large region.

The persistent association of dolomite, chert, and a molluscan fauna in a position between the shaly facies and the comparatively pure facies suggests that all three elements were primary, or nearly primary, in origin, and attained maximum development in this environment.

Fauna.—Fossils are common to profuse and occur in great variety in most Platteville strata of the northern outcrop area. In the southern outcrop area they are less numerous. The most prolific faunas generally are found in the northern shaly limestone facies of the Mifflin and Quimbys Mill Formations. In the Pecatonica, fossils commonly are scarce. A few particularly abundant and characteristic Platteville species are listed below. Well known but obsolete generic names are shown in brackets. An asterisk preceding the name denotes species apparently confined to Platteville and equivalent strata. The letter preceding the name indicates that the species ranges (A) above or (B) below the Platteville Group. (N) or (S) following the name shows whether the species occurs chiefly in the northern or southern outcrop area.

Stromatoporids
- * *Cryptophragmus antiquatus* Raymond (S)
- A *Stromatocerium rugosum* Hall (S)

Corals
- A *Foerstephyllum [Columnaria] halli* (Nicholson) (N,S)
- A *Lambeophyllum [Streptelasma] profundum* (Conrad) (N)
- B *Tetradium syringoporoides* Ulrich (S)

Bryozoans
- A *Escharopora subrecta* Ulrich (N,S)
- A *Rhinidictya exigua* Ulrich (N)
- A *Rhinidictya trentonensis* (Ulrich) (N)

Brachiopods
- AB *Campylorthis deflecta* (Conrad) (N,S)
- AB *Glyptorthis bellarugosa* (Conrad) (N,S)
- AB *Hesperorthis tricenaria* (Conrad) (N,S)
- A *Öpikina minnesotensis* (N. H. Winchell) (N,S)
- A *Öpikina transitionalis* (Okulitch) (N,S)
- A *Pionodema conradi* (N. H. Winchell) (N)
- A *Skenidioides anthonensis* (Sardeson) (N)
- * *Strophomena plattinensis* Fenton (N,S)

Pelecypods
- A *Ctenodonta astartaeformis* Salter (N)
- * *Vanuxemia dixonensis* Meek & Worthen (N,S)
- * *Vanuxemia rotundata* (Hall) (N)

Gastropods
- A *Liospira vitruvia* (Billings) (N,S)
- A *Loxoplocus [Lophospira] serrulatus* (Salter) (N,S)
- * *Phragmolites fimbriatus* (Ulrich & Scofield) (N)
- * *Sinuites rectangularis* (Ulrich & Scofield) (N)
- A *Tetranota obsoleta* Ulrich & Scofield (N)

Cephalopods
- A *Actinoceras bigsbyi* Bronn (N)
- A *Beloitoceras pandion* (Hall) (N)
- * *Plectoceras occidentale* (Hall) (N)

Trilobites
- * *Basiliella [Basilicus] barrandei* (Hall) (N)
- * *Calliops plattevillensis* Ulrich & Delo (N)
- A *Illaenus americanus* Billings (N,S)
- A *Thaleops ovatus* Conrad (N)

Ostracodes
- AB *Eoleperditia fabulites* (Conrad) (N,S)

Most species not confined to Platteville strata range upward rather than downward. This fact suggests that in fauna and in depositional environment the Platteville is more closely related to the overlying Galena Group than to the underlying Ancell Group.

Stratigraphic Relations.—The Platteville Group is separated from the underlying Ancell Group and the overlying Galena Group by strong diastems and local unconformities. Evidence for the Ancell-Platteville interruption in sedimentation consists of (1) a persistently sharp contact with an abrupt change in lithology; (2) the presence of a scour surface having relief of from 2 to 12 inches in nearly all exposures in the southern outcrop area and at a few exposures in the northern outcrop area, as at the Daysville-Chana contact in a quarry in Green County, Wisconsin (SW NW NE 20, 2N-8E, Monroe Quad.); (3) the almost universal presence of small black phosphatic pellets just above the contact in the northern area; (4) the absence of Glenwood strata in much of central southern Wisconsin and in parts of northern Illinois; and (5) the local occurrence in the basal Platteville of central southern Wisconsin of pebbles of St. Peter Sandstone, for example, in an outcrop in Green County, Wisconsin (SE NE SW 13, 2N-6E, Monroe Quad.), or of pebbles of Daysville Limestone, as in a railroad cut in Rock County, Wisconsin (NW NE NE 34, 2N-12E, Janesville Quad.). Evidence for the Platteville-Galena break in sedimentation is presented in the discussion of the Galena Group.

Except for a regional diastem at the top of the Pecatonica Formation and for relatively local diastems indicated by the wedging out of certain formations or members, no major breaks in sedimentation are present within the Platteville Group. Minor interruptions in sedimentation between most formations and members are suggested by sharp contacts. Between Dixon, northern Illinois, and Minneapolis, Minnesota, as well as in upper Michigan, many short breaks in post-Pecatonica deposition are indicated by corrosion surfaces, chiefly within the members.

Correlation.—The Platteville Group is correlated with the Lowville and Chaumont Formations of the Black River Group in New York State (fig. 30). Cooper (1956) correlated the Platteville with the Chaumont and lower Rockland strata. Other correlations are discussed under *Regional Correlations*.

Other Names.—Upper Plattin strata that have undergone secondary silicification at places in eastern Missouri have been called the Auburn Chert (Rowley, 1908, p. 14), but the beds do not represent a constant stratigraphic interval and are a local, surficial feature. Use of the name Auburn therefore has been dropped (Branson, 1944, p. 72).

The name McGregor Member (Kay, 1935a, p. 286-287) was proposed for strata lying between the Pecatonica and Spechts Ferry Formations, and in Minnesota Pecatonica beds have been included within the McGregor (Stauffer and Thiel, 1941, p. 77-78). Recently McGregor has been redefined to exclude the Quimbys Mill Formation (Agnew and Heyl, 1946) and thus has become equivalent to the Mifflin, Grand Detour, and Nachusa Formations of the present paper. The McGregor is essentially equivalent in interval to the Plattin, but the name Plattin has priority.

Although not needed in Illinois, McGregor is a useful name in the thin Platteville sequence of southeastern Minnesota and parts of northeastern Iowa. There the Pecatonica-Mifflin contact is conspicuous, Mifflin-Grand Detour differences generally are slight because of westward increase in the shaliness of the Grand Detour, and the Nachusa Formation is missing.

In Minnesota the McGregor has been subdivided recently into three members, the Magnolia (at the top), Hidden Falls, and Mifflin (Sloan, 1956; Weiss and Bell, 1956). The Mifflin is equivalent to the Mifflin Formation of this report. The Hidden Falls is equivalent to our Stillman Member and the Magnolia to our Forreston Member of the Grand Detour Formation (see *Pecatonica Formation, Hennepin Member*). The Hidden Falls Member is equivalent to part of the type Magnolia in Wisconsin, and is lithologically more like the type Magnolia than the upper member.

The name Magnolia Member (Bays and Raasch, 1935, p. 289-299; Willman and Payne, 1942, p. 63) is equivalent to most of the Upper Buff Limestone of central southern Wisconsin (Chamberlin, 1878, p. 291, 295-297) and represents the combined Grand Detour and Nachusa Formations. It is no longer needed in the Illinois classification.

The name Lowell Park Member (Knappen, 1926, p. 54) was introduced for strata

This Report				Larson (1951) and Grohskopf (1948)		
Grp.	Formation		Member	Member	Formation	Grp.
Galena ↑	Guttenberg				Decorah	
	Kings Lake					
	Spechts Ferry		Glencoe			
			Castlewood	Zell	Macy	Plattin
Platteville	Plattin Subgroup	Quimbys Mill	Strawbridge			
			Shullsburg			
			Hazel Green			
		Nachusa	Everett	Hook		
			Elm			
			Eldena			
		Grand Detour	Forreston			
			Victory		Hager	
			Hely			
			Clement			
			Stillman	Upper Beckett	Beckett	
			Walgreen			
			Dement			
		Mifflin	Briton	Lower Beckett		
			Hazelwood			
			Establishment		Bloomsdale	
			Brickeys			
			Blomeyer		Rock Levee	Buffalo River
	Pecatonica		Oglesby			
			Medusa			
			New Glarus			
			Dane			
			Chana			
			Hennepin			
Ancell	Joachim		Metz			
			Matson			
			Defiance			
			Boles		Joachim	
			Augusta			
			Abernathy			
↓	Dutchtown				Dutchtown	↓

FIG. 17.—Comparison of classifications of Platteville and Plattin strata in the southern outcrop area.

in central northern Illinois that are now subdivided into the Nachusa and Quimbys Mill Formations. The name therefore is no longer needed.

In Missouri, Pecatonica and lowermost Mifflin strata have been placed in the Rock Levee Formation (Grohskopf, 1948, p. 360-362), which is not adopted for use in Illinois for reasons cited under *Joachim Formation.*

Recently the Plattin Formation of eastern Missouri has been elevated to a group and divided into several formations and members (Larson, 1951). The correlation between the Platteville nomenclature proposed herein and the nomenclature used by Grohskopf and Larson for equivalent strata is shown in figure 17.

Except for the Blomeyer, Brickeys, and Establishment Members of the Mifflin Formation, the Platteville units herein described were differentiated in the northern outcrop area prior to Larson's study and were traced independently to southern Illinois and eastern Missouri. During this tracing Larson generously made his preliminary classification as well as much outcrop data available to us. Although use of Larson's nomenclature in Illinois has been carefully considered, we prefer the classification developed in the northern outcrop area because (1) it divides the sequence into formational units that are more natural from a regional point of view, and because (2) it recognizes as members distinctive units that Larson combined. Many units that we consider members were differentiated independently by Larson, but not named, in part because of differing interpretations of stratigraphic relations. For example, Larson (1951, p. 2053-2058) regarded the Clement, Hely, and Victory Members as contemporaneous facies of the Hager Formation in Missouri, although detailed tracing in Missouri and elsewhere in the Mississippi Valley shows that these members have wide distribution. The fact that many of the units were recognized independently in Missouri attests to the distinctiveness and persistence of the Platteville members.

Cooper (1956, chart 1) correlates the Macy with the Spechts Ferry and extends the Bloomsdale to the base of the Pecatonica. The Spechts Ferry is present above the Macy in essential type lithology and fauna, and the Pecatonica is below the Bloomsdale.

Pecatonica Formation

Hershey, 1894, 1897

The Pecatonica Formation was named for outcrops along the Pecatonica River north of the Illinois-Wisconsin state line (Hershey, 1894, p. 175; 1897). As Hershey designated no type section, a section in the quarries and roadcut on the East Branch of the Pecatonica River, just north of Woodford, Lafayette County, Wisconsin (geol. sec. 12), is proposed. Another good exposure in a roadcut on the west side of State Highway 78, near the East Branch of the Pecatonica River, north of Argyle, Lafayette County, Wisconsin (W. line NW NW SW 13, 3N-5E, South Wayne Quad.) shows the following sequence from the top: *Platteville Group, Mifflin 6′, Pecatonica 20′10″ (Medusa 4′10″, New Glarus 4′, Dane 8′10″, Chana 6″, Hennepin 2′8″); Ancell Group, St. Peter 9′.*

The name Pecatonica originally was proposed as a replacement for the name Buff Limestone in northwestern Illinois (Owen, 1840; Everett, 1861, p. 56; Shaw, 1873, p. 22-23), which was equivalent to the Lower Buff Limestone of Wisconsin (Chamberlin, 1878, p. 291, 293-294). Pecatonica was not used again until revived by Kay (1935a, p. 286).

In comparison with the underlying Ancell formations, the Pecatonica as a whole is less argillaceous and sandy, has more uniform lithology, contains a different and more abundant fauna, and is more widely distributed. Compared to the overlying Mifflin Formation, the Pecatonica is more dolomitic, much less argillaceous and shaly, less fossiliferous, and thicker bedded. In the northern outcrop area it generally has a molluscan fauna that contrasts with the bryozoan-brachiopod-arthropod fauna of the Mifflin. The Pecatonica is further set off from adjacent strata by strong diastems at the base and top.

On the basis of differences in clay and clastic content, texture, and fucoid content, the Pecatonica Formation is divided into the following five members in ascending order: Hennepin (very argillaceous, silty, and sandy), Chana (nonargillaceous but sandy), Dane (argillaceous), New Glarus (pure), Medusa (weakly argillaceous, fucoidal), Oglesby (pure, detrital).

Distribution.—In the northern outcrop area the Pecatonica Formation generally is present throughout the area, but it is missing over local anticlines in Carroll and Ogle Counties, northern Illinois. In the southern outcrop area it is absent north of Perry County, Missouri, but it is well exposed near Cape Girardeau, Missouri. Outcrops described in this report are listed in the index.

Thickness.—In the northern outcrop area the Pecatonica Formation commonly is about 20 feet thick, although in most of Minnesota it is about one foot thick, and at Kentland, northwestern Indiana, it reaches 72 feet. In the southern outcrop area it thickens rapidly southward from Perry County. Because of faulting, its thickness is difficult to determine in outcrops, but the formation is 140 feet thick in the Midwest Dairy Company well at Cape Girardeau (525′ to 665′). In subsurface between the outcrop areas, the Pecatonica is 3 feet thick in McDonough County, western Illinois, but thickens eastward to 39 feet in Sangamon County, central Illinois.

Lithology.—The Pecatonica Formation consists of dolomite and dolomitic limestone. It is relatively pure, fine to medium grained, dense to finely vuggy, and occurs in 6- to 36-inch beds with some shale partings. It grades southward into thick-bedded, dolomite-mottled, lithographic limestone which has a calcarenite bed at the top. The limestone facies extends from southeast Missouri through north-central Illinois to northwestern Indiana. Chert nodules are common near the contact between the dolomite and limestone facies, and they are persistent at a few levels in the limestone facies. In the northwestern part of the northern outcrop area, the basal Hennepin Member consists of very argillaceous dolomite grading to dolomitic shale, siltstone, or sandstone. Throughout the northern outcrop area, medium-grained St. Peter-type sand is common to abundant in the Chana Member and occurs locally in all higher members. The sand is progressively finer grained upward.

Fauna.—The Pecatonica fauna has been listed for the northern outcrop area by Chamberlin (1878, p. 292, 294), Knappen (1926, p. 59), Shrock (1937), and Shrock and Raasch (1937, Divisions 5, 6, and 7). Common forms in the northern outcrop area are *Cryptophragmus antiquatus* Raymond, *Arthropora simplex* Ulrich, *Öpikina minnesotensis* (N. H. Winchell), *Strophomena plattinensis* Fenton, *Ctenodonta nasuta* (Hall), *Liospira obtusa* Ulrich & Scofield, *Lophospira sexlineata* Raasch, *Ophiletina sublaxa* Ulrich & Scofield, *Actinoceras beloitense* Whitfield, and *Ceraurus pleurexanthemus* Green. In the southern outcrop area *Stromatocerium rugosum* Hall, *Tetradium syringoporoides* Ulrich, and *Öpikina minnesotensis* were the only species noted. No species are definitely known to be confined to the Pecatonica, and most recur in those younger Platteville formations that are similar lithologically to the Pecatonica. "Lower Buff" or "Buff" species reported in Minnesota Geological Survey Final Report, vol. 3, 1895 and 1897, actually were collected from lower Pecatonica, Mifflin, and lower Grand Detour strata (geol. sec. 5).

Stratigraphic Relations.—The Pecatonica Formation rests on the Glenwood, St. Peter, or Shakopee beds in the northern outcrop area, on the Joachim Dolomite in the southern outcrop area, and generally on the St. Peter Sandstone (Starved Rock Sandstone Member) between the outcrop belts. Pecatonica strata lying on the Shakopee Dolomite are well exposed in the city quarry at Argyle, Lafayette County, southwestern Wisconsin (SE SW NE 26, 3N-5E, South Wayne Quad.), and in a quarry at Ripon, Fond du Lac County, eastern Wisconsin (SW SE NW 20, 16N-14E, Ripon Quad.) (See also Chamberlin, 1878, p. 270-275.) Evidence for a diastem at the base of the Pecatonica is described under *Platteville Group.*

The Pecatonica is separated from the overlying Mifflin Formation by a regional diastem, indicated by (1) a ferruginous, locally phosphatic, pitted, corrosion surface at the top of the Pecatonica that extends from Minneapolis, Minnesota, southeastward to the Oglesby type section at Deer Park, LaSalle County, north-central Illinois, and thence northeastward through eastern Wisconsin to the upper peninsula of Michigan; (2) partial truncation of the Pecatonica sequence northwest of the Deer Park section and also northwest of Spring Grove, Houston County, southeastern Minnesota; and (3) an undulatory scour surface having from 2 to 12 inches relief at the top of the Pecatonica in the southern outcrop area. Dolomite underlying the corrosion surface in the northern outcrop area normally contains worm-borings filled with brown-red, argillaceous, ferruginous dolomite. Over a local upwarp in Ogle County, northern Illinois, and in most of Hancock and McDonough Counties, western Illinois, the Mifflin is absent and Pecatonica beds underlie the Grand Detour Formation.

Correlation.—The Pecatonica is equivalent to the basal part of the Lowville Formation in New York State (fig. 30).

Hennepin Member (new)

The Hennepin Member of the Pecatonica Formation is here named for Hennepin County, eastern Minnesota. The type section is in a bluff on the west side of the Mississippi River at Lock and Dam No. 1 in Minneapolis (geol. sec. 5).

Hennepin strata compose the basal member of the Pecatonica Formation. They formerly were placed in the Glenwood at the type locality (Stauffer and Thiel, 1941, p. 76, unit 7 of Washington Avenue Bridge section; p. 82, unit 5 of Dam No. 1 section; p. 162, units 7 and 8 of Dam No. 1 section), but in other areas were included in the St. Peter, Glenwood, or Pecatonica, depending upon the facies present.

The Hennepin Member resembles underlying Glenwood strata in being a clastic deposit or a very impure carbonate of local extent, and it is bounded by diastems, either of which might be taken as the boundary between the Ancell and Platteville Groups. However, the Hennepin is placed in the Platteville Group because (1) the presence of carbonates in all Hennepin sediments and the absence of carbonates in the Glenwood of the Hennepin type area suggest that the Hennepin is the initial Pecatonica deposit; (2) the Hennepin carbonates closely resemble higher Platteville beds but differ from the Daysville Dolomite, the carbonate facies of the Glenwood Formation farther southeast; (3) the Hennepin lacks glauconitic clay typical of underlying Glenwood strata; and (4) the sand in the Hennepin is well sorted, like sand in the overlying Pecatonica beds, rather than bimodal like sand in the Glenwood. The occurrence in the Hennepin of accessory garnets like those of the Glenwood (Thiel, 1937, p. 118, table 4, samples M1 and F2) and the presence of Platteville-like fossils (Stauffer, 1935a, p. 127, unit 7 of Washington Avenue Bridge section; p. 129) do not conflict because similar minerals and fossils are found in both Glenwood and Platteville beds in Minnesota. The Hennepin probably grades southeastward into the lower part of the Chana Member.

Distribution and Thickness.—The Hennepin Member is present in most of southeastern Minnesota, northeastern Iowa, southern Wisconsin eastward to Rock County, and very locally in northwestern Illinois (geol. secs. 4, 6). It also occurs at Kentland, Indiana, but is not recognized elsewhere. Its maximum thickness, in eastern Lafayette County, Wisconsin, is only 4 feet.

Lithology.—The Hennepin Member consists of limestone or dolomite that is very argillaceous to very silty, brown-gray, gray-blue, or gray-green, chalky, nodular to thin bedded, partly shaly, and fossiliferous. It grades laterally from calcareous or dolomitic shale into sandstone that is dolomitic, ferruginous, nonargillaceous, nonsilty, chiefly medium grained, and has St. Peter-like texture. The dolomite facies commonly has a distinctive crust of white salts on weathered surfaces. The Hennepin is in its limestone facies at Minneapolis, shale facies at Cannon Falls, Goodhue County, Minnesota, sandstone facies near Fountain, Fillmore County, Minnesota (Stauffer and Thiel, 1941, p. 145, units 8, 9), and dolomite facies at McGregor, Clayton County, Iowa.

Stratigraphic Relations.—The Hennepin Member generally overlies Harmony Hill Shale, but in central southern Wisconsin it rests on Daysville Dolomite or St. Peter Sandstone. A diastem at the base is shown by the sharp contact, by phosphatic nodules just above the contact, and by St. Peter or Daysville pebbles in Hennepin Sandstone at places in central southern Wisconsin. A diastem at the top is indicated by a local corrosion surface and by phosphatic nodules in the basal Chana.

Chana Member (new)

The Chana Member of the Pecatonica Formation is here named for Chana, a village in Ogle County, northern Illinois, 9 miles east of the type section, which is described with the type section for the Harmony Hill Shale (geol. sec. 6). The Chana is less well exposed, but its relation to the entire Pecatonica Formation is shown better 8 miles northeast of the type section in a quarry in Rocky Hollow, Ogle County (4300′ from S line and 600′ from E line sec. 5 elongated, 23N-11E, Kings Quad.). In this exposure the sequence from the top is: *Platteville Group, Grand Detour 4′, Mifflin absent, Pecatonica 27′8″ (Medusa 6′8″, New Glarus 4′2″, Dane 12′3″, Chana 4′7″); Ancell Group, Glenwood (Harmony Hill) 4″*. Where the Hennepin is absent, the Chana is the basal member of the Pecatonica Formation.

Distribution.—Distribution of the Chana for the most part coincides with that of the Pecatonica Formation. However, it is absent locally in southeastern Minnesota, missing in northern Illinois over certain anticlines where the rest of the formation is present, and absent over hills of the Shakopee Dolomite in parts of eastern Wisconsin.

Thickness.—In the northern outcrop area the Chana commonly is less than 5 feet thick, but at Kentland, northwestern Indiana, it reaches 20 feet. It is about 9 feet thick in a core from Sangamon County, central Illinois. Good outcrops have not been found in the southern outcrop area, but it is 20 feet thick in the Midwest Dairy Company well at Cape Girardeau, Missouri (645′ to 665′).

Lithology.—The Chana Member consists of dolomite or limestone that is mainly pure and thick bedded but locally has argillaceous or weakly shaly layers in the lower part. In the northern area the Chana is dolomite or dolomitic limestone. It generally is distinguished by a vuggy, weathered face, ordinarily contains disseminated sand, and in places includes beds of dolomite-cemented sandstone at or near the base. The sand is mostly medium grained and has St. Peter texture. The basal bed in the northern area normally contains small, scattered phosphatic pellets. Minute brown-red unicellular algae and fucoids are locally common in the dolomite. In the southern area it is relatively pure, thick-bedded limestone.

Stratigraphic Relations.—In Illinois the Chana rests on Glenwood or St. Peter strata. It overlies Hennepin, Glenwood, St. Peter, or Shakopee strata in northeastern Iowa, southeastern Minnesota, and southern Wisconsin.

Dane Member (new)

The Dane Member of the Pecatonica Formation is named for Dane County, central southern Wisconsin, and the type section is a quarry and roadcut 4 miles north of New Glarus (geol. sec. 13).

Distribution.—The Dane Member generally is present in the Mississippi Valley region but is missing in parts of southeastern Minnesota, as well as over certain hills of Shakopee Dolomite in eastern Wisconsin and local anticlines in Carroll and Ogle Counties, northern Illinois.

Thickness.—In the northern outcrop area and in central Illinois the Dane commonly is 5 to 10 feet thick, although it is 22½ feet at Kentland, Indiana. In the southern outcrop area it has a maximum thickness of 60 feet in the Midwest Dairy Company well at Cape Girardeau, Missouri (585′ to 645′).

Lithology.—The Dane Member consists of relatively argillaceous dolomite or limestone that is partly cherty in places and occurs in thin to medium beds separated by thin shale partings. A platy shaly bed 2 to 4 inches thick commonly is present at the top in the northern area.

Fauna.—Fossils are more numerous and better preserved in the Dane than in other Pecatonica members. *Öpikina minnesotensis* (N. H. Winchell) seems to be present everywhere in this stratigraphic interval and is more abundant here than in other parts of the Platteville–Galena sequence, except locally in the Quimbys Mill Formation. In the southern area *Tetradium syringoporoides* Ulrich seems to appear first in the Dane and is most abundant in that member, although it extends at least as high as the Victory Member of the Grand Detour Formation.

New Glarus Member (new)

The New Glarus Member of the Pecatonica Formation is here named for New Glarus, Green County, central southern Wisconsin, 4 miles south of the type section, which is described with the type section for the Dane Member (geol. sec. 13).

Distribution.—The distribution of the New Glarus is the same as that of the Dane Member, except that the New Glarus is absent at Limestone Mountain, Houghton County, upper Michigan.

Thickness.—In the northern outcrop area and in central Illinois the New Glarus generally is about 5 feet thick, but it is 7½ feet at Kentland, Indiana. In the southern outcrop area it normally is thicker, and is 25 feet thick in the Midwest Dairy Company well at Cape Girardeau, Missouri (560′ to 585′).

Lithology.—The New Glarus consists of dolomite or limestone that is relatively pure and thick bedded, locally cherty, and distinguished by a vuggy, weathered face in the dolomite facies.

Fauna.—*Tetradium syringoporoides* Ulrich occurs in the limestone facies of the southern area but is more abundant in the underlying Dane Member. In places the limestone facies has laminations that may be algal.

Medusa Member (new)

The Medusa Member of the Pecatonica Formation is here named for the Medusa Cement Company plant, 2 miles northeast of Dixon, Lee County, northern Illinois. The plant is 1½ miles south of the type section, a quarry on the east side of Rock Valley (geol. sec. 14).

Distribution.—The Medusa Member has the same distribution as the Dane Member except that (1) the Medusa is absent in southeastern Minnesota north of Fillmore County and at Bony Falls, Delta County, upper Michigan, and (2) the Medusa overlaps certain hills of Shakopee Dolomite in eastern Wisconsin where the remainder of the Pecatonica is missing, for example at Ripon, Fond du Lac County.

Thickness.—The Medusa is commonly 5 to 7 feet thick in the northern outcrop area, reaching 9 feet in Sangamon County, central Illinois. In the southern outcrop area it is 20 feet thick in a quarry on the north side of State Highway 74 at Rock Levee, Cape Girardeau County, Missouri (E line NW NW NW 24, 30N-13E, Cape Girardeau Quad.). The sequence in the quarry, continued 0.1 mile west to a roadcut on the east side of U. S. Highway 61 and an outcrop on the east bank of Ramsey Branch, is as follows from the top: *Platteville Group, Mifflin (Blomeyer) 2′2″; Pecatonica 63′ (Oglesby 14′10″, Medusa 20′, New Glarus, mostly covered, 25′, Dane 3′2″).* The Medusa also is 20 feet thick in the Midwest Dairy Company well at Cape Girardeau (540′ to 560′).

Lithology.—The Medusa commonly consists of limestone heavily mottled with dolomite but in places is all dolomite. It is slightly argillaceous, very fucoidal, thick bedded to massive, and in places contains thin shale partings. Southward from Ogle County, northern Illinois, it locally contains white chert nodules that become partly black in the Cape Girardeau area. It is distinguished from the underlying New Glarus Member by moderate impurity and abundant fucoids.

Oglesby Member (new)

The Oglesby Member of the Pecatonica Formation is here named for the town of Oglesby in LaSalle County, north-central Illinois. The type section is an exposure in Deer Park Canyon in Matthiessen State Park just east of Oglesby (geol. sec. 15).

Distribution.—The Oglesby Member extends from eastern Missouri through north-central Illinois and northwestern Indiana to Bony Falls, Delta County, upper Michigan. It is absent in Illinois north and west of the type section, in Iowa, Minnesota, and Wisconsin, and at Limestone Mountain, Houghton County, upper Michigan.

Thickness.—In the northern outcrop area, the Oglesby thickens from 15 inches at Bony Falls, upper Michigan, to 8 feet at Kentland, Indiana, and to nearly 12 feet at the type section in north-central Illinois. In Sangamon County, central Illinois, it is 11 feet thick. In the southern outcrop area it is 15 feet thick in the Midwest Dairy Company well at Cape Girardeau (525′ to 540′) and in a quarry about 3½ miles south of that well, at Rock Levee (see *Medusa Member*).

Lithology.—The Oglesby Member is pure, light gray, white, or buff calcarenite that is dolomitic in places. It is medium to coarse grained in the type section and in upper Michigan, but it is fine grained elsewhere in the Mississippi Valley region. It is laminated, rarely conglomeratic, thick bedded, and locally cross-bedded. It is cherty in the type section, but in central Illinois and in the southern outcrop area it is generally cherty only near the base. It has a few thin shale partings and mud-cracks in the southern area. In all exposures studied, a 6- to 16-inch bed of argillaceous or shaly thin-bedded calcarenite occurs from 4 to 8 feet below the top of the member.

Fauna.—In the northern outcrop area the Oglesby contains *Cryptophragmus antiquatus* Raymond, *Kentlandia,* and other fossils (Shrock, 1937, p. 489-491; Shrock and Raasch, 1937, p. 536-539). A layer of *Stromatocerium rugosum* Hall is present just above the argillaceous bed in the Cape Girardeau area in Missouri.

Stratigraphic Relations.—A prominent corrosion surface on the top of the Oglesby is equivalent to a similar surface on the top of the Pecatonica in northwestern Illinois where the Oglesby is missing.

PLATTIN SUBGROUP

Ulrich, 1904; Weller and St. Clair, 1928

The Plattin Subgroup was named for Plattin Creek, Jefferson County, Missouri, near the mouth of which it is partially exposed (Ulrich, *in* Buckley and Buehler, 1904, p. 111). As originally defined, the Plattin included strata up to the base of the Kimmswick Limestone. It therefore included Decorah strata until they were differentiated from the Plattin by Weller and St. Clair (1928, p. 109-110). The Plattin has long been classified as a formation, but Larson (1951) proposed that it be elevated to a group.

Because the Pecatonica Formation, as previously noted, is absent in the Plattin type area, the name Plattin is not synonymous with Platteville. However, the Platteville formations above the Pecatonica are distinguishable from the Pecatonica in many areas and are essentially equivalent to the Plattin of the type region. Plattin strata make an even more distinctive unit in the northern outcrop area than they do in the southern, and in general their distinctiveness persists regionally. The break at the top of the Pecatonica is one of the well defined breaks noted in subsurface. As a name frequently will be useful for the post-Pecatonica Platteville beds, the name Plattin is retained for this unit. Recognition of the Platteville as a group necessarily restricts the Plattin to a subgroup.

As used herein the Plattin Subgroup consists of the Mifflin (at the base), Grand Detour, Nachusa, and Quimbys Mill Formations.

Grohskopf (1948, p. 354-359) and Larson (1951, p. 2043-2046, 2061-2066) restricted the Plattin to strata that are close to type-region Plattin, although it appears from described sections that this definition in some areas excludes basal Mifflin beds and includes lowermost Decorah strata.

In the Upper Mississippi Valley the name McGregor is widely used for Plattin strata. However, the name Plattin has precedence, and the Nachusa Formation, as well as all but a few inches of the Quimbys Mill Formation is absent in the McGregor type area. Redefinition of the McGregor to exclude the Quimbys Mill (Agnew and Heyl, 1946) also favors use of the name Plattin.

Excellent reference sections for the Plattin Subgroup in the type region are those at West Point Landing, Calhoun County, Illinois (geol. sec. 11), 1 mile east of Glencoe, St. Louis County, Missouri, and at Zell, Ste. Genevieve County, Missouri (geol. sec. 18). The section east of Glencoe is an essentially continuous exposure of the Plattin Subgroup. It is compiled from a quarry and the higher exposures in the bluffs of Meramec River east of the quarry which is on the east side of Rocky Hollow at its mouth (NE NE NE 19, 44N-4E, Manchester Quad.). The sequence from the top is: *Galena Group, Kimmswick Subgroup, Dunleith 28'8" (Eagle Point and Beecher 16'3", St. James, 3" bentonite 3'2" above base, 12'5"), Decorah Subgroup, Kings Lake 14', Spechts Ferry 11'8" (Glencoe with bentonite near base 4'3", Castlewood 7'5"); Platteville Group, Plattin Subgroup, Quimbys Mill 32'5" (Strawbridge 9', Shullsburg 19'3", Hazel Green 4'2"), Nachusa 41' (Everett 22'9", Elm 7', Eldena 11'3"), Grand Detour 47'11" (Forreston 25'5", Victory 3'6", Hely 8'5", Stillman, 8'3", Dement 2'4"), Mifflin 15'3" (Establishment 2'5", Brickeys 12'10"); Ancell Group, Joachim (Metz) 13'8", quarry floor.*

Correlation.—The Plattin Subgroup is equivalent to upper Lowville and Chaumont strata of New York (fig. 30). The Plattin is a well defined lithologic unit with only minor variations in sequence in the Missouri, Illinois, and Arkansas area where the name has been most widely used. The unit is entirely Blackriveran in age, although a few feet of limestone at the top, locally included in the Plattin, is here assigned to the Spechts Ferry Formation of Trentonian age. In Arkansas where only the thick major units (Plattin and Kimmswick) are recognized, all the Decorah is considered part of the Plattin. The Plattin has been variously interpreted as Trentonian in some areas and Blackriveran in others (Twenhofel et al., 1954), or as both Trentonian and Blackriveran (Cooper, 1956).

Mifflin Formation

Bays, 1938

The Mifflin Formation was named for the village of Mifflin, in Iowa County, Wisconsin, just west of the type section, a roadcut and bluff on the east side of the Pecatonica River (E line NE NE NE 34, 5N-1E, Mineral Point Quad.), where the sequence from the top is: *Galena Group, Spechts Ferry 2'; Platteville Group, Quimbys Mill 3'7", Nachusa 1'7", Grand Detour 19'2", Mifflin 17'10" (Briton 7'9", Hazelwood 1'10", Brickeys 7'3", Blomeyer, 1'), Pecatonica 2'6".* The name Mifflin was proposed (Bays, 1938, p. 269) to replace the name Lower Blue Limestone (Chamberlin, 1878, p. 290-291, 294-295).

As a whole the Mifflin is more argillaceous and shaly, more fossiliferous, thinner bedded, and less dolomitic than the formations above and below. On the basis of variations in argillaceousness the Mifflin is divisible into the following five members in ascending order: Blomeyer (argillaceous), Brickeys (pure), Establishment (argillaceous), Hazelwood (pure), and Briton (argillaceous).

The argillaceous zones generally weather shaly, and the pure zones are thicker bedded and in places massive. In a few places in the northern outcrop area the Mifflin is threefold, consisting of upper and lower shaly zones separated by a massive unit. In these areas it appears that the lower two units generally are missing, because the massive unit present is the strongly fucoidal upper massive member (Hazelwood) rather than the equally pure but not fucoidal lower massive member (Brickeys). In places the lower two or three members may be represented in the lower shaly zone, but, where evidence of a break within the lower shaly unit is lacking and there is no unusual thickness, it seems better to relate the variation in sequence to irregular deposition of the lower units on the uneven surface of the underlying Pecatonica Dolomite.

In the northern part of the southern outcrop area, the lower pure member (Brickeys) contains shale beds as much as 6 inches thick. However, as the limestone beds are pure and the Establishment Member above is nearly all shale, the Brickeys is still a relatively pure unit in that area.

Distribution.—The distribution of the Mifflin Formation coincides with that of the Platteville Group except that it is absent locally over the Oregon Anticline, Ogle County, northern Illinois, and locally in Hancock and McDonough Counties, western Illinois. Geologic sections with outcrops of Mifflin strata are shown in figure 41. Other sections are listed in the index.

Thickness.—In the northern outcrop area the Mifflin commonly is 15 to 25 feet thick, although at places in southeastern Minnesota it is less than one foot thick. In Sangamon County, central Illinois, it is 46 feet thick. In the southern outcrop area it ranges from 15 feet thick in Calhoun County, western Illinois, to a maximum of 120 feet in the Midwest Dairy Company well at Cape Girardeau, southeastern Missouri (405′ to 525′).

Lithology.—The Mifflin Formation consists of lithographic limestone that is mostly argillaceous, shaly, and thin bedded, but is partly pure and massive. It locally grades to chalky or fine-grained dolomite in the northern area. Oolitic limestone layers occur in the lower part of the Mifflin in the southern area. Shale partings are blue-gray to gray-green, in contrast to the brown-red shale partings of the overlying Grand Detour Formation. The formation locally thins and passes into calcareous shale and sandstone in Adams County, western Illinois.

Fauna.—The Mifflin is the most generally fossiliferous formation of the Platteville Group, although fossils are much less abundant in the southern area than in the northern area. A few especially common or characteristic species are *Rhinidictya exigua* Ulrich, *Rhinidictya trentonensis* (Ulrich), *Cyclospira* sp. nov. aff. *C. bisulcata* (Emmons), *Öpikina wagneri* (Okulitch), *Pionodema conradi* (N. H. Winchell), *Skenidioides anthonensis* (Sardeson), *Strophomena plattinensis crassa* Raasch, *Strophomena winchelli* Hall & Clarke, *Sinuites rectangularis* (Ulrich & Scofield), *Onchometopus simplex* Raymond & Narraway, *Leperditella germana* (Ulrich), and *Schmidtella crassimarginata* Ulrich.

Stratigraphic Relations.—The Mifflin is separated from the underlying Pecatonica Formation by a prominent diastem, as described in the section on Pecatonica. A consistently sharp contact separates the Mifflin from the overlying Grand Detour Formation. The presence of a break in deposition between the Mifflin and Grand Detour Formations in the vicinity of the Mississippi River between St. Louis and Minneapolis is indicated by the irregular westward wedging-out of upper Mifflin and lower Grand Detour members. At the top of the Hazelwood Member in central northern Illinois, a ferruginous corrosion surface overlying a zone of wormborings filled with brown-red, argillaceous, ferruginous limestone suggests a minor diastem. The Mifflin members generally are separated by sharp contacts. A persistent corrosion surface occurs within the Hazelwood Member in the northwestern part of the northern outcrop area.

Correlation.—The Mifflin is considered equivalent to the middle portion of the lower Lowville in New York (fig. 30).

Blomeyer Member (new)

The Blomeyer Member of the Mifflin Formation is here named for the village of Blomeyer, Missouri, about 6 miles southwest of the type section, which is a small quarry on the north side of Missouri Highway 74, a quarter of a mile east of the highway junction at Rock Levee, Cape Girardeau County (geol. sec. 16). The Blomeyer is the basal member of the Mifflin Formation.

Distribution.—The Blomeyer Member is more irregular in distribution than other Mifflin members. It is absent in southeastern Minnesota and in the upper peninsula of Michigan, and it is missing locally elsewhere in the northern outcrop area. It appears to be generally absent in the southern outcrop area from Calhoun County, Illinois, to Perry County, Missouri. However, the 1 to 2 feet of argillaceous limestone and dolomite included in the lower part of the Brickeys Member in the latter area may be equivalent to the Blomeyer.

Thickness.—The Blomeyer is commonly less than 1 foot thick in the northern area, but is nearly 3 feet in the type section of the Medusa Member of the Pecatonica Formation in Lee County, northern Illinois. Although 12 feet thick in the type section at Rock Levee, the Blomeyer is 20 feet thick in the Midwest Dairy Company well at Cape Girardeau (505′ to 525′). In subsurface between the outcrop areas the member is about 5 feet thick in Scott County and 9 feet in Sangamon County.

Lithology.—The unit is limestone or dolomite, argillaceous, lithographic to chalky, blue-gray to brown-gray, and weathers gray to buff. It commonly weathers thin bedded to shaly. In the southern outcrop area it locally contains a few beds of calcareous shale as much as 6 inches thick. It is generally recognized as the basal shaly or impure unit of the Mifflin.

Brickeys Member (new)

The Brickeys Member of the Mifflin Formation is here named for the village of Brickeys, in Ste. Genevieve County, southeastern Missouri. The type section is an exposure in a quarry on the east side of Missouri Highway 25, 0.3 mile south of the side road to Brickeys (geol. sec. 17). About 1 foot of the basal Brickeys is not exposed here but is well exposed 9 miles southeast at Zell (geol. sec. 18).

Distribution.—The Brickeys Member has about the same distribution as the formation, except that it is missing at several places in southeastern Minnesota and locally elsewhere in the northern outcrop area.

Thickness.—In the northern outcrop area the Brickeys ranges from 1 foot thick at Bony Falls, Delta County, upper Michigan, to 16 feet at the Spechts Ferry type section, Dubuque County, northeastern Iowa. In the southern outcrop area it is commonly 13 to 20 feet thick from Calhoun County, Illinois, to Ste. Genevieve, Missouri, but thickens rapidly southward and is 40 feet thick in the Midwest Dairy Company well at Cape Girardeau (485′ to 525′). In subsurface between the outcrop areas it is 10 feet thick in Scott County, and 16½ feet in Sangamon County.

Lithology.—In the southern area the Brickeys consists mostly of pure, purplish brown, lithographic to fine-grained, thick-bedded limestone, but it contains a few beds of gray to buff, argillaceous, thin-bedded limestone and dolomite and several thin beds of green shale. Several of the limestone beds are oolitic, others a fine conglomerate or breccia. The member is characterized by several prominent scour surfaces which commonly have a relief of 2 to 4 inches but locally of as much as 8 inches. Scour surfaces 2 and 8 feet below the top and at the base are the most persistent. A thin bentonite is found 2 feet 4 inches above the base in the section at Zell.

The lateral continuity of thin beds in the Platteville Group is well shown in the Brickeys Member because of the lithologic contrasts between its beds. Most of the beds in the following composite sequence are present in numerous exposures from Calhoun County, Illinois, to Ste. Genevieve, Missouri, a distance of about 75 miles.

	Ft.	*In.*
Brickeys Member		
Limestone, mostly pure with shale partings; locally dolomitic and argillaceous; oolitic in places	1-2	
Shale, green		2-5
Limestone, pure, conglomeratic; locally argillaceous and dolomitic at base		5-11
Scour surface		
Shale, green		2-4
Limestone, pure, oolitic, massive, laminated	0-1½	
Limestone, pure and argillaceous, thin bedded; *Tetradium* present; contains several 1-2″ beds of green shale, one bed of dark gray shale in places	1-3	
Limestone, pure, massive, oolitic, conglomeratic; contains *Stromatocerium* domes in places; locally argillaceous and dolomitic in middle	2-4½	
Scour surface, locally 9″ green shale		

(continued)

	Ft.	In.
Limestone and dolomite, argillaceous, silty, thin bedded; contains several 1-7″ beds of green shale, one bed of dark gray shale in places	1¼-4¾	
Limestone, pure, oolitic, strongly laminated; contains *Stromatocerium* domes, *Tetradium*	1½-3¼	
Limestone, argillaceous, green shale in places		0-8
Ferruginous scour surface in places		

All of these units, with the exception of the basal bed, are present in the Brickeys type section.

The prominent shale beds thin out both northward and southward. Between Ste. Genevieve and Cape Girardeau, Missouri, the shale beds are mere streaks, the oolitic character becomes less prominent, and the member consists largely of slightly shaly lithographic limestone. Oolite or conglomerate occurs as far north as Pike County, Missouri (Grohskopf, 1948, figs. 1, 2), and Adams and Sangamon Counties, Illinois. *Eoleperditia* is locally very abundant in these beds.

In the northern outcrop area the Brickeys consists of limestone or dolomite, relatively pure blue-gray to buff, lithographic to fine grained, and as a rule distinctly less shaly and thicker bedded than the succeeding Establishment Member from which it is weakly differentiated in many other places. A 2- to 3-inch bed of shale that occurs about a foot above the base in many exposures is black and graptolite-bearing in eastern Wisconsin.

Establishment Member (new)

The Establishment Member of the Mifflin Formation is here named for Establishment Creek in Ste. Genevieve County, southeastern Misouri. The type section is an exposure in a ravine just north of the village of Zell (geol. sec. 18).

Distribution.—The Establishment Member is a nearly continuous unit except in southeastern Minnesota where it is missing at places.

Thickness.—It is uniformly about 5 feet thick at most exposures in the northern outcrop areas, although it thins to about 3 feet in eastern Wisconsin and upper Michigan. It is commonly 2 to 5 feet thick in the southern outcrop area. Its maximum thickness is 8 feet in a well in Sangamon County, central Illinois.

Lithology.—In the southern outcrop area the Establishment Member consists of blue-green, laminated clay or shale with thin interbeds of argillaceous, greenish gray to buff, chalky limestone. The facies is well exposed in the Brickeys type section and is present in the Midwest Dairy Company well at Cape Girardeau (480′ to 485′). The shale facies appears to be limited to the region bordering the Ozarks where it is an excellent key bed. From that area it grades laterally into shaly limestone. In the northern outcrop area the limestone is dolomite mottled, argillaceous, blue-gray to buff, lithographic, thin bedded, and shaly, it contains some calcarenite or coquina layers, and it grades into fine-grained dolomite at places.

Hazelwood Member (new)

The Hazelwood Member of the Mifflin Formation is here named for Hazelwood School, Lee County, northern Illinois, 2 miles west of the type section, which is the Dixon North section (geol. sec. 14).

Distribution.—The Hazelwood generally is present throughout the area of the Mifflin Formation, but it is missing in the vicinity of St. Louis, Missouri (including Calhoun County, western Illinois), around McGregor, Clayton County, Iowa, and in parts of Grant County, southwestern Wisconsin.

Thickness.—In most of the northern outcrop area the Hazelwood Member is slightly more than 1 foot thick, but in central southern Wisconsin, central northern Illinois, and northwestern Indiana, it ranges from 3½ to 5½ feet thick. It thickens southward to 12½ feet in Sangamon County, central Illinois. In the southern outcrop area it varies from about 10 feet thick in the Brickeys type section north of Bloomsdale, Missouri, to 35 feet in the Midwest Dairy Company well at

Cape Girardeau (445′ to 480′) and about 50 feet in a high bluff 3 miles south of Cape Girardeau and half a mile northeast of Rock Levee.

Lithology.—The Hazelwood Member consists of relatively pure limestone that is blue-gray, light tan, or dark purplish brown, lithographic to fine grained, and thick bedded. It generally is dolomite mottled, fucoidal, and has few fossils. In Carroll and Ogle Counties, northern Illinois, the upper 1 to 2 feet contains worm-borings filled with brown-red, argillaceous, ferruginous limestone. A well developed ferruginous corrosion surface occurs at the top in central northern Illinois.

Briton Member (new)

The Briton Member of the Mifflin Formation is here named for Briton School, 2 miles northeast of Dixon, Lee County, Illinois. The school is a mile and a half southwest of the type section, which is the Dixon North section (geol. sec. 14).

Distribution.—The Briton Member generally is present in most exposures of the Mifflin Formation except at places in southeastern Minnesota and in the vicinity of St. Louis, Missouri, including Calhoun County, western Illinois.

Thickness.—In the northern outcrop area the Briton ranges from 3 feet thick at Beloit, Rock County, central southern Wisconsin, to 12 feet at Kentland, northwestern Indiana. In Sangamon County, central Illinois, it is only about 9 feet thick, but it thickens rapidly southward to 55 feet at Zell, Ste. Genevieve County, Missouri, and then thins to 40 feet in the Midwest Dairy Company well at Cape Girardeau, Missouri (405′ to 445′).

Lithology.—In the northern area the Briton consists of limestone, mostly very argillaceous, calcarenitic toward base, lithographic, very fossiliferous, light gray, white-weathering, in ½-inch to 2-inch, irregular, nodular beds separated by shale partings up to 1 inch thick. It grades laterally to fine-grained dolomite in a few places. A slightly argillaceous and shaly, medium-bedded to massive unit about 1 foot thick is present near the middle in northern Illinois. Southward and eastward it becomes weakly argillaceous, is slightly shaly, medium to thick bedded, and sparsely fossiliferous, but it remains distinctly more impure than adjoining members. It contains silty beds in Missouri. In quarries east of Kentland, Indiana, 4½ feet of pure, light gray to white, lithographic, finely brecciated limestone that is in 1- to 4-inch regular beds and carries *Tetradium cellulosum* (Hall) occurs at the base of the Briton (Shrock, 1937, p. 492, unit 17) (see *Regional Correlations, Indiana*). Because this unit has not been found elsewhere and has a reciprocal thickness relation to the Briton Member, it may be a local facies of the lower Briton.

Fauna.—The Briton is the most fossiliferous member of the Mifflin. At places in southwestern Wisconsin and northwestern Illinois a basal zone about 1 foot thick contains abundant *Sinuites rectangularis* (Ulrich & Scofield).

Grand Detour Formation (new)

The Grand Detour Formation is here named for the village of Grand Detour, Ogle County, northern Illinois, which is 3 miles east of the type section, a quarry in the west bluff of the Rock River on the Walgreen estate, 2 miles north of Dixon (geol. sec. 19).

In general, the Grand Detour Formation is less argillaceous and shaly, less fossiliferous, more dolomitic, and thicker bedded than the underlying Mifflin Formation but is more impure, more calcareous, and thinner bedded than the overlying Nachusa Formation and hence is transitional in lithology between the Mifflin and Nachusa. On the basis of variations in argillaceous content and other lithologic features, the Grand Detour is divided into the following seven members in ascending order: Dement (pure), Walgreen (argillaceous), Stillman (pure, fucoidal), Clement (calcarenite), Hely (argillaceous), Victory (pure, white to light colored), Forreston (alternating pure and argillaceous units).

Distribution and Thickness.—The Grand Detour is the most widely distributed of the Platteville formations and has the same distribution as the group. In the northern outcrop area the Grand Detour thickens southward from less than 10 feet in parts of southeastern Minnesota and 15 or 20 feet in upper Michigan to more than 59 feet at Kentland, northwestern Indiana. In the southern outcrop area it ranges from 45 feet thick in Calhoun County, western Illinois (geol. sec. 11) to 48 feet near St. Louis (Glencoe East section, see *Plattin Subgroup*), and then thickens rapidly southeastward to 210 feet in the Hely type section at Cape Girardeau, southeastern Missouri. In subsurface between the outcrop areas it varies from as little as 3 feet thick in Hancock and McDonough Counties, western Illinois, to 75 feet in Sangamon County, central Illinois. Outcrops described in this report are listed in the index.

Lithology.—The Grand Detour consists of dolomite-mottled, lithographic limestone, chalky to medium-grained dolomite, and subordinate beds of calcarenite. It is pure to moderately argillaceous, mainly blue-gray to buff and medium to thick bedded, partly cherty and fucoidal, and in part has dark brown-red, dark gray-blue, or black shale partings that contrast with the thicker blue-gray to green shale partings of the underlying Mifflin Formation. In western Illinois lower Grand Detour strata commonly are sandy.

Fauna.—Particularly common or characteristic species are *Lambeophyllum profundum* (Conrad), *Streptelasma breve* Ulrich, *Öpikina inquassa* (Sardeson), *Strophomena auburnensis impressa* Raasch, *Ctenodonta astartaeformis* Salter, *Vanuxemia rotundata* (Hall), *Ectomaria prisca* (Billings), *Liospira vitruvia* (Billings), *Loxoplocus serrulatus* (Salter), *Tetranota obsoleta* Ulrich & Scofield, *Trochonema umbilicatum* (Hall), and *Metaspyroceras minneapolis* Foerste. *Tetradium syringoporoides* Ulrich and *Glyptorthis bellarugosa* (Conrad) are common in the southern outcrop area. *Tetradium cellulosum* (Hall) and *Stromatocerium rugosum* Hall are found commonly in upper Michigan. Certain abundant Mifflin species, such as *Pionodema conradi* (N. H. Winchell) and *Eoleperditia fabulites* (Conrad) also are numerous in the Grand Detour. Many characteristic Pecatonica species, seemingly absent in the Mifflin, recur in the Grand Detour, as for example *Lophospira sexlineata* Raasch.

Stratigraphic Relations.—In the St. Louis area the absence of several members suggests a diastem between the Mifflin and Grand Detour Formations, and at places scour or corrosion surfaces occur between and within the members. At Bony Falls, Delta County, upper Michigan, the Clement, Hely, and Victory Members are absent at a strong corrosion surface at the top of the Stillman Member.

Correlation.—The Grand Detour is correlated with the upper Lowville and the upper part of the lower Lowville in New York State.

Dement Member (new)

The Dement Member of the Grand Detour Formation is named for Dement Avenue in Dixon, Lee County, northern Illinois, 2 miles south of the type section, which is part of the Grand Detour type section (geol. sec. 19).

Distribution.—The Dement Member extends from southeastern Missouri to northern Illinois and is present locally in northeastern Iowa and southwestern Wisconsin. It is missing in southeastern Minnesota, in central southern and eastern Wisconsin, at Limestone Mountain, upper Michigan, in northwestern Indiana, and over much of western Illinois, but is present in Calhoun County.

Thickness.—In the northern outcrop area the Dement ranges from about 1 foot thick at Bloomington, Grant County, southwestern Wisconsin, to 8 feet in the type section. In the southern outcrop area it varies from about 2 feet thick near St. Louis (Glencoe East section) to 20 feet at Zell in Ste. Genevieve County, Missouri (geol. sec. 18). In Sangamon County, central Illinois, it is about 9 feet thick.

Lithology.—In the northern area the Dement normally consists of limestone, relatively pure, dolomite mottled, blue-gray, lithographic and thick bedded. It contains a few calcarenite layers and locally grades to fine-grained dolomite. It is composed of coarse-grained calcarenite at Bony Falls, Delta County, upper Michigan. In the southern area it consists of limestone that is similar to that in northern exposures, but is dark brown, fucoidal, and only locally cherty. Near St. Louis (Glencoe East section) it is a conglomeratic, vuggy, very fine-grained calcarenite. In Sangamon County, central Illinois, a 2½-foot shaly bed appears 2½ feet below the top.

Walgreen Member (new)

The Walgreen Member of the Grand Detour Formation is here named for the Walgreen estate, Lee County, northern Illinois, on which the type section (part of Grand Detour type section) is located.

Distribution.—The Walgreen Member is generally present throughout the areal extent of the Grand Detour but is absent between Limestone Mountain, Houghton County, upper Michigan, and Winnebago County, northernmost Illinois. It also is missing north of southern Goodhue County, Minnesota, and in most of western Illinois (excluding Calhoun County) and around St. Louis, Missouri.

Thickness.—In the northern outcrop area the Walgreen thickens from about 1 foot in southeastern Minnesota and upper Michigan to 11½ feet in northern Illinois (geol. sec. 20), but thins to 2 feet at Kentland, Indiana. In Sangamon County, central Illinois, it is 5 feet thick. In the southern outcrop area it ranges from 4 feet thick in Calhoun County, Illinois, to 9 feet at Zell in Ste. Genevieve County, Missouri.

Lithology.—The Walgreen Member, like the underlying Dement Member, consists of limestone and dolomite but is generally argillaceous, thin to medium bedded, and shaly. It becomes moderately argillaceous, medium bedded to massive, and nonshaly in the vicinity of Cape Girardeau, southeastern Missouri. It commonly has disseminated fossil debris and thin interbeds of purplish calcarenite. It contains thin conglomeratic layers in Ste. Genevieve County, Missouri.

Stillman Member (new)

The Stillman Member of the Grand Detour Formation is named for Stillman's Run, a stream emptying into the Rock River 1½ miles east of the type section in a quarry just north of Byron, Ogle County, northern Illinois (geol. sec. 20).

Distribution.—The Stillman is the most extensive Grand Detour member. It is present thoughout the Mississippi Valley region, with the possible exception of a few small areas in western Illinois.

Thickness.—In the northern outcrop area the Stillman commonly is 5 to 8 feet thick, although it is only 3 feet thick in most of southeastern Minnesota and nearly 12 feet thick at Kentland, Indiana. In the southern outcrop area it ranges from 5 feet in Calhoun County, Illinois, to 64 feet at Cape Girardeau, Missouri.

Lithology.—The Stillman Member consists of limestone, dolomitic or dolomite mottled and lithographic to fine grained, and of dolomite, fine to medium grained, and commonly vuggy. The dolomite facies is best developed in central northern Illinois and central southern Wisconsin. The member generally is pure, cherty, fucoidal, and thick bedded. Although it becomes moderately argillaceous and has some shale partings west and north of the type area, it remains distinctly purer and less shaly than the Walgreen, Hely, or Forreston Members. In the southern area and in the northwestern part of the northern area it is divisible into an upper fucoidal unit, a middle unit that is argillaceous to shaly, partly cherty or conglomeratic, and a basal calcarenitic, fucoidal unit. These units from the top are 3 feet 6 inches, 3 feet 3 inches, and 3 feet 1 inch thick in the Mifflin type section in southwestern Wisconsin, and 14 feet 6 inches, 28 feet 6 inches, and 21 feet thick at Cape Girardeau in southeastern Missouri (geol. sec. 21), but they disappear eastward or become very weakly differentiated.

Stratigraphic Relations.—In the vicinity of Cannon Falls and Minneapolis, Minnesota, the two lowermost Grand Detour members are absent and the Stillman rests on the underlying Mifflin Formation. In this area a corrosion surface is present at the top of the Mifflin and phosphatic pellets occur in the basal Stillman.

Clement Member (new)

The Clement Member of the Grand Detour Formation is here named for Clement Station, Ste. Genevieve County, southeastern Missouri. The type section is half a mile north of Zell (geol. sec. 18). The member is also well exposed half a mile farther north in a roadcut along Missouri State Highway 25 and in a gully on the south side of the highway (S½ NE SE 28, 38N-8E, Weingarten Quad.), where the sequence from the top is: *Galena Group, Dunleith 10′, Spechts Ferry, almost covered, 3′; Platteville Group, Quimbys Mill 29′ (Strawbridge 10′, Shullsburg 17′5″, Hazel Green 1′7″), Nachusa 41′5″ (Everett 20′7″, Elm 6′9″, Eldena 14′1″), Grand Detour 42′9″ (Forreston 15′, Victory 5′3″, Hely 7′, Clement 13′, Stillman 2′6″).*

Distribution.—The Clement Member is absent in northeastern and central southern Wisconsin, in part of central northern Illinois, and from Warren County, western Illinois, southward along the Mississippi River to the vicinity of St. Louis, Missouri, but it is persistent elsewhere in the Mississippi Valley region.

Thickness.—The Clement Member generally is very thin. It ranges from 1 to 4 inches thick in the northern outcrop area, and thickens to only 9 inches in Sangamon County, central Illinois. In the southern outcrop area it is 6½ feet thick at Cape Girardeau, and it attains a maximum of 13 feet at the Clement type locality.

Lithology.—The Clement consists of purplish gray, medium- to coarse-grained, pure calcarenite. Where thick it occurs in 2- to 15-inch beds that locally are cross-bedded. It grades to calcarenitic limestone at Cape Girardeau, southeastern Missouri, at places in southeastern Minnesota and adjoining areas, and at Kentland, northwestern Indiana.

Hely Member (new)

The Hely Member of the Grand Detour Formation is here named for Hely's upper quarry, which, with the adjoining Federal and Marquette quarries, constitutes the type section, at the southern outskirts of Cape Girardeau, Missouri (geol. sec. 21). The name also has been spelled Healy (Ulrich, 1939, p. 108), but a photograph on which the name is visible (Buckley and Buehler, 1904, pl. 15) is authority for the spelling used.

Distribution.—The Hely Member is absent in southeastern Minnesota, southwestern Wisconsin, northeastern Iowa, and central western Illinois, but is present elsewhere in the Mississippi Valley.

Thickness.—The member is nearly 3½ feet thick in the northern outcrop area and 5 feet in Sangamon County, central Illinois. In the southern outcrop area it ranges from 5 to 8½ feet thick between Calhoun County, Illinois, and Ste. Genevieve County, Missouri, then thickens rapidly southward to 73 feet at Cape Girardeau.

Lithology.—The Hely Member consists of limestone that is argillaceous, lithographic, occurs in 3- to 15-inch beds separated by shale partings or by prominent argillaceous dolomitic bands next to bedding surfaces. Much of the limestone is very calcarenitic, or contains thin calcarenite layers that are locally cherty, rarely dolomite mottled, and generally nonfucoidal. It grades to chalky or fine-grained dolomite in part of central northern Illinois and in central southern Wisconsin. Cephalopods filled with crystalline quartz are abundant in the lower 3 feet at Zell, Missouri (geol. sec. 18).

Victory Member (new)

The Victory Member of the Grand Detour Formation is here named for Mt. Victory school, Calhoun County, western Illinois, which is 4½ miles north of the type section, a quarry north of West Point Landing (geol. sec. 11).

Distribution.—The Victory Member is persistent throughout most of the Mississippi Valley but is absent (1) in central western Illinois and much of northeastern Iowa, (2) north of Olmstead County, southeastern Minnesota, and (3) in eastern Wisconsin and upper Michigan.

Thickness.—The Victory is commonly 1 foot or less thick in the northern outcrop area, but about 3 feet in LaSalle County, north-central Illinois (geol. sec. 15), and 4 feet at Kentland, northwestern Indiana. It is less than 2 feet thick in Sangamon County, central Illinois. In the southern outcrop area it ranges from 3½ feet thick near St. Louis (Glencoe East section) to nearly 7 feet at Cape Girardeau (geol. sec. 21).

Lithology.—The Victory Member is a distinctive white to light blue-gray lithographic limestone containing calcite flecks. It is relatively pure but rarely contains a few shale partings. It is massive or thick bedded. In the southern area it is partly cherty and contains *Tetradium syringoporoides* Ulrich. In the central portion of northern Illinois and southern Wisconsin it grades locally to dolomite, pure, light gray to light buff, fine to medium grained, vuggy and massive, with a smooth, white-weathered face. It is not as distinctive in the northern area as in the southern, where it is the most readily recognized member of the Platteville Group.

Forreston Member (new)

The Forreston Member of the Grand Detour Formation is here named for the town of Forreston, Ogle County, northern Illinois. The type section is a quarry on the north side of a ravine 1 mile northwest of Brookville and 7 miles southwest of Forreston, Carroll County (geol. sec. 22).

Distribution.—The Forreston Member is missing in central western Illinois but is present elsewhere in the Mississippi Valley and in upper Michigan.

Thickness.—In the northern outcrop area the Forreston commonly is 5 to 25 feet thick, although it is as thin as 1½ feet in Dubuque County, northeastern Iowa (Spechts Ferry type section), and more than 38½ feet thick at Kentland, northeastern Indiana. In Sangamon County, central Illinois, it is 20½ feet thick. In the southern outcrop area it is only 15 feet thick in a roadcut a mile north of Zell, Ste. Genevieve County, Missouri (see Clement Member), but thickens northward to 25½ feet near St. Louis (Glencoe East section, see Plattin Subgroup) and southward to 40½ feet at Cape Girardeau, Missouri.

Lithology.—The Forreston consists of dolomite-mottled lithographic limestone and fine-grained, dense dolomite. It commonly can be differentiated into three argillaceous units alternating with three relatively pure units, the last of which is at the top. The argillaceous units are thin to medium bedded, and they normally have conspicuous, argillaceous, dolomitic, light colored bands next to the bedding surfaces. The argillaceous units generally contain the thickest red shale partings in the Grand Detour Formation. The purer units are medium bedded to massive and slightly shaly to nonshaly. The Forreston ordinarily contains some bands of chert nodules. In the Cape Girardeau area the chert is black. Calcarenite beds are common in most northern exposures and layers of calcarenite or conglomerate occur locally in southern outcrops. In eastern Missouri (Grohskopf, 1948, p. 357) and in western and central Illinois a persistent sandy zone about 5 feet thick is present at or near the base.

Fauna.—In the dolomite facies of northern Illinois and southern Wisconsin a zone from 7 to 11 feet thick containing numerous *Lambeophyllum profundum* (Conrad) and a few *Foerstephyllum magnificum* (Okulitch) usually is present at the top. In the dolomite facies of central northern Illinois, at the bottom of the middle argillaceous unit, *Streptelasma breve* Ulrich and a great variety of mollusks generally are abundant in a 1-foot zone 5 feet above the base.

Nachusa Formation (new)

The Nachusa Formation is here named foı the village of Nachusa in Lee County, northern Illinois. The type section is a quarry on the east side of State Highway 2 at the east edge of Dixon (geol. sec. 23).

The Nachusa Formation is equivalent to the middle portion of the Upper Buff Limestone (lower third of Division I, plus Divisions II and III) (Chamberlin, 1878, p. 295-297), to the upper part of the Magnolia Member (Bays and Raasch, 1935, p. 297-298) in southern Wisconsin, and to the lower part of the Lowell Park Member (Knappen, 1926, p. 53-58) in northern Illinois. Nachusa beds locally have been included in the Mc-

Gregor, but they are absent in the McGregor type area.

As a whole, the Nachusa is the purest and most massively bedded formation in the Platteville Group and contrasts sharply with the underlying Grand Detour Formation and the overlying Quimbys Mill Formation, both of which are thinner bedded and somewhat argillaceous and shaly.

On the basis of variations in argillaceous content and bedding, the Nachusa is divided into the following three members, in ascending order: Eldena (slightly argillaceous, thick bedded), Elm (argillaceous, thin bedded), and Everett (pure, massive).

Distribution.—The Nachusa Formation is present throughout the Mississippi Valley except southeastern Minnesota, northeastern Iowa, and adjacent parts of southwestern Wisconsin. It also is missing in part of Hancock County, western Illinois. Outcrops described in this report are listed in the index.

Thickness.—In the northern outcrop area the Nachusa ranges from 1½ feet thick near Mifflin, southwestern Wisconsin (Mifflin type section), to 47½ feet at Kentland, northwestern Indiana, but it is most commonly 15 to 20 feet thick. In the southern outcrop area it is close to 41 feet thick between Calhoun County, western Illinois, and Ste. Genevieve County, Missouri, but from the latter area it thickens rapidly southward to 75 feet at Cape Girardeau, southeastern Missouri (Midwest Dairy Company well, 120′ to 195′). Between the outcrop areas, the Nachusa is less than 5 feet thick in parts of central western Illinois but is 40 feet thick in Sangamon County, central Illinois.

Lithology.—The Nachusa consists of dolomite-mottled, lithographic limestone and chalky to medium-grained dolomite that is mostly pure to slightly argillaceous, cherty, fucoidal, and thick bedded to massive. The two lower members contain a few blue-gray to buff shale films. In the southern outcrop area the Nachusa contains layers of bentonite, calcarenite, and conglomeratic limestone. The dolomite facies, characterized by a vuggy, weathered face, is confined to the northern outcrop area and extends north and east of a line connecting points just northwest of Kentland, Indiana, near Dixon, Illinois, and just east of Platteville, Wisconsin. The upper members are the first to become dolomitized. In the dolomite facies the Nachusa resembles the Galena dolomite and it has been called Galena in some localities.

Fauna.—A typical Nachusa faunal assemblage includes the following:

AB *Foerstephyllum halli* (Nicholson)
AB *Foerstephyllum magnificum* (Okulitch)
AB *Lambeophyllum profundum* (Conrad)
B *Lichenaria carterensis* (Safford)
A *Tetradium fibratum* Safford
B *Tetradium halysitoides* Raymond (*"Halysites"* of Chamberlin)
AB *Hesperorthis tricenaria* (Conrad)
AB *Öpikina transitionalis* (Okulitch)
AB *Rhynchotrema minnesotensis* (Sardeson)
AB *Clathrospira subconica* (Hall)
B *Salpingostoma buelli* Whitfield
A *Actinoceras tenuifilum* (Hall)

The letters preceding the names indicate that the species ranges above (A) or below (B) the Nachusa Formation. With the exception of *Lambeophyllum* and *Hesperorthis* the species listed either first become common to abundant in the Nachusa or first appear there. Silicified specimens of *Foerstephyllum halli* are the most abundant and conspicuous element in northern outcrops, but in Missouri exposures this species is uncommon.

The range of *Foerstephyllum halli* is important in regional correlations (fig. 27). The fossil first appears in upper Mifflin strata in Missouri and equivalent strata (Wardell) in southwestern Virginia. It first becomes abundant in the Chaumont Formation of New York, the Nachusa Formation of Illinois, the lower part of the Tyrone Formation of Kentucky, and the Lower Carters Formation of Tennessee, in beds that probably represent the same stratigraphic interval. In the Mississippi Valley *F. halli* is unknown above Nachusa strata except in the Shullsburg Member of the Quimbys Mill Formation at Kentland, Indiana, and, rarely, in the Spechts Ferry

Formation of Minnesota. It also is found in the Upper Carters of Tennessee, which is equivalent to the Quimbys Mill Formation. In New York and Ontario it is abundant in the Napanee (Guttenberg) and is present, although rarely, in beds as high as Shoreham (Eagle Point–Fairplay). The highest known occurrence of the species is in the Woodburn (Sinsinawa) Limestone of Kentucky, where it is common.

Stratigraphic Relations.—The Nachusa has a sharp contact with the overlying Quimbys Mill Formation but in places the contact with the underlying Grand Detour is transitional through a 1 to 2 foot interval. In much of central western Illinois and southwestern Wisconsin, where the two lower Nachusa members are missing, a sharp break separates the Grand Detour and upper Nachusa strata. The contacts between Nachusa members generally are sharp.

Correlation.—Because of striking similarities in fauna and lithologic sequence the Nachusa Formation is correlated with the Chaumont Formation of New York State (fig. 30).

Eldena Member (new)

The Eldena Member of the Nachusa Formation is here named for Eldena, a village in Lee County, northern Illinois. The type section is part of the Nachusa type section (geol. sec. 23).

Distribution.—The distribution of the Eldena generally is similar to that of the Nachusa Formation, although in areas of marked Nachusa thinning, such as southwestern Wisconsin and central western Illinois, the Eldena is absent. In the northern outcrop area the Eldena ranges from about 5 feet thick in parts of Green and Lafayette Counties, Wisconsin, to 20 feet at Kentland, Indiana, but it averages about 8 feet. In Sangamon County, central Illinois, the Eldena is 22 feet thick. In the southern outcrop area it varies from 9½ feet thick in Calhoun County, Illinois, to 14 feet in Ste. Genevieve County, Missouri; it then thickens rapidly to 40 feet at Cape Girardeau, Missouri (Midwest Dairy Company well, 155′ to 195′).

Lithology.—The Eldena consists of limestone that is dolomite mottled, slightly argillaceous, lithographic, moderately cherty, fucoidal, and fossiliferous. It is generally in beds 6 to 12 inches thick (but locally 30 inches thick) that are separated by thin films or partings of blue-gray to gray-green or brown to buff shale. In the southern outcrop area it is partly conglomeratic or pseudo-oolitic and there is bentonite up to 6 inches thick at or near top. In the northern outcrop area north of Dixon, Illinois, it grades into fine- to medium-grained buff dolomite with a pitted or vuggy weathered face.

Correlation.—The Eldena Member is correlated with the Leray Member of the Chaumont Limestone in New York State.

Elm Member (new)

The Elm Member of the Nachusa Formation is here named for Elm Street in Dixon, Lee County, northern Illinois, just southwest of the type section, which is part of the Nachusa type section (geol. sec. 23).

Distribution.—The Elm Member has the same distribution as the Nachusa Formation except that it is absent in most of central western Illinois, in southwestern and northeastern Wisconsin, and in the northern peninsula of Michigan.

Thickness.—In the northern outcrop area the Elm is commonly 2 to 3 feet thick and ranges from less than 1 foot to a maximum of 4½ feet near LaSalle, Illinois. In Sangamon County, central Illinois, it is about 5 feet thick. In the southern outcrop area it is about 7 feet thick between Calhoun County, Illinois, and Ste. Genevieve County, Missouri, but it thickens southward to about 15 feet at Cape Girardeau, Missouri (Midwest Dairy Company well, 140′ to 155′).

Lithology.—In the northern outcrop area the Elm Member consists of argillaceous dolomite that is gray to light buff, chalky, mostly dense, commonly cherty, sparsely fossiliferous, mainly nonfucoidal, and thin bedded to massive. It commonly has thin shale partings like those in the underlying Eldena Member, but they are more numerous. It is usually distinguished from the members above and below by its smooth-weathered face. South of LaSalle County, northern Illinois, the Elm grades into moderately argillaceous and dolomitic limestone that is somewhat conglomeratic, cherty, thin to medium bedded, and has weak shale partings and local calcarenite layers.

Correlation.—The Elm Member is correlated with the Glenburnie Member of the Chaumont Limestone in New York and Ontario.

Everett Member (new)

The Everett Member of the Nachusa Formation is named for Everett Street in Dixon, Lee County, northern Illinois, which was named for Dr. Oliver Everett, pioneer geologist of the Rock River Valley, who first noted the abundance of *Foerstephyllum ("Favosites")* in Nachusa ("lower Galena") strata (Everett, 1861, p. 57-58). The type section is part of the Nachusa type section (geol. sec. 23).

Distribution and Thickness.—The distribution of the Everett Member coincides with that of the Nachusa Formation. In the northern outcrop area the Everett ranges from 1½ feet thick in southwestern Wisconsin (Mifflin type section) to 26 feet at Kentland, Indiana, but it averages about 7 feet thick. In Sangamon County, central Illinois, the Everett is 12½ feet thick. Throughout the southern outcrop area it is close to 20 feet thick, except in the vicinity of Calhoun County, Illinois, where it reaches nearly 25 feet.

Lithology.—The Everett consists of dolomite that is generally pure, medium grained, porous, cherty, fossiliferous, very fucoidal, and thick bedded to massive, with a brown, vuggy, weathered face. South of Dixon, Illinois, the Everett grades into dolomite-mottled, lithographic, dense limestone but otherwise resembles the dolomite facies. It has a deeply pitted weathered face. The member is pure except in parts of southwestern Wisconsin, where it is slightly argillaceous, and in Missouri, where it contains a few weak, widely separated, gray-green shale partings. At the top of the member there is a distinctive 3- to 8-inch bed of fine-grained, dense, nonfucoidal dolomite or limestone that weathers to a smooth, gray-white face and commonly overlies a band of very large chert nodules. This bed has been found from Janesville, Wisconsin, to Nashville, Tennessee. A thin bed of bentonite commonly is present from 8 to 9 feet below the top of the Everett in the southern outcrop area.

Fauna.—*Foerstephyllum halli* (Nicholson) is most abundant in the Everett Member.

Stratigraphic Relations.—In southwestern and northeastern Wisconsin and in northern Michigan, where the Elm Member is absent, a scour surface separates the Everett from the underlying Eldena Member. Where the latter also is missing, as in much of southwestern Wisconsin and central western Illinois, the Everett rests with sharp contact on the Forreston Member of the Grand Detour Formation.

Correlation.—The Everett Member is considered equivalent to the Watertown Member of the Chaumont Limestone in New York State.

Quimbys Mill Formation

Agnew and Heyl, 1946

The Quimbys Mill Formation was named for Quimby's Mill, near the village of Etna, Lafayette County, Wisconsin, by Agnew and Heyl (1946), who designated it a member of the Platteville Formation. The type section is a quarry at the mill (geol. sec. 24).

The Quimbys Mill Formation is equivalent to the "Glassrock" of southwestern Wisconsin (Hall and Whitney, 1862, p. 163), to the uppermost part of the Upper Buff Limestone (Chamberlin, 1878, p. 295-297), to the upper Lowell Park Limestone of northern Illinois (Knappen, 1926, p. 53-58), to the uppermost McGregor Limestone ("Glass Rock") in southwestern Wisconsin (Kay, 1935a, p. 286), and to the "Spechts Ferry dolomite facies" in central southern Wisconsin (Bays and Raasch, 1935, p. 298-299; Bays, 1938).

The limestone of the Quimbys Mill Formation is finer grained, much less fucoidal, thinner bedded, and contains many more shale partings than the limestone of the underlying Nachusa Formation. It is much less argillaceous and shaly and is finer grained than most of the limestone beds in the overlying Spechts Ferry Formation, has predominantly dark brown shale partings instead of green, gray, or gray-brown shale layers, and contains a different fauna. Although the lower limestone (Castlewood Member) of the Spechts Ferry generally is similar to the Quimbys Mill, it is more argillaceous, commonly contains *Pionodema subaequata* (Conrad) and other Trentonian fossils, and it is above the unconformity and bentonite at the base of the Spechts Ferry Formation.

Chiefly on the basis of differences in bedding and shaliness, the Quimbys Mill Formation is divided into the following three members in ascending order: Hazel Green (thick bedded, slightly shaly, white weathering), Shullsburg (thin bedded and shaly), and Strawbridge (thick bedded, slightly shaly, finely fucoidal).

Distribution.—The Quimbys Mill Formation is present throughout the Mississippi Valley region except in southeastern Minnesota, northeastern Iowa and adjacent parts of southwestern Wisconsin, most of Hancock County in central western Illinois, and much of northeastern Missouri. It thins toward these areas mainly by truncation from the top downward. Quimbys Mill outcrops described in this report are listed in the index.

Thickness.—In the northern outcrop area the Quimbys Mill generally is close to 12 feet thick. It is 18 feet at Kentland, northwestern Indiana, but in Sangamon County, central Illinois, it is less than 3 feet thick, and only the Shullsburg Member is present. In the southern outcrop area it thickens rapidly southward from 14 feet in Lincoln County, eastern Missouri (geol. sec. 26), to nearly 32 feet in the St. Louis area (Glencoe East section, see *Plattin Subgroup*). It is between 29 and 35 feet thick from St. Louis to Cape Girardeau, Missouri (Midwest Dairy Company well, 85′ to 120′).

Lithology.—The Quimbys Mill is pure to slightly argillaceous, brown, lithographic, locally cherty, partly fucoidal, fossiliferous, and thin- to thick-bedded limestone. It generally has dark brown shale partings. In Missouri some of the shale partings are greenish gray, and the formation contains some thin layers of conglomerate, coquina, and bentonite. The bedding surfaces and face are relatively smooth. In central northern Illinois and central southern Wisconsin the formation grades to chalky or fine-grained dolomite that weathers yellow-buff, and in the type area of southwestern Wisconsin the upper half is dolomite.

Fauna.—Epecially common and characteristic species are *Lambeophyllum profundum* (Conrad), *Homotrypa minnesotensis* Ulrich, *Camerella bella* Fenton, *Campylorthis deflecta* (Conrad), *Rostricellula missouriensis* (Fenton & Fenton), *Strophomena trentonensis* Winchell & Schuchert, *Strophomena auburnensis* Fenton, *Helicotoma planulata* Salter, *Basiliella barrandei* (Hall), and *Eoleperditia fabulites* (Conrad).

Stratigraphic Relations.—A sharp contact and the local absence of the Hazel Green Member suggest the presence of a diastem between the Quimbys Mill and the underlying Nachusa Formation. A regional unconformity, described under the Galena Group, occurs at the top of the Quimbys Mill and marks the break between the Platteville (upper Blackriveran) and Galena (Trentonian) Groups.

Correlation.—The Quimbys Mill Formation is missing in most of New York and Ontario. The easternmost known occurrence is at Point Anne, near Belleville, Hastings County, Ontario (see *Regional Correlations, New York* and *Ontario*), where 20 inches of Shullsburg Limestone intervenes between Chaumont (Nachusa) and Selby (Spechts Ferry) strata. It seems to have been included with the Chaumont Formation (Young, 1943, p. 215).

Hazel Green Member (new)

The Hazel Green Member of the Quimbys Mill Formation is here named for Hazel Green, a village in Grant County, southwestern Wisconsin. The type section is part of the Quimbys Mill type section (geol. sec. 24).

Distribution.—The Hazel Green is generally present throughout the region occupied by the Quimbys Mill but is missing in northern Michigan, eastern Wisconsin, and northwestern Indiana. It also is absent for the most part in central and central western Illinois and in northeastern Missouri, although at the Kings Lake and West Point Landing sections it is represented only by the bentonite that occurs at its base.

Thickness.—In the northern outcrop area the Hazel Green ranges from 1 foot 8 inches thick at the type locality to 2 feet 6 inches thick at places in Ogle County, central northern Illinois. In the southern outcrop area it ranges from a few inches thick in northeastern Missouri to about 5 feet thick at Cape Girardeau, southeastern Missouri (Midwest Dairy Company well, 115′ to 120′). It is over 4 feet thick near St. Louis (Glencoe East section). The maximum known thickness is 9½ feet at Cape Nelson, Garrand County, central Kentucky, including a basal bentonite that is more than 3 feet thick.

Lithology.—The Hazel Green Member consists of lithographic limestone and fine-grained dolomite, mainly pure and thick-bedded to massive, with a smooth, light buff to gray-white weathered face and a basal bentonite that extends as far north as Lincoln County, Missouri. Directly overlying the bentonite is a bed of argillaceous, cherty, thin-bedded, shaly limestone that varies from 4 to 8 inches thick in the northern outcrop area and 19 to 22 inches thick in the southern outcrop area. As a whole, the Hazel Green is purer, less shaly, and thicker bedded than the overlying Shullsburg Member.

Shullsburg Member (new)

The Shullsburg Member of the Quimbys Mill Formation is named for Shullsburg, a town in Lafayette County, southwestern Wisconsin. The type section is part of the Quimbys Mill type section (geol. sec. 24).

Distribution and Thickness.—The Shullsburg is the most widely distributed member of the Quimbys Mill and has the same extent as the formation. In the northern outcrop area the Shullsburg ranges from 2½ feet thick at the type locality to nearly 5 feet in part of LaSalle County, north-central Illinois, and it reaches a maximum of 9½ feet at Neenah, Winnebago County, eastern Wisconsin. In Sangamon County, central Illinois, it is only about 3 feet thick and is the only representative of the Quimbys Mill Formation. In the southern outcrop area it ranges from 5 feet thick in Lincoln County, Missouri (geol. sec. 26), to 19 feet thick near St. Louis (Glencoe East section), and it is commonly about 15 feet thick.

Lithology.—The Shullsburg consists of lithographic limestone and chalky dolomite that is slightly argillaceous, brown to buff, and thin to medium bedded. It is strongly shaly in southwestern Wisconsin but moderately or slightly shaly in Missouri. It has a thin bentonite at top as far north as Lincoln County, Missouri. It is distinctly less pure than adjoining members. In Missouri it contains occasional layers of white, glassy limestone. At places in central northern Illinois the bedding surfaces show mud-cracks or ripple-marks.

Strawbridge Member (new)

The Strawbridge Member of the Quimbys Mill Formation is named for Strawbridge, a village in Lafayette County, southwestern Wisconsin. The type section is part of the Quimbys Mill type section (geol. sec. 24).

Distribution.—The Strawbridge occurs throughout most of the area of the Quimbys Mill Formation, but it is locally missing at the margins of the area because of post-Quimbys Mill, pre-Spechts Ferry erosion.

Thickness.—In the northern outcrop area the Strawbridge most commonly is about 7 feet thick, but it ranges from less than a foot thick at places in southwestern Wisconsin to 14 feet at Kentland, northwestern Indiana, and 16 feet near Trenary, Alger County, upper Michigan. In the southern outcrop area it generally is about 10 feet thick, but it is locally absent in Lincoln County, Missouri (geol. sec. 26), and 15 feet thick at Cape Girardeau, Missouri (Midwest Dairy Company well, 85′ to 100′).

Lithology.—The Strawbridge Member consists of lithographic limestone and dense, fine to locally medium-grained, partly vuggy dolomite. It is pure, partly cherty, and generally medium to thick bedded, with some thin shale partings or films. It weathers to weak, irregular, thin to medium beds. It commonly contains numerous fucoids, which are rare in older Quimbys Mill strata and are much smaller than those in the underlying Nachusa Formation. At the top in central northern Illinois there is ordinarily 10 to 15 inches of very cherty, shaly, thin-bedded dolomite, but as a whole the Strawbridge is conspicuously thicker bedded and less shaly than the underlying Shullsburg Member.

GALENA GROUP

Hall, 1851; modified by Kay, 1935; modified in present report

The Galena Group (fig. 18) was named for the town of Galena, Jo Daviess County, Illinois (Hall, 1851, p. 146-148). It is the uppermost group of the Champlainian Series in the Mississippi Valley and consists of strata from the base of the Spechts Ferry Formation to the top of the Dubuque Formation. The Galena Group normally overlies the Platteville Group and is overlain by the Maquoketa Group of the Cincinnatian Series. On the flanks of the Ozark Uplift, the Galena overlaps older formations and it in turn is truncated by Maquoketa and younger formations.

No specific type section was described by Hall, but about two-thirds of the group is exposed in Galena and the entire group is exposed along the Galena River within 4 miles of Galena. The following exposures are considered typical of the dolomite facies of the Galena Group in the type region:

(1) One mile southeast of Millbrig in the east bluff of the Galena River (near cen. 34, 29N-1E, Galena Quad.), from the top: *Galena Group, Dunleith 34′4″ (Eagle Point 5′+ poorly exposed, Beecher 9′7″, St. James 14′4″, Buckhorn 5′5″), Guttenberg 14′2″ (Glenhaven 11′6″, Garnavillo 2′8″), Spechts Ferry 3′4″ (Glencoe 1′6″, Castlewood 1′10″); Platteville Group, Quimbys Mill (Strawbridge) 3′11″*. One inch of bentonite occurs at the base of the Glenhaven, and 4 inches of bentonite overlying one-half inch of brown shale occurs at the base of the Spechts Ferry.

(2) Three-fourths of a mile northeast of Millbrig in the south bluff of Galena River (NE SW 27, 29N-1E, Galena Quad.), from the top: *Galena Group, Dunleith 49′ (Fairplay 6′, Eagle Point 19′, Beecher 9′, St. James 13′, Buckhorn 2′).*

(3) Three miles northeast of Galena in the north bluff of East Fork (NW NE SE 3, 28N-1E, Galena Quad.), from the top: *Galena Group, Dunleith 79′3″ (Wyota 4′8″, Wall 9′2″, Sherwood 18′3″, Rivoli 18′7″, Mortimer 17′, Fairplay 11′7″).*

(4) Three miles south of Galena, 1 mile southeast of Galena Junction, in the Mississippi River bluffs (near cen. SE 1, 27N-1W, Galena Quad.), from the top: *Galena Group, Wise Lake (Sinsinawa) 25′, Dunleith 73′2″ (Wyota 19′, Wall 12′6″, Sherwood 14′, Rivoli 15′, Mortimer 8′6″, Fairplay 4′2″).*

(5) Roadcut of U. S. Highway 20 in the southern part of Galena, the type section of the Sinsinawa Member (geol. sec. 33).

(6) Six miles south of Galena, the Wise Lake type section, which includes both the Wise Lake and Dubuque Formations (geol. sec. 32).

Hall may have intended to include in the Galena all the dolomite down to the top of the Guttenberg, but most of the early reports appear to extend the Galena to the base of the Guttenberg (fig. 19). This practice was followed until the Decorah Shale was differentiated, which moved the base of the Galena up to the top of the Decorah. As commonly accepted, the Galena is a formation above the Decorah Shale and beneath the Maquoketa Shale. Some consider the uppermost shaly beds (Dubuque) to be in the Cincinnatian Series, and a few consider that the underlying Stewartville beds also are Cincinnatian. In practice, the base of the Galena has not been consistently recognized. In some areas it has been put at the base of the Ion, in others at the base of the Guttenberg, and locally at the base of the Nachusa Formation in the Platteville Group.

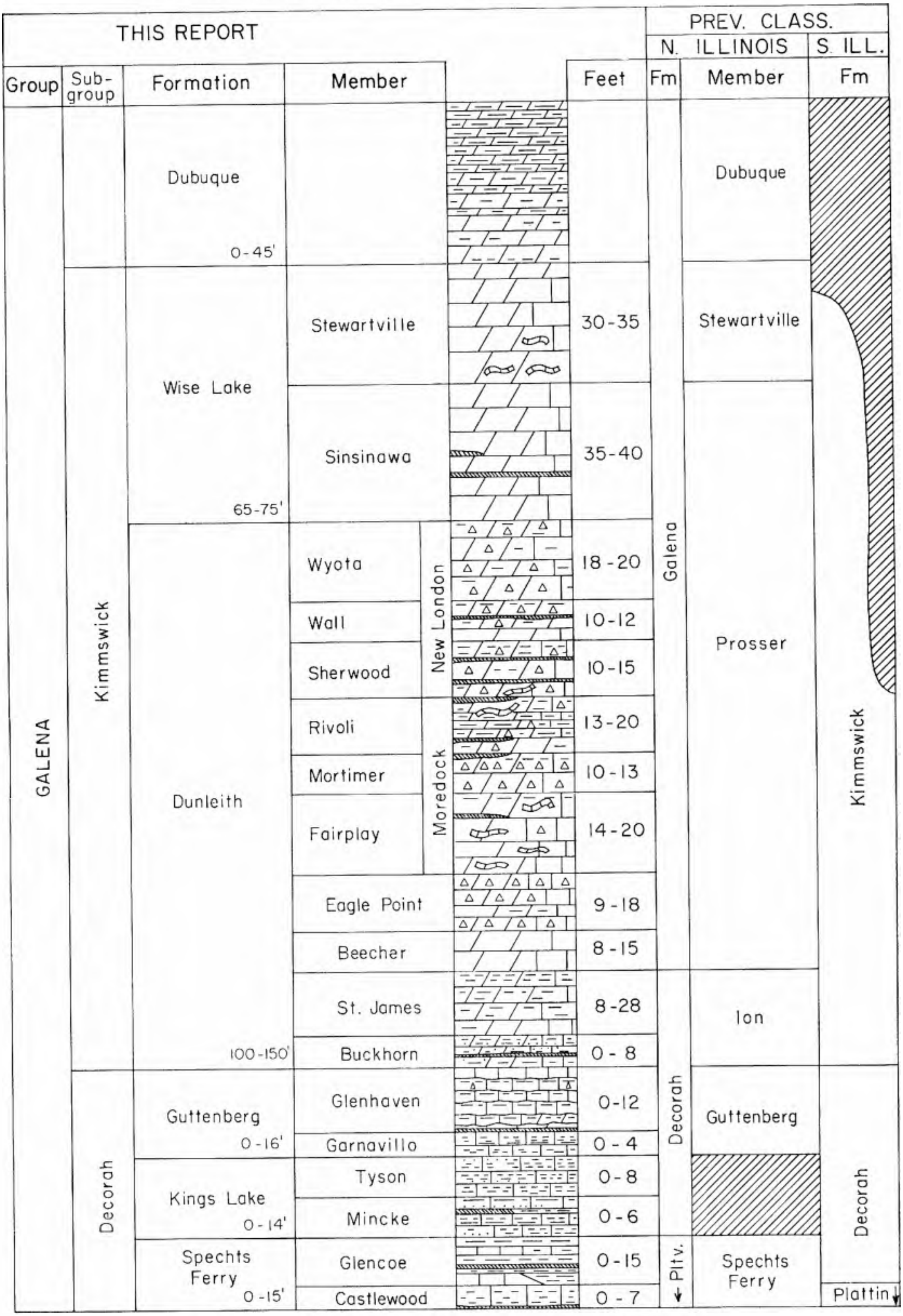

FIG. 18.—Classification of the Galena Group in Illinois.

The name Galena (Kimmswick) Formation has been used in Illinois to show contemporaneity of the Galena and Kimmswick Formations (DuBois, 1945, p. 17). It is now proposed to drop the name Kimmswick from this combination because Galena has priority, and because neither the top nor bottom boundaries of the Galena and Kimmswick are the same. Kimmswick is retained as a subgroup of the Galena Group.

Classification.—Differentiation of a "Galena Group" as a provincial group in the Mississippi Valley, equivalent to the Trenton Group of the New York section, was suggested by Kay (1935a, p. 289). Kay included the Decorah and Galena Formations in the Galena Group and raised the members of the Galena to the rank of formations. Although this proposal was not generally accepted, its merit has become evident during the present study. Recognition of the Galena Group as defined by Kay, with the exception that the base of the group is lowered to include the Spechts Ferry Formation, is favored for the following reasons:

(1) It recognizes the general lithologic similarity of the Decorah and Galena strata and their distinct differentiation throughout much of eastern North America from the underlying Platteville or Black River strata, which likewise have a general lithologic unity.

(2) The close relationship of the Decorah and Galena Formations in the Mississippi Valley is shown by the northwestward increase in shaliness that transects the boundary between them in their type region.

(3) The units previously considered as members are, with the changes proposed, lithologically distinct units of wide distribution and are worthy of elevation to formation rank.

(4) The new formations are differentiated into less distinct or relatively thin units which, because of wide distribution and importance in correlation, need to be named and recognized as members.

(5) Regional correlations show that the new ranking of the units will be in much better accord with the ranking in New York, Kentucky, Tennessee, and the Appalachian region.

The location of the Black River-Trenton contact at the top of the Spechts Ferry in the Mississippi Valley was based entirely on faunal evidence, which in part was confused by miscorrelation of upper Platteville strata with Spechts Ferry strata and mixing of the faunas. Herbert (1949) found that the major unconformity in the Mississippi Valley occurs at the base of the Spechts Ferry rather than above it. In the present study of sections through southern Ontario to New York it was found that the Spechts Ferry is equivalent to the Selby Member of the Rockland Formation at the base of the Trenton Group, rather than to the Watertown Limestone at the top of the Black River Group, as previously correlated.

Alternative Classifications.—Because of the strong contrasts in lithology, consideration has been given to differentiation of a northern limestone-shale facies, a central dolomite facies, and a southern calcarenite facies as separate groups (fig. 20). However, the transition northward from the dolomite to the limestone facies is gradual and transects the group at a low angle. The transition southward from the dolomite facies to the calcarenite facies is poorly exposed, but subsurface data show that it occurs in a relatively narrow zone. In most localities an irregular zone of mottled limestone-dolomite separates the facies. As the formations and most of the members can be differentiated in all three facies, different groups do not seem desirable.

Distribution and Thickness.—The Galena Group is widely exposed throughout the northern and southern outcrop areas (fig. 1). It is commonly 250 to 275 feet thick in the northern outcrop area and 100 to 125 feet thick in the southern outcrop area, except at the extreme northern end of the southern area where it thickens to about 175 feet.

Lithology.—The Galena Group consists predominantly of limestone or dolomite, but where fully present it has shaly units at both bottom and top (fig. 21). In the type region in northwestern Illinois it consists largely of fine- to medium-grained dolomite. The lower

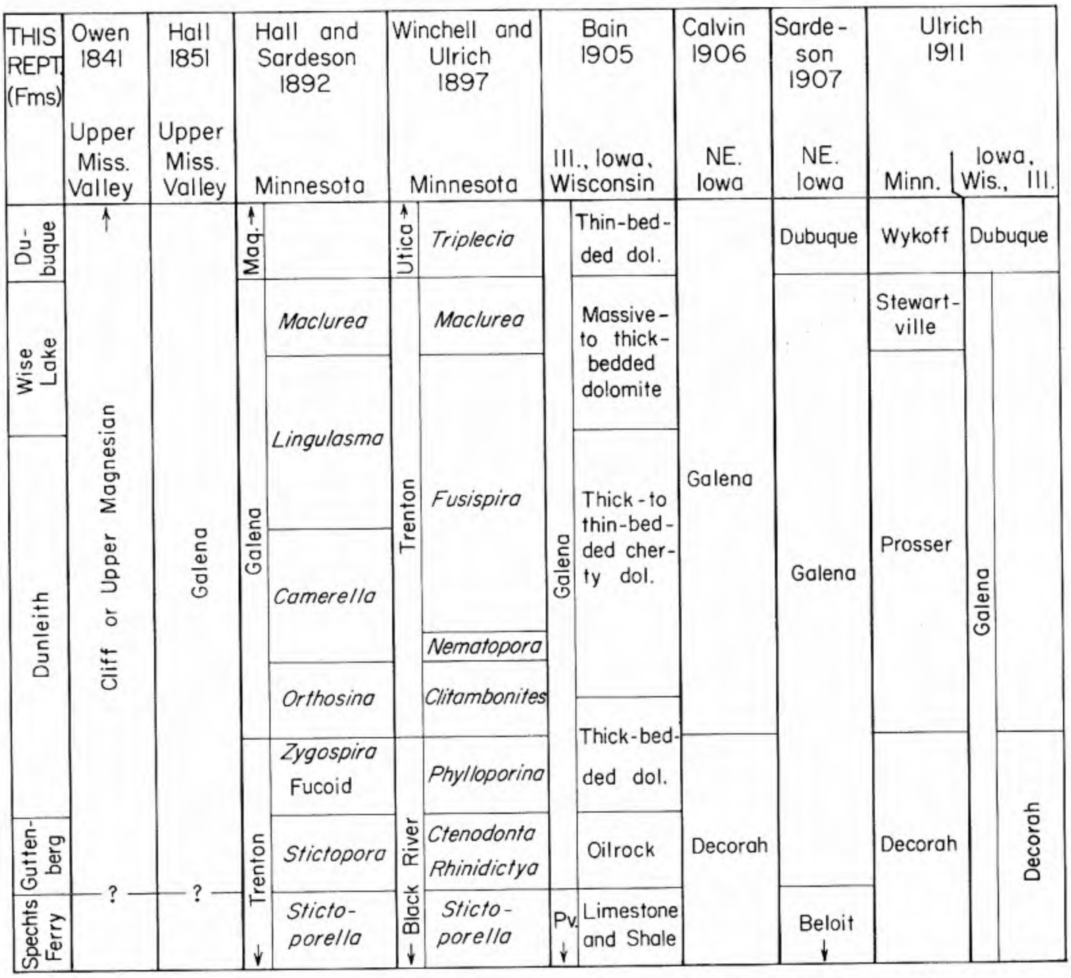

FIG. 19-A.—Development of the classification of the Galena Group in the northern outcrop area from 1841 to 1911.

half has argillaceous zones and is mostly cherty; the upper half is relatively pure and noncherty. Farther east, in north-central and northeastern Illinois, some of the shaly beds thin out and the argillaceous beds become purer so that the entire group is medium-grained dolomite, sharply differentiated from the fine-grained limestone and dolomite of the Platteville Group below and the shale of the Maquoketa Group above. Northward from Illinois the group changes from the base upward to very fine-grained, nearly lithographic limestone, and its lower formations become more shaly and less cherty. Southward from the outcrop area in northern Illinois the basal shaly beds persist with little change, but the upper part of the dolomite changes to limestone similar to the northern limestone facies, and the lower part changes to coarse calcarenite.

Fauna.—The Galena Group has an abundant, varied, and well preserved fauna dominated by bryozoans and brachiopods in both the northern limestone facies (Winchell and Ulrich, 1895, 1897; Kay, 1929, 1935a, 1940a, b; Stauffer (1935b); Stauffer and Thiel, 1941, and Perry, 1962) and in the southern calcarenite facies (Bradley, 1925; Branson, 1944, p. 86-92). The fauna in the intermediate dolomite facies of central southern Wisconsin and central northern Illinois consists mostly of poorly preserved molluscan molds with some

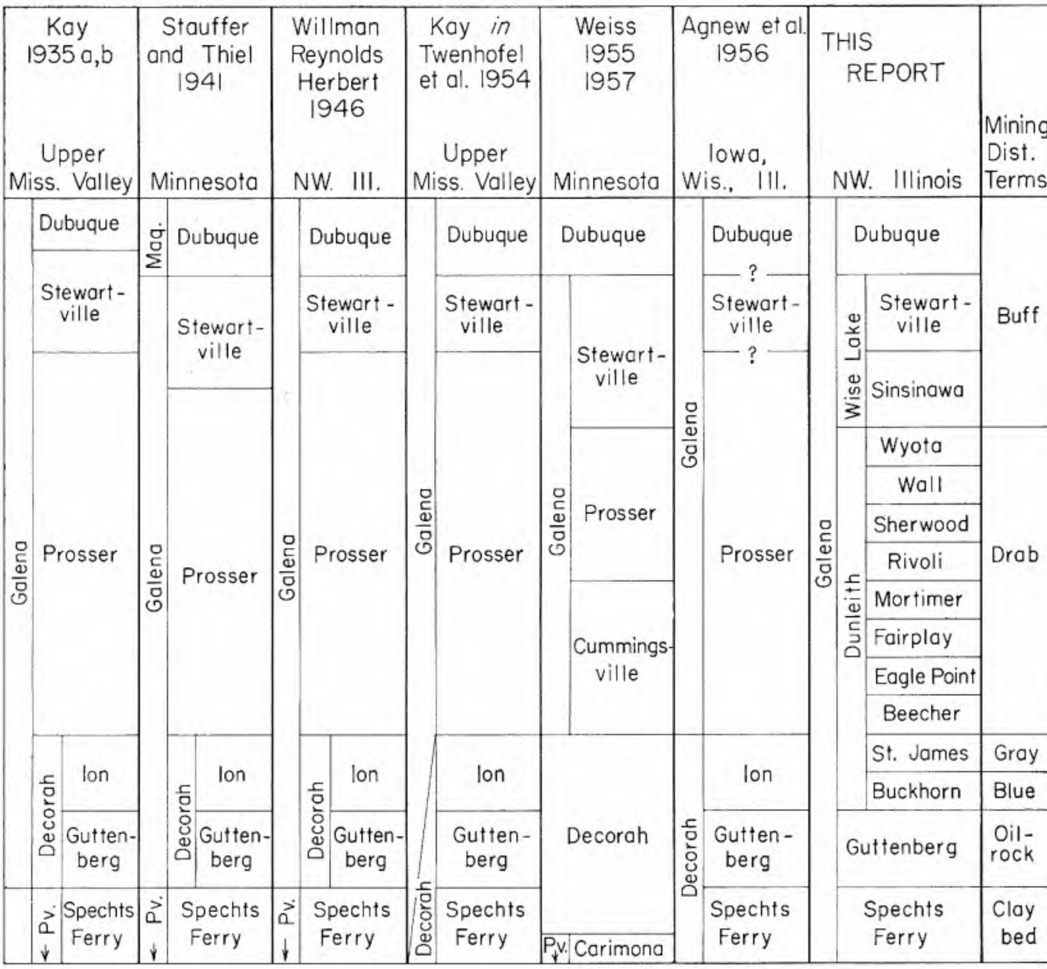

FIG. 19-B.—Development of the classification of the Galena Group in the northern outcrop area from 1935 to date.

brachiopods. It is in general less abundant and varied, and has been less adequately studied (Whitfield, *in* Chamberlin, 1878, p. 320-326; Whitfield, 1878, 1880, 1883, 1895; Knappen, 1926, p. 64).

The fauna of the Galena Group is better known than that of the Platteville and more of the species seem to have restricted ranges within the group. The sponge *Receptaculites oweni* Hall is ubiquitous in Dunleith-Wise Lake (Ion-Prosser-Stewartville) strata and occurs in the Guttenberg in Minnesota (Stauffer and Thiel, 1941, p. 85). The brachiopod genera *Rafinesquina, Dalmanella,* and *Sowerbyella* extend from the base of the Spechts Ferry throughout the group. They first appear in the Galena Group of the Mississippi Valley and in the Trenton Group of New York and Ontario, except for *Sowerbyella,* which occurs in pre-Trenton strata in the Appalachians and in Tennessee.

The most conspicuous fossils in the Galena formations and members, especially in the dolomite facies, are mentioned below under the descriptions of those units. The ranges of the more important species that appear restricted to certain parts of the Galena Group are given under *Correlations, New York* and *Ontario.*

Stratigraphic Relations.—The Galena Group is separated by unconformities from the Platteville Group below and the Cincinnatian Series above (fig. 20). The basal Spechts Ferry Formation truncates the Quimbys Mill, Nachusa, and part of the Grand Detour Formation of the Platteville Group.

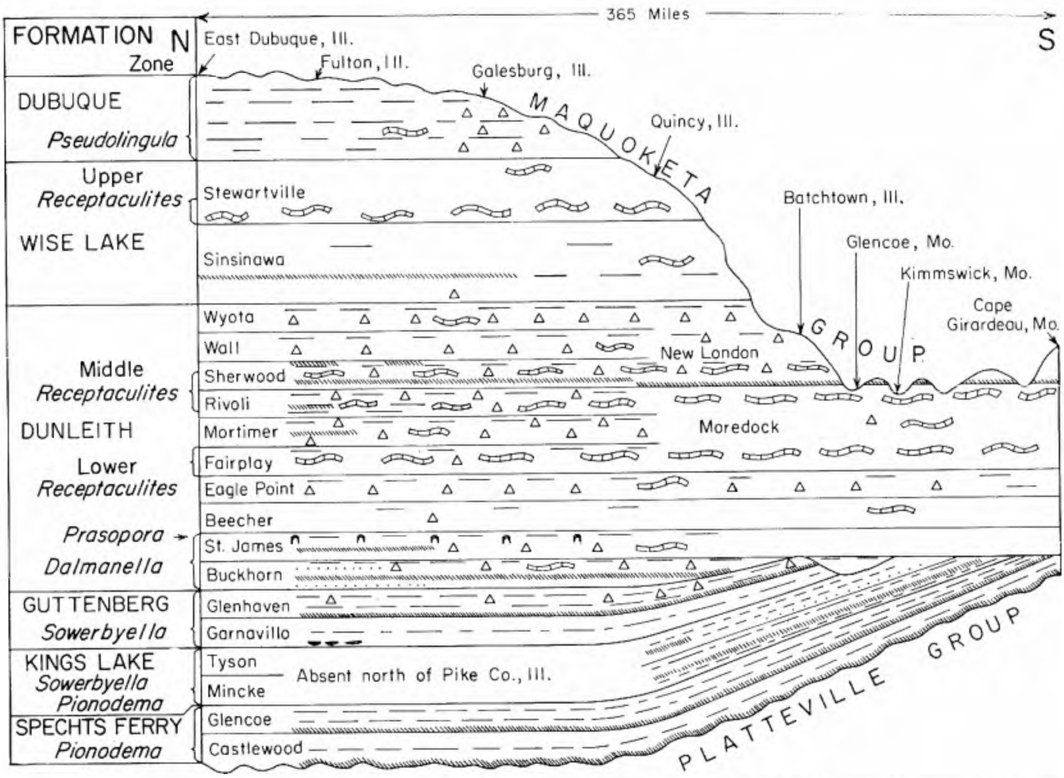

FIG. 20.—Diagrammatic cross section of the Galena Group from East Dubuque, Illinois, to Cape Girardeau, Missouri. Figure 4 gives key to symbols. The limestone and dolomite patterns are omitted for clarity (see fig. 21).

The unconformity at the top of the Galena is shown by the southward thinning of the group in Illinois (DuBois, 1945, fig. 5, p. 20). Between northern Illinois and the outcrop area in Ralls County, Missouri, the Dubuque Formation and the upper part of the Wise Lake Formation are truncated by the Maquoketa Shale, and from Ralls County into Calhoun County, Illinois, the rest of the Wise Lake and the upper part of the Dunleith Formation also are truncated. From Calhoun County south to Thebes, Illinois, the top of the Galena Group generally is about 150 feet below the top of the type Galena.

Correlation.—The Galena Group is of Trentonian age. It is equivalent to the Trenton Group of New York, as defined by Twenhofel et al. (1954), which excludes the Upper Utica (Collingwood and Gloucester). The Galena Group also is equivalent to the Lexington Limestone of Kentucky and the Nashville Group of Tennessee (figs. 33, 36).

From a study of the faunas in Minnesota, Weiss (1957) concluded that time correlations of the Minnesota Ordovician section with the Black River and Trenton of New York are meaningless and that the rapid change of numbers, relative dominance, and species of fossils at the Platteville-Decorah boundary is largely quantitative rather than qualitative, reflecting mainly the significant changes of bottom environment at that level. Granting that relative abundance and environmental control are dominant factors, the presence of a significant faunal change at the base of the Carimona Limestone, which we consider to be the Blackriveran-Trentonian contact, still seems evident in his fossil lists (Weiss, 1957, table 1, p. 1044-1048). A major reason for his inconclusive comparison of Blackriveran and Trentonian faunas is the inaccurate assignment of some of the faunas in other areas.

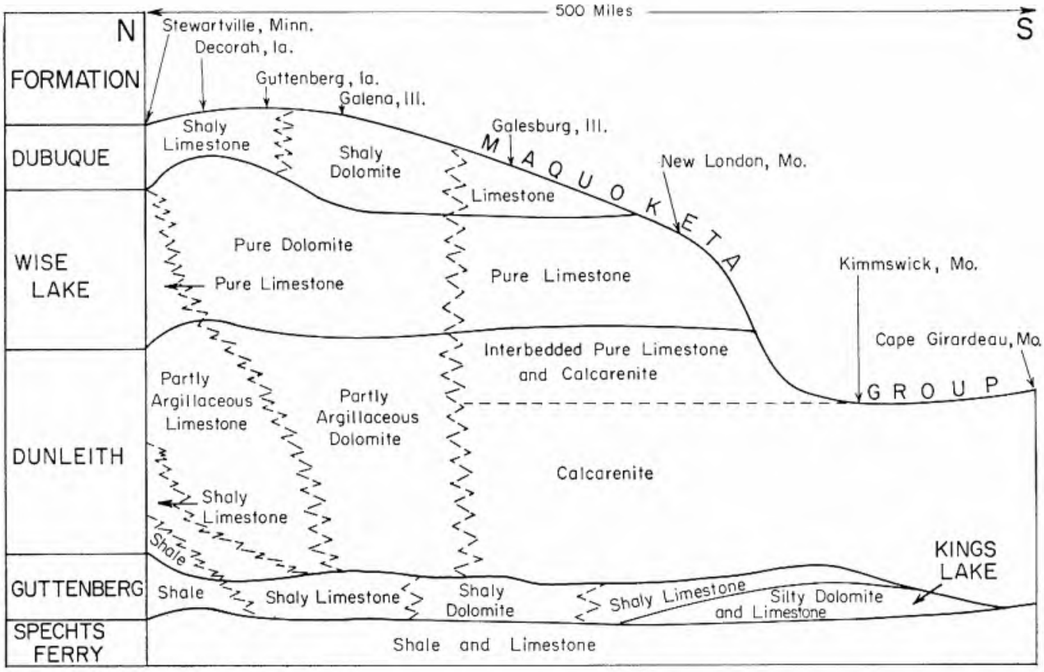

FIG. 21.—Facies in the Galena Group between southeastern Minnesota and southeastern Missouri.

Agnew et al. (1956, p. 260) likewise believed that the fossils of the Platteville, Decorah, and Galena strata of the Upper Mississippi Valley had not been studied in sufficient detail to permit a time assignment closer than Middle Ordovician. In our opinion, however, the lithologic comparisons of the Mississippi Valley sequence with the type Blackriveran and Trentonian sequences confirms the assignment of the stage boundary to the base of the Decorah, where it has long been established almost entirely on faunal evidence.

Although further paleontological studies, particularly on a regional basis, are highly desirable, much pioneering paleontological work already has been done on these strata, and the fact that the Blackriveran-Trentonian contact seems to have been correctly identified indicates that certain fossils, or fossil assemblages, have more time significance than has been granted.

Subdivisions.—Changes in the correlation and rank of many units and the need for further subdivision have made necessary the modification of the classification and nomenclature within the Galena Group in Illinois (fig. 3).

Classification within the group is complicated by facies that have intricate intertonguing relations and transect the sequence at low angles (fig. 20). In Illinois, this complication has resulted in the use of different classifications in the northern and southern outcrop regions and in their erratic use in subsurface in the remainder of the state. The revised classification (fig. 18) is an attempt to blend the classifications and, by recognizing continuity of units through changes in facies, to develop a unified classification applicable throughout the state.

In many types of studies, particularly those based on well samples, it is advantageous to recognize as a unit the predominantly carbonate formations of the middle and major part of the group, previously called Galena, Kimmswick, or Galena (Kimmswick). As the name Galena has been adopted for the entire group, the name Kimmswick can be appropriately assigned to this carbonate unit, which is here recognized as a subgroup. The predominantly argillaceous formations of the lower part of the group, previously called Decorah in Illinois and Missouri, also frequently require recognition as a unit. The unit is here accepted as a subgroup and the name Decorah is retained for it. Although comparable to type Decorah in lithologic relations, it is only partly equivalent in age to type Decorah, as noted later. The upper shaly strata of the Galena Group, differentiated as the Dubuque Formation, are not included in the Kimmswick Subgroup.

Elevation of the previous members of the Galena and Decorah Formations to formational rank is based on (1) their distinctive lithology throughout an extensive region, (2) the correlation of many of them with units differentiated as formations in other regions (fig. 27), (3) the achievement of better agreement with the evaluation of formations in other systems in Illinois, and (4) the desirability of subdividing the new formations into members.

The Dubuque, Wise Lake, and Dunleith Formations are mappable units with distinctive lithology and can be readily differentiated in the field. The Guttenberg, Kings Lake, and Spechts Ferry Formations are even more distinctive units, but they have maximum thicknesses of only 15 to 30 feet, and they generally are thinner. The common lack of adequate thickness for separate mapping is considered to be outweighed by lithologic distinctiveness, regional differences in distribution, and equivalence with relatively thick and distinctive units in other regions. In many areas the three formations combined, the Decorah Subgroup, compose a mappable unit.

Miners' Terminology

The units differentiated as formations in the Galena Group are commonly recognized by miners and drillers in the lead-zinc district of Illinois, Iowa, and Wisconsin. The "Upper Buff" or "Buff" of the mining district is the Wise Lake Formation. The overlying Dubuque Formation is not encountered in the drilling in much of the district, but where present it is included in the "Upper Buff."

The term "Drab" is used for the strata beneath the "Upper Buff" and recognizes the color change at the top of the Dunleith Formation. The "Gray" underlies the "Drab" and is the St. James Member of the Dunleith. The unit is distinctly more grayish than the "Drab" above and this change is readily apparent in the color of the drill cuttings. Its recognition in drilling is important because it indicates approach to one of the major ore-bearing parts of the section. The "Blue," underlying the "Gray," is the Buckhorn Member of the Dunleith. It is a darker gray than the "Gray" above.

The "Oilrock" is the Guttenberg Formation. The red-brown shale in the "Oilrock" contains enough distillable oil to burn briefly when it is ignited by a match. It was called the "Brown" by the early miners and geologists.

The underlying "Clay Bed" is the green shale of the Spechts Ferry Formation. Recognition of the "Clay Bed" was important in the early days of exploration, because it indicated that the major ore-producing zones had been penetrated.

The glassy fracture of the lithographic limestone beneath the "Clay Bed," resulted in its early designation as the "Glassrock." The "Glassrock" is the Quimbys Mill Formation.

Deeper drilling into gray limestone strata called "Trenton" was not generally practiced in the early days but became more common as exploration below the floors of some old mines revealed ore deposits in the upper part of the "Trenton." The "Trenton" includes the Grand Detour and Mifflin Formations.

Only a few prospect drill holes penetrate to the underlying brown dolomite, called the "Lower Buff," which is the Pecatonica Formation.

The terminology of the miners and drillers is not affected by changes in the stratigraphic nomenclature introduced by successive generations of geologists, and gives a desirable continuity to the nomenclature on drill records throughout the district. Conversion to geologic names is not difficult when needed.

DECORAH SUBGROUP

Calvin, 1906

The Decorah Subgroup was named for the town of Decorah, Winneshiek County, Iowa, in and near which it is well exposed (Calvin, 1906, p. 61). It consists of dominantly shaly formations at the base of the Galena Group—the Guttenberg (at the top), Kings Lake, and Spechts Ferry Formations (fig. 18). A typical section of the Decorah Subgroup in northern Illinois is included in the Galena type section. A representative section of the Decorah in the southern outcrop area is the type section of the Kings Lake Formation.

Classification.—The present usage of the term Decorah differs from that of the type locality where the Decorah is classified as a formation and includes higher strata, the Ion Member. At the time of our field study, it excluded the Spechts Ferry, but the Spechts Ferry has been returned to its original position in the Decorah in several recent reports (Herbert, 1949; Twenhofel et al., 1954; Agnew, 1955; Agnew et al., 1956).

For many years the Decorah Formation in northern Illinois (fig. 19) consisted of the Guttenberg and Ion Members, but Herbert (1949) showed that the underlying Spechts Ferry should be returned to its original designation as the basal unit of the Decorah Formation, and that in Illinois the Ion is much more closely related lithologically to the overlying Galena strata. In practice the Decorah was seldom subdivided, and beds equivalent to the Ion generally were included in the Galena.

In southern Illinois and Missouri, the name Decorah has been applied to shaly beds between the Plattin and Kimmswick Formations, which were believed to be equivalent to the Spechts Ferry Member (fig. 14). Although the Spechts Ferry strata were included in the Platteville rather than the Decorah in the northern outcrop area, the name Decorah continued in use in the southern area. However, Herbert (1949) also showed that in the southern area the Decorah contained both Spechts Ferry and Guttenberg beds with distinctive lithology and that the Ion was represented in the basal Kimmswick. He also differentiated silty strata between the Guttenberg and Spechts Ferry as a new member, the Kings Lake, not present in the type Decorah area, although possibly equivalent to a few thin silty beds of the uppermost Spechts Ferry.

Cooper (1956, p. 116) proposed the name Barnhart to replace the name Decorah in Missouri for an exposure at Koch Valley school, 2 miles south of Barnhart, Missouri, about 20 miles south of St. Louis. He correlated the Decorah (Barnhart) with the Guttenberg, rather than with the Spechts Ferry as Kay (1935a, p. 288) had done. Although both Guttenberg and Spechts Ferry strata are present in most of the area of Decorah strata in Missouri, at Koch Valley school the Kimmswick has truncated the Guttenberg and rests directly on Kings Lake strata (see fig. 23, section 5).

Rejection of the name Decorah for use in Illinois was at first deemed necessary because retaining it would require redefinition of both upper and lower contacts as currently used and long established in the Upper Mississippi Valley. However, acceptance of the name, as recommended by Herbert (1949), seems desirable because (1) its usage has been long established in Illinois and Missouri, (2) the Spechts Ferry has been accepted as the basal unit of the Decorah in several recent publications, which will probably eliminate the conflict at the base of the Decorah, (3) the top boundary of the type Decorah, although commonly recognizable by close study, lacks the ease of identification desirable for a formational boundary, except in the type region, and (4) the general recognition of the Decorah as a relatively shaly unit at the base of the Galena, although time-transgressive, is consistent with recent practice and the name is appropriate because it does not require redefinition in the type region.

Although the boundaries of rock-stratigraphic units in this part of the sequence are essentially parallel to time planes and we attempt to project these boundaries as far as usefulness in the field permits, the upper boundary of the Decorah is one where recognition of a series of steps seems desirable.

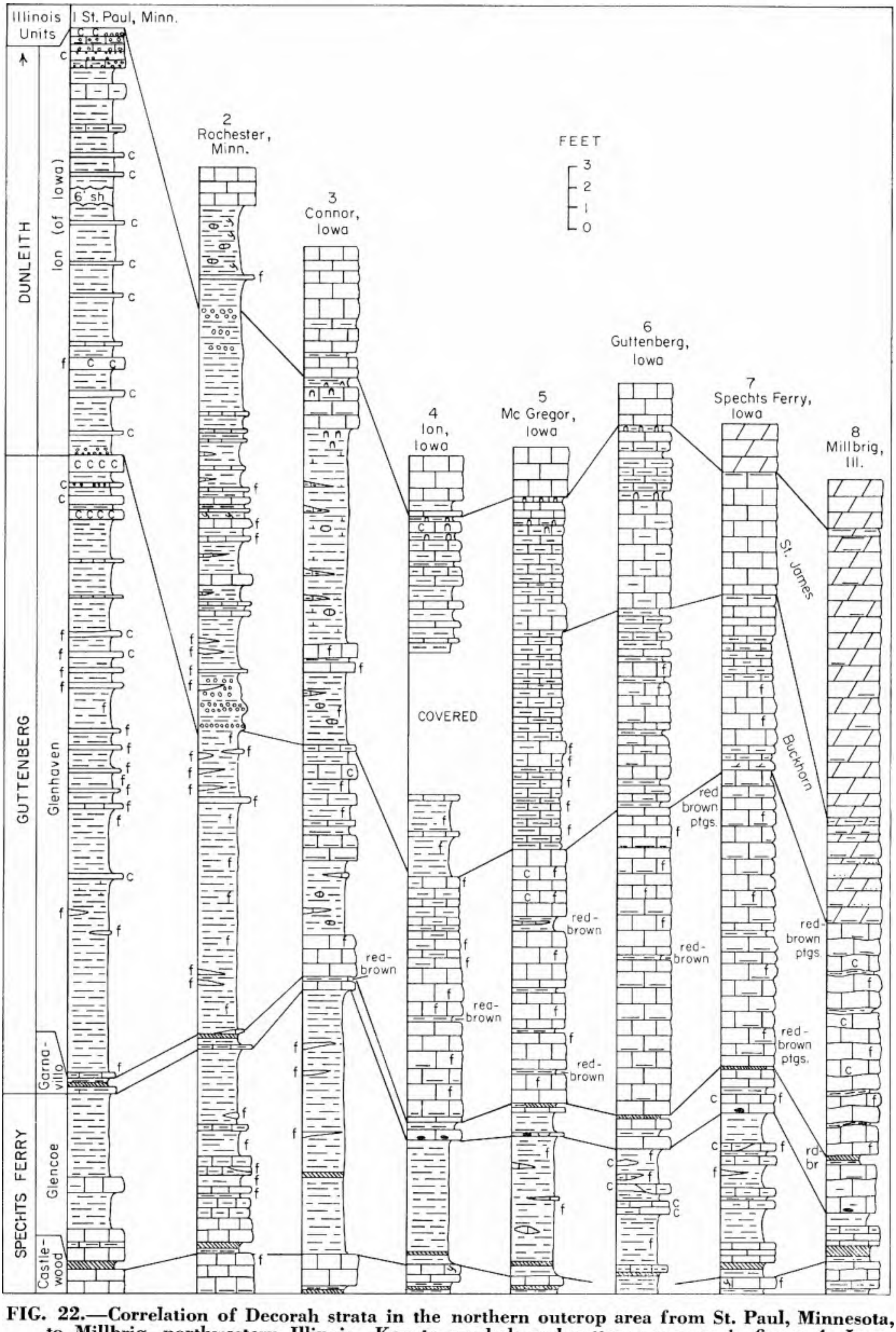

FIG. 22.—Correlation of Decorah strata in the northern outcrop area from St. Paul, Minnesota, to Millbrig, northwestern Illinois. Key to symbols and patterns appears in figure 4. Locations of sections are given on next page.

The Decorah is a well defined, dominantly shale unit at Decorah, but southeast of Decorah the upper member (Ion) becomes more calcareous and near the northwest corner of Illinois becomes dominantly a dolomite similar to the overlying Dunleith (Prosser or Galena of other reports). Consequently, the top of the Decorah is stepped down about 20 feet to the top of the Guttenberg. Farther southeast in north-central and northeastern Illinois, the Guttenberg becomes so much like the Dunleith that another step down is required, in this case only 2 to 4 feet because of thinning of the Guttenberg.

Northward from Decorah, the lower part of the overlying Prosser strata grades progressively to shale so that the top of the Decorah Shale at Rochester, Minnesota, is about 4 feet higher than the top of the type Decorah, and at St. Paul it is about 20 feet higher.

Consistent application of this step practice is difficult because the lateral changes are gradual and not the same in all beds. Differences in individual judgments of the proper position for the step, the vertical cut-off, will be great. Further, if the object is to maintain a uniform lithology between each step, the problem is even more complicated. For example, to maintain a degree of shaliness comparable to that at St. Paul, the top of the Decorah, coming southward, would be dropped to the top of the Spechts Ferry at McGregor, or at least before reaching Guttenberg. Although this practice becomes involved with the difficult problem of facies nomenclature, the alternative is to introduce new names at each step, and this seems even less desirable.

Even though the positions of the boundaries between many of the units differentiated in the Illinois-Wisconsin-Iowa region can be traced into the shaly facies of the Decorah at St. Paul (fig. 22), it is clear that these do not differentiate logical rock units in that area, and they therefore are useful only as minor or local time-stratigraphic units, principally for determining the equivalence of units, sedimentational variations, and for comparing faunas. Figure 22 does not show all the intermediate sections used in establishing the correlations, nor all the details of the sections. The section in the shale facies probably can be matched in even more detail than was possible in this study.

In Minnesota the top of the Decorah has been placed recently at the top of the dominantly shaly facies, well above the top of type Decorah (Weiss and Bell, 1956, p. 64, fig. 16), but in Wisconsin the top of the Decorah has been kept at the top of type Decorah even in the pure dolomite facies (Agnew et al., 1956, fig. 36). By stepping the Decorah top down to the top of the Guttenberg in Illinois, we leave the Ion Member in the Decorah in the west and assign Ion equivalents to the Dunleith (or Prosser) in

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1. Twin City Brick and Tile Company pit at Cherokee Heights, St. Paul, Ramsey County, Minnesota. Description of strata correlated with the Spechts Ferry and the presence of oolites at the base of the Ion from Stauffer and Thiel, 1941, p. 188.

2. Quarry 1 mile east of Rochester, Goodhue County, Minnesota (SW NW SE 32, 107N-13W, Rochester Quad.).

3. Southwest-trending ravine on northeast side of Coon Creek, 1 mile west of Connor, Allamakee County, Iowa (ravine heads at north-south road near center SE 12, 98N-7W, Winneshiek County, Decorah Quad.).

4. Composite section along road in ravine 2 miles southwest of Ion, Allamakee County, Iowa (NW 35, 96N-4W, Waukon Quad.). Description by Herbert (1949).

5. Ravine south of U. S. Highway 18, 1 mile west of McGregor, Clayton County, Iowa (E½ SE NE 29, 95N-3W, Waukon Quad.). See also Agnew et al., 1956, p. 305.

6. Cut along U. S. Highway 52, northwest of Guttenberg, Clayton County, Iowa (SW SW 5, 92N-2W, Elkader Quad.) (geol. sec. 27). See also Agnew et al., 1956, section 11, p. 308.

7. Ravine and quarry at Spechts Ferry, Dubuque County, Iowa (SW NW 4, 90N-2E, Lancaster Quad.). See also Agnew et al., 1956, p. 307.

8. Cutbank on southeast side of Galena River, 1 mile southeast of Millbrig, Jo Daviess County, Illinois (cen. 34, 29N-1E, Galena Quad.). Description in part after Herbert (1949).

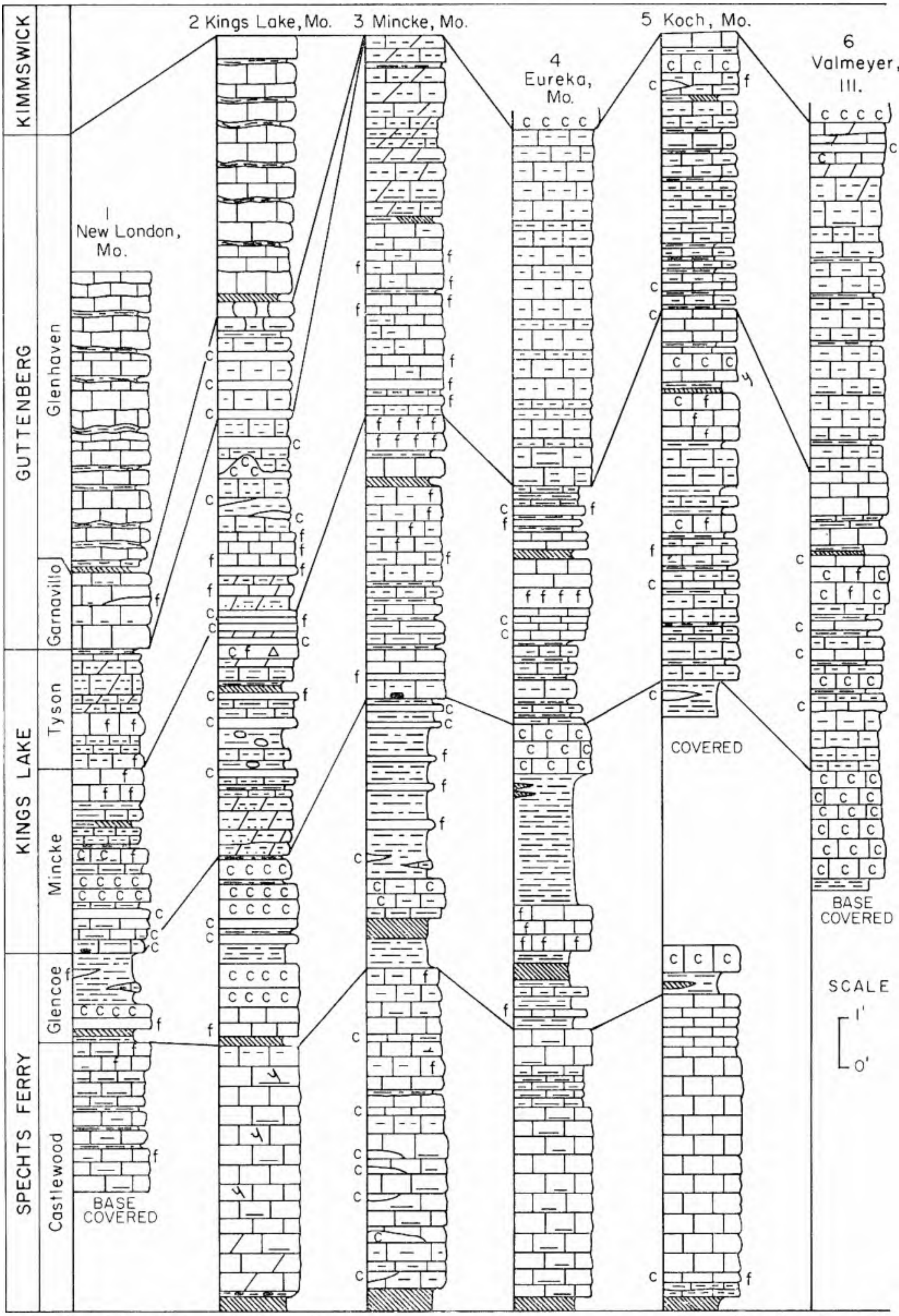

FIG. 23.—Correlation of Decorah strata in the southern outcrop area from New London, Missouri, to Valmeyer, Illinois. Key to symbols and patterns appears in figure 4. Locations of sections are given on next page.

the east. As a step is required, we prefer to put it where it maintains the Decorah as a shaly unit.

Classification of the Decorah as a subgroup in Illinois is desirable because its subdivisions merit rank as formations, and the formations have subdivisions that are widely distributed and need naming as members. A name is needed for the whole Decorah unit, particularly in some areas in subsurface where the formations cannot be readily subdivided.

Distribution and Thickness.—The Decorah Subgroup is well developed throughout the western and southern part of Illinois. It appears to be absent at many places in the central and northeastern part of the state, but it may be overlooked in some areas as the more accurate and detailed well samples suggest that 1 to 5 feet of Decorah strata commonly are present. The Decorah is 15 to 30 feet thick in the western part of Illinois.

Lithology.—The Decorah consists largely of limestone, partly argillaceous, silty, calcarenitic, green-gray to blue-gray, lithographic to fine grained, thin bedded, with gray-green to brown-red shale partings. It locally grades to buff-weathering, argillaceous or shaly dolomite. It contains calcarenite beds, four persistent bentonite layers and traces of others, and a persistent bed of green shale. It contrasts sharply with the brown, lithographic, purer limestone of the Platteville Group below, and with the coarse-grained calcarenite or the medium-grained dolomite of the Dunleith above. Lithologic variations in the northern outcrop area are shown in figure 22, those in the southern outcrop are shown in figure 23.

Fauna.—Decorah strata contain an abundant fauna typical of lower Trentonian strata.

Stratigraphic Relations.—The Decorah is unconformable on the underlying Platteville (see *Spechts Ferry*). On the flanks of the Ozarks the Decorah is overlapped by Dunleith strata that locally truncate the Guttenberg and Kings Lake Formations and, less commonly, the entire subgroup. In parts of northwestern Illinois the Decorah has a 1- to 2-foot gradational zone to the Dunleith above, but in other areas uppermost Guttenberg strata appear to be missing and the sharp contact with the Buckhorn Member of the Dunleith Formation appears to be erosional, probably representing a minor unconformity. Regionally, the upper contact of the Decorah is marked by a series of steps, as previously described.

Correlation.—Decorah strata in Illinois (Spechts Ferry-Guttenberg Formations) are equivalent to the Rockland Formation of New York and Ontario (fig. 30).

Spechts Ferry Formation

Kay, 1928, modified 1935

The Spechts Ferry Formation was named for Spechts Ferry, Dubuque County, Iowa (Kay, 1928, p. 16). The type section is along

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1. Cut along U. S. Highway 61 on south side of Salt River, 1½ miles north of New London, Ralls County, Missouri (NW SW NE 36, 56N-5W, Hannibal Quad.).

2. Exposure near top of Mississippi Valley bluffs above high talus slope, 1 mile west of Kings Lake and 1.7 miles north of Foley, Lincoln County, Missouri (SE SE NE 26, 50N-2E, Hardin Quad.) (geol. sec. 26). Slightly modified from Herbert (1949).

3. South bluff of Meramec River, a quarter of a mile northeast of Mincke Hollow, 1¼ miles southwest of Castlewood, St. Louis County, Missouri (NE SE SE 21, 44N-4E, Manchester Quad.) (geol. sec. 25).

4. Cut along County Highway B, north of crest of hill, 1 1/3 miles north of Eureka, St. Louis County, Missouri (NW NW NE 25, 44N-3E, Eureka Quad.).

5. Cut along U. S. Highways 61 and 67, near Koch Valley School, 4 miles south of Kimmswick, Jefferson County, Missouri (NE SW SW 6, 41N-6E, Kimmswick Quad.).

6. Mississippi River Bluff just north of the crushing plant of the Columbia Quarry Company, 1 mile north of Valmeyer, Monroe County, Illinois (cen. N line SW 3, 3S-11W, Kimmswick Quad.) (geol. sec. 30).

a ravine just southwest of the Chicago, Milwaukee, St. Paul, and Pacific Railroad station (SW NW 4, 90N-2E, Lancaster Quad.), where the sequence from top is: *Galena Group, Dunleith 22'8" (Eagle Point and Beecher 10', St. James 9'1", Buckhorn 3'7"), Guttenberg 13'8" (Glenhaven 11'8", Garnavillo 2'), Spechts Ferry 7'9" (Glencoe 7'3", Castlewood 6"); Platteville Group, Grand Detour 11'6" (Forreston 1'6", Stillman 7'6", Walgreen 2'6"), Mifflin 16'10" (Briton 3', Hazelwood 1'7", Establishment 6', Brickeys 5'6", Blomeyer 9"), Pecatonica 18'10" (Medusa 1'4", New Glarus 2'5", Dane 8'7", Chana 6'6").* (See also Agnew et al., 1956, p. 107).

Classification.—The Spechts Ferry was defined as the basal member of the Decorah Formation but later was made the uppermost member of the Platteville Formation (Kay, 1935a, p. 287-289), which usage has been followed in Illinois. It is herein considered the basal formation of the Galena Group because, as shown by Herbert (1949), (1) it is lithologically more like the overlying strata, (2) it thins out eastward like the overlying Guttenberg, whereas all Platteville formations thicken in that direction, and (3) the major unconformity is at its base. Diagnostic Trentonian species first appear in the Spechts Ferry.

Distribution and Thickness.—The Spechts Ferry Formation is exposed in both the northern and southern outcrop areas. It is present along the west side of Illinois, but it thins eastward and generally is absent in the central part of the state. Its maximum thickness ranges from 10 feet in the type area in northeastern Iowa to 15 feet in Missouri. Outcrops described in this report are listed in the index.

Lithology.—The upper part of the Spechts Ferry Formation consists of calcareous green shale containing thin layers of limestone, coquina, and calcarenite. The lower part of the formation is limestone with some shale and two beds of bentonite. Many of the limestone beds are distinctive and can be traced widely (Herbert, 1949).

Fauna.—Some limestone beds are a coquina of *Pionodema subaequata* (Conrad), *Doleroides pervetus* (Conrad), *Stictoporella frondifera* Ulrich, and other Bryozoa. Diagnostic Trenton species such as *Rafinesquina trentonensis* (Conrad) emend. Salmon, and *Trematis ottawaensis* Billings first appear in the Spechts Ferry.

The Spechts Ferry is essentially equivalent to the *Stictoporella* bed of Minnesota (Kay 1929, p. 643, emend. 1940a, p. 234; Stauffer and Thiel, 1941, p. 79, 188), but the thin limestone and overlying bentonite included in the top of the *Stictoporella* bed are the Garnavillo Limestone and the bentonite at the base of the overlying Glenhaven Member, both in the Guttenberg Formation.

Stratigraphic Relations.—The Spechts Ferry is unconformable on the ferruginous, phosphatic, pitted surface of the Quimbys Mill Formation, and locally contains Quimbys Mill fragments. It truncates the underlying Platteville in Iowa, Minnesota, and southwestern Wisconsin, and rests on beds as old as Grand Detour. It is overlain conformably by the Kings Lake Formation, but where Kings Lake strata are absent it is separated from the Guttenberg or Dunleith Formations by a diastem, frequently marked by abundant phosphatic nodules.

Correlation.—The Spechts Ferry is equivalent to the Selby Member, the basal member of the Rockland Formation in New York and Ontario (fig. 30), and to similar strata in other regions (fig. 27). Twenhofel et al. (1954) placed the Spechts Ferry somewhat above the base of the Rockland, and Cooper (1956) made it equivalent to the upper part of the Rockland.

Subdivisions.—The Spechts Ferry Formation is subdivided into the Glencoe Shale Member above and the Castlewood Limestone Member below. Although the Castlewood is a distinctive limestone composing about half the Spechts Ferry Formation in the southern outcrop area, it is only locally prominent in the northern outcrop area and in many places is less prominent than other beds of limestone in the overlying Glencoe. In northern Illinois the Castlewood is so thin that differentiation of the Spechts Ferry into members is not needed.

A dark purplish coquina in the basal Glencoe, separated from the Castlewood below by a few inches of shale containing bentonite, is a remarkably widespread unit that may deserve recognition as a member. It frequently is associated with dark gray argillaceous limestone to which it has a lenticular relationship. The unit is only 6 inches to 1 foot thick in the southern outcrop area. Although locally as much as 3 feet thick in the northern outcrop area, where the argillaceous limestone is dominant, it is missing in many exposures and in others it is not easily distinguished from similar beds that occur in the overlying shale.

In Minnesota the Castlewood has been referred to as the *Lingula elderi* bed, and the limestone in the basal Glencoe has been called the "trilobite bed" (Stauffer and Thiel, 1941, p. 79).

The name Carimona Limestone has been proposed (Weiss, 1955, p. 759) for the basal Spechts Ferry beds in which limestone is dominant, in effect combining the two units of Stauffer and Thiel and in places including overlying limestone beds (see also, Weiss and Bell, 1956, p. 62; Agnew, 1956, p. 49; Agnew et al., 1956, p. 264). The zone included in the Carimona Limestone contains several strikingly different limestones that appear to extend widely and may be individually named when more accurately traced. Our Castlewood Limestone Member is equivalent to only the basal unit of the Carimona Limestone in the type area, but where the upper unit is absent, which is common south of Decorah, Iowa, the Carimona is equivalent to the Castlewood (fig. 24).

Differences in the correlations of lower Decorah strata in the northern outcrop area result in part from disagreement on the matching of beds of bentonite. Bell (1954), Weiss and Bell (1956, p. 63), and Agnew (1956, p. 50) recognized two bentonites, and Agnew et al. (1956, fig. 36, p. 263) recognized one bentonite. We recognize three bentonites in the lower Decorah, one below the Castlewood at the base of the Spechts Ferry, another above the Castlewood in the Glencoe, the most continuous and generally the thickest, and a third in the lower part of the Guttenberg at the base of the Glenhaven Member. Four well developed bentonites have been recognized in the same interval in the southern outcrop area (fig. 23).

Bell (1954) and Weiss and Bell (1956) considered the higher of their two bentonites (called the "putty layer" at St. Paul) to be the principal, widespread Spechts Ferry bentonite, rather than the lower as previously correlated by Kay (1931) and Stauffer and Thiel (1941). Our correlations (fig. 23) suggest that the earlier identification of the lower of the two as the principal Spechts Ferry bentonite is generally correct and that the upper bentonite is the Guttenberg bentonite, which becomes more conspicuous in the northern shale facies than in the limestone sequence farther south. Also, the third bentonite that we recognize appears to remain at or close to the base of the Spechts Ferry, and the bentonite reported within the Carimona generally is the upper of the two Spechts Ferry bentonites.

Weiss (1955) classified the Carimona Limestone as a member in the Platteville because it is dominantly limestone and the overlying Decorah is dominantly shale. We retain these beds in the Spechts Ferry Formation of the Decorah because: (1) the limestones are mostly argillaceous or coquinal and resemble limestones in the Spechts Ferry more than they do the relatively pure limestones of the Platteville; (2) where the basal limestone (Castlewood) thickens and becomes a prominent ledge, the zone contains, except locally, many beds of green shale like that of the overlying Glencoe; (3) the beds are separated from the underlying Platteville by an unconformity; and (4) the top of the limestone zone has little stratigraphic continuity and is placed on various beds, which shows its close relationship to the overlying shale. The fossils of the limestones are the same as those in similar beds in the overlying shale.

Castlewood Member (new)

The Castlewood Member is here named for the village of Castlewood, St. Louis County, Missouri, 1½ miles northeast of the type section, which is in the Mincke section (geol. sec. 25). The Castlewood is the basal member of the Spechts Ferry Formation. It has been

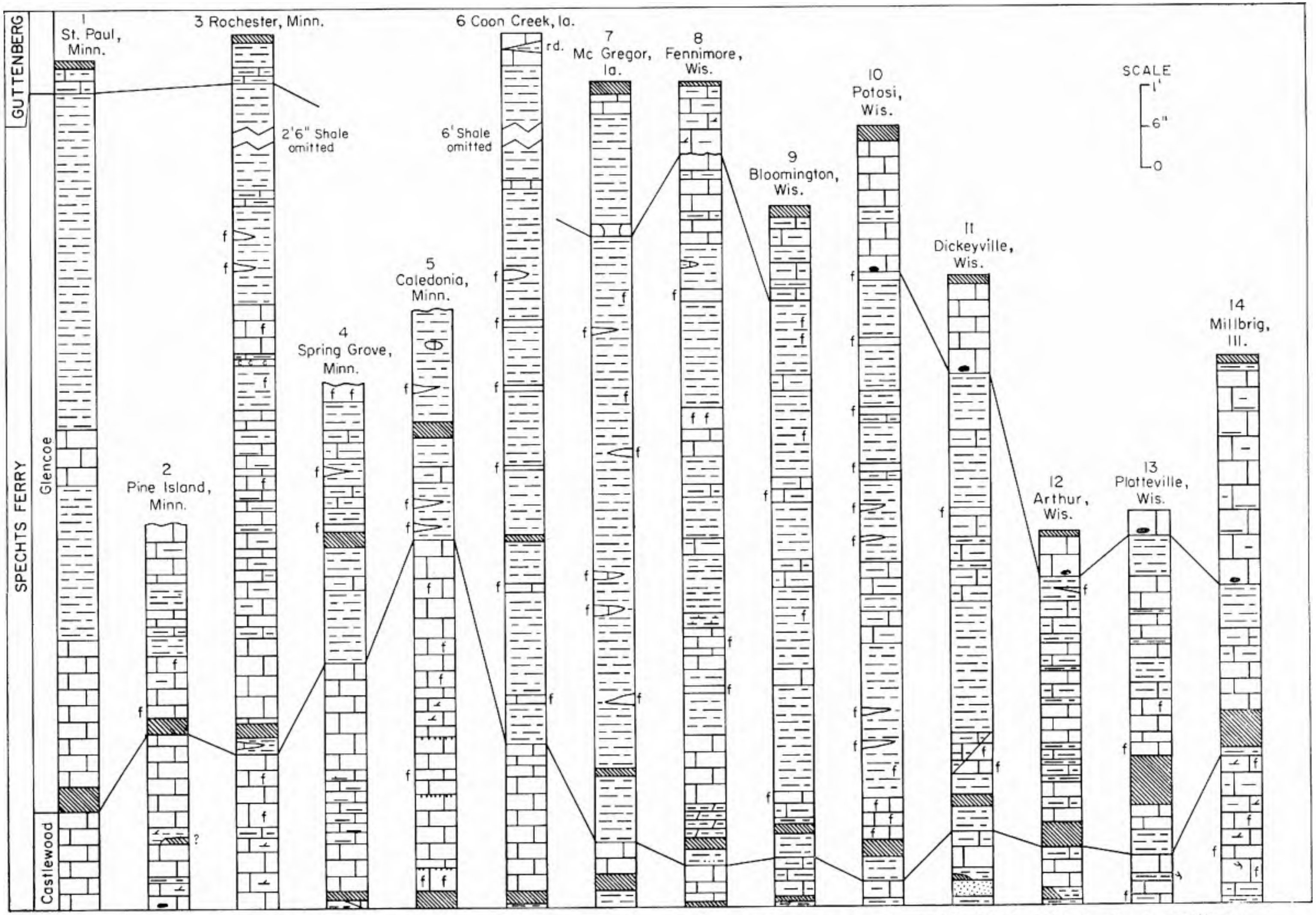

FIG. 24.—Correlation of the Spechts Ferry Formation in the northern outcrop area from St. Paul, Minnesota, to Millbrig, northwestern Illinois. Key to symbols and patterns appears in figure 4. Locations of sections are given on next page.

included locally with the Platteville in the northern outcrop area, and in the southern outcrop area it previously has been included in the Plattin rather than in the Decorah.

Distribution and Thickness.—The Castlewood Member is present throughout the area of Spechts Ferry beds except in the northern outcrop area where it is locally absent. In the southern outcrop area it is commonly 3 to 6 feet thick and has a maximum thickness of 6 feet 11 inches in the type section. In the southern part of the northern outcrop area it is commonly 6 inches to 1½ feet thick. It thickens northward and is commonly over 2 feet thick north of Decorah, Iowa, with a maximum thickness of 4 feet near Caledonia, Minnesota.

Lithology.—At the base of the member, 1 to 3 inches of black to dark brown shale is overlain by bentonite, generally less than half an inch thick but as much as 3 inches thick. In places, one or the other, or both, are absent. The bentonite is only locally present in the southern part of the northern outcrop area, but it has been observed at Bloomington, Wisconsin, and numerous places farther northwest.

Above the bentonite the member consists of limestone that is argillaceous, partly calcarenitic, gray to brown, locally purplish, lithographic to medium grained, commonly massive, and locally contains thin beds of brown or green shale and calcarenite. It is cherty at the base in the type area. Although in gross lithology this unit is similar to the Quimbys Mill below, it is more argillaceous, coarser grained, more massive, and lacks the conchoidal fracture of the "glassy" Quimbys Mill.

Fauna.—Fossils ordinarily are not common in the massive limestone in the southern area; the most common species is *Pionodema sub-*

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1. Twin City Brick and Tile Company pit, Cherokee Heights, St. Paul, Ramsey County, Minnesota. Description by Stauffer and Thiel, 1941, p. 188.

2. Quarry in isolated hill three-eighths of a mile east of U. S. Highway 52 on north side of Pine Island, Goodhue County, Minnesota (SW SW SE 29, 109N-15W).

3. Quarry 1 mile east of Rochester, Goodhue County, Minnesota (SW NW SE 32, 107N-13W, Rochester Quad.).

4. Quarry on State Highway 44, 3 miles west of Spring Grove city limit, Houston County, Minnesota, west of railroad overhead crossing and east of road jog.

5. Cut on north side and quarry on south side of State Highway 44, 6 miles southwest of Caledonia city limit, Houston County, Minnesota.

6. Roadcut on southwest side of Coon Creek, 8 miles east of Decorah, Winneshiek County, Iowa (SE SW 13, 98N-7W, Decorah Quad.), and small ravine north of the road. Near the Coon Creek section described by Kay, 1929, p. 652, and Agnew et al., 1956, p. 306.

7. Ravine south of U. S. Highway 18, 1 mile west of McGregor, Clayton County, Iowa (E½ SE NE 29, 95N-3W, Waukon Quad.). See also Agnew et al., 1956, p. 305.

8. Cut along U. S. Highway 18, 4 miles west of Fennimore, Grant County, Wisconsin (SW SE NE 21, 6N-3W, Lancaster Quad.).

9. Quarry half a mile east of Bloomington, Grant County, Wisconsin (NE NE NW 25, 5N-5W, Lancaster Quad.).

10. Ravine in Mississippi River bluff, three-fourths of a mile southeast of Potosi Station, Grant County, Wisconsin (SW SE NW 10, 2N-3W, Lancaster Quad.).

11. Cut along U. S. Highway 61 in ravine on west side of Platte River, 4 miles northwest of Dickeyville, Grant County, Wisconsin (SW SE NW 7, 2N-2W, Lancaster Quad.).

12. Quarry behind cheese factory at the southwest corner of Arthur, Grant County, Wisconsin (SE SE 2, 4N-1W, Mineral Point Quad.).

13. Quarry along secondary road on north side of Little Platte River, 3 miles west of Platteville, Wisconsin (NE NW NW 19, 3N-1W, Lancaster Quad.).

14. Cutbank southeast side of Galena River, 1 mile southeast of Millbrig, Jo Daviess County, Illinois (cen. 34, 29N-1E, Galena Quad.).

aequata (Conrad). In Minnesota this bed carries *Lingula elderi* Whitfield (Stauffer and Thiel, 1941, p. 79-80), and locally has an abundant molluscan fauna.

Glencoe Member (new)

The Glencoe Member is here named for the village of Glencoe, St. Louis County, Missouri, 3 miles west of the type section, which is in the Mincke section (geol. sec. 25). The Glencoe is the upper member of the Spechts Ferry Formation. It is equivalent to the "clay bed" in the lead-zinc district of Illinois, Iowa, and Wisconsin.

Distribution and Thickness.—The Glencoe Member is present thoughout the area of Spechts Ferry beds. In the northern outcrop area it is commonly 5 to 8 feet thick near the Mississippi River but thins to the east. It has a maximum thickness of about 15 feet near Decorah, Iowa.

Lithology.—Near the base of the Glencoe is the most persistent Ordovician bentonite in the Mississippi Valley. It commonly is from 1 to 3 inches thick, locally 8 inches thick, and occurs in a 1- to 2-foot zone of interbedded green, gray, or brown shale with thin beds of fine-grained limestone, coquina, or calcarenite. In places the bentonite occurs in the shale and in other places it has limestone both above and below. Locally in southwestern Wisconsin and northeastern Iowa the bentonite is replaced by a distinctive, hard, pink bed which consists almost entirely of potash feldspar (H. D. Glass, personal communication).

Above the bentonite, but in places separated from it by 2 to 6 inches of gray or green shale, is a persistent bed of limestone. The limestone is brown, locally gray, fossiliferous, fine grained, argillaceous, and commonly 1 to 3 feet thick. In the southern outcrop area the limestone more commonly is a dark purplish gray coquina of *Pionodema* and is about a foot thick.

The upper two-thirds or more of the member consists largely of green shale, but in some areas the lower part is gray or brownish gray. It contains beds, locally as thick as 1 foot, of greenish gray argillaceous limestone, calcarenite, coquina, and dark gray coarse-grained limestone.

Fauna.—A typical Spechts Ferry fauna is abundant in both limestone and shale beds. The limestone near the base contains *Isotelus gigas* DeKay and *Zygospira nicoletti* Winchell & Schuchert and has been referred to as the "trilobite bed" in Minnesota (Stauffer and Thiel, 1941, p. 79).

Correlation.—The bentonite in the Glencoe is correlated with the Hounsfield bentonite in the Selby Member of the Rockland Formation of New York and Ontario (Kay, 1931, p. 370; 1937, p. 252-253).

Kings Lake Formation

Herbert, 1949

The Kings Lake Formation was named for Kings Lake, Lincoln County, Missouri, 1 mile east of the type section, which is at the top of the Mississippi River bluffs, 500 feet north of the road junction at Kings Lake (geol. sec. 26).

Classification.—Although differentiated by Herbert as a member of the Decorah Formation in the southern outcrop area, the Kings Lake is classified here as a formation overlying the Spechts Ferry Formation and underlying the Guttenberg Formation, and subdivided into the Tyson (above) and Mincke Members.

Distribution and Thickness.—The Kings Lake Formation is present throughout the southern outcrop area, except locally where overlapped by the Dunleith Formation, but it is absent in the northern area. It is commonly 5 to 10 feet thick, has a maximum thickness of 15 feet, and thins out to the northeast in subsurface. Outcrops described in this report are listed in the index.

Lithology.—The Kings Lake consists largely of argillaceous, very silty, dolomitic limestone with some thin beds of shale and calcarenite. It locally contains finely sandy beds and Guttenberg-type red shale partings. In many characteristics it is transitional between the Spechts Ferry and Guttenberg, but it is more silty and sandy than either of them.

Fauna.—The Kings Lake contains a mixture of Spechts Ferry and Guttenberg species. The most abundant forms are *Pionodema subaequata* (Conrad), *Zygospira recurvirostris* (Hall) and locally *Sowerbyella curdsvillensis* (Foerste).

Stratigraphic Relations.—The Kings Lake is conformable to the Spechts Ferry below and the Guttenberg above. The absence of Kings Lake beds in the northern outcrop area seems best explained by the minor unconformity at the base of the overlying Garnavillo Member of the Guttenberg Formation in that region. It is possible that the Kings Lake thins and becomes more shaly northward from the southern outcrop region and is equivalent to upper beds of the Spechts Ferry Shale. The additional possibility that the Kings Lake is equivalent to the Garnavillo Member of the Guttenberg has been considered, because the Garnavillo is argillaceous and somewhat silty. However, beds comparable to the Garnavillo overlie the Kings Lake and this makes it more plausible that the Kings Lake thins and disappears northward rather than that the Garnavillo expands southward to include the Kings Lake.

Correlation.—Kings Lake strata appear to be missing in the New York section but are widely present in Kentucky, Tennessee, and Virginia (figs. 33, 36, 39). The bentonite in the Mincke Member is correlated with the T-5 bentonite in Tennessee (fig. 38).

Mincke Member (new)

The Mincke Member is here named for Mincke Hollow, a small tributary of the Meramec River in St. Louis County, Missouri, the mouth of which is a quarter of a mile southwest of the type section, an exposure along the St. Louis-San Francisco Railroad (geol. sec. 25). The Mincke Member is the lower member of the Kings Lake Formation.

Distribution and Thickness.—The Mincke Member is present thoughout the area of the Kings Lake. It is 6 feet thick in the type section and thins northward to 4 feet 11 inches at Kings Lake, Missouri, and 3 feet 7 inches at New London, Missouri.

Lithology.—The Mincke Member consists of interbedded layers 1 to 5 inches thick of (1) silty argillaceous limestone like the Tyson above, some layers of which contain coarse silt and a small amount of fine sand, and rare medium sand grains; (2) very fossiliferous calcarenite; and (3) green to brown shale. A thin bed of yellow bentonite ½ to 2 inches thick is persistently present, commonly in a bed of brown shale, from 1 foot to 1 foot 6 inches below the top. The member contains more shale and calcarenite than the Tyson above and much less shale and calcarenite than the Glencoe below.

Tyson Member (new)

The Tyson Member is here named for Tyson Hollow, a small branch of the Meramec Valley in St. Louis County, Missouri. The mouth of the hollow is half a mile northeast of the type section, which is in the Mincke section (geol. sec. 25). The Tyson is the upper member of the Kings Lake Formation.

Distribution and Thickness.—The Tyson Member is present throughout the area of Kings Lake strata. In places in the St. Louis area the uppermost beds are missing where the Dunleith truncates the Guttenberg and rests directly on the Tyson Member. The member is 7 feet 6 inches in the type section but thins northward to 4 feet 3 inches at Kings Lake, Missouri, and 3 feet 11 inches at New London, Missouri.

Lithology.—The Tyson consists largely of dolomitic, very silty, and argillaceous limestone. It weathers buff and chalky. It is generally medium to thick bedded but some beds weather thin bedded. It contains a few thin beds of buff to reddish brown shale, coarse calcarenite, and coquina. It differs from the Garnavillo Member of the Guttenberg Formation above, which is purer, and from the Mincke Member below, which commonly contains some beds of Tyson-like lithology but in general is less silty and has many beds of shale and a much higher proportion of calcarenite.

Guttenberg Formation

Kay, 1928, modified 1935

The Guttenberg Formation was named for the town of Guttenberg, Clayton County, Iowa (Kay, 1928, p. 16). The type section is in a ravine half a mile north of town, but at present the Guttenberg is better exposed in a nearby roadcut on U. S. Highway 52, which is referred to as the Guttenberg North section (geol. sec. 27). The above section, combined with the roadcut on Highway 52 half a mile south of the Guttenberg city limits where the Wise Lake Formation is 90 feet thick and the Dubuque Formation 21 feet thick, exposes what is probably the most nearly complete section of the Galena and Platteville Groups in the Mississippi Valley.

Classification.—The Guttenberg was defined originally as a member of the Decorah Formation. It is herein classified as a formation in the Galena Group and the Decorah Subgroup, overlying the Kings Lake Formation and underlying the Dunleith Formation. It is subdivided into two members, the Glenhaven (above) and Garnavillo Members. The formation is equivalent to the *Rhinidictya* and *Ctenodonta* beds in Minnesota (Kay, 1940a, p. 235; Stauffer and Thiel, 1941, p. 83), except that the Garnavillo is very thin and appears to have been generally included in the top of the *Stictoporella* bed. In southwestern Illinois and in Missouri, Guttenberg strata were included in the Decorah but were correlated with the Spechts Ferry until differentiated by Herbert (1949).

Distribution and Thickness.—The Guttenberg Formation is present in the northern and southern outcrop areas. Its extent is generally similar to the Spechts Ferry except in the St. Louis region on the flanks of the Ozarks where the Guttenberg locally is truncated by the Dunleith. In the northern half of Illinois the Guttenberg also extends considerably farther east than the Spechts Ferry, but it thins out in central Illinois. Its maximum thickness is 30 feet in Minnesota, 15 to 20 feet in northwestern Illinois, and 10 to 15 feet in the southern outcrop area. Outcrops described in this report are listed in the index.

Lithology.—From Guttenberg south to the northern part of the southern outcrop area (Calhoun County, Illinois), the Guttenberg is a distinctive and remarkably uniform unit. It consists of thin-bedded, tan to gray, white-weathering, lithographic limestone interbedded with brown-red carbonaceous shale. The Guttenberg grades eastward to fine- to medium-grained dolomite in north-central Illinois. It is locally dolomite in subsurface between the northern and southern outcrop areas. North of Guttenberg the limestone is interbedded with green shale, and in Minnesota it grades to green shale with thin limestone beds and is similar to adjacent Decorah strata (fig. 22). It loses its character as a distinctive lithologic unit in the vicinity of Decorah, Iowa.

In the mineralized region in Wisconsin, Illinois, and Iowa, the Guttenberg is locally thinned by solution of the limestone beds, leaving a residue of the shale beds and the insoluble constituents of the limestone. This material is largely a dark red-brown shale called "oilrock." In extreme cases the Guttenberg is thinned to about 2 feet (Kay and Atwater, 1935; Willman et al., 1946).

Fauna.—Some of the limestone and shale beds are very fossiliferous. *Dinorthis pectinella* (Emmons), *Rafinesquina trentonensis* (Conrad) emend. Salmon, *Sowerbyella curdsvillensis* (Foerste), and *Strophomena filitexta* (Hall) are especially abundant. Minute, brown-red, spore-like fossils which may be unicellular algae are profuse in the limestone or dolomite and the shale partings from Guttenberg southward.

Stratigraphic Relations.—The Guttenberg is conformable on the Kings Lake Formation in southern Illinois and Missouri. Where it overlies the Spechts Ferry in the northern area, the persistence of phosphatic nodules in the basal Guttenberg suggests a diastem representing the absent Kings Lake (Herbert, 1949). Where the Guttenberg extends beyond the Spechts Ferry and Kings Lake, it rests on the pitted surface of the Quimbys Mill and locally contains Quimbys Mill fragments. In such areas worm-borings and fractures filled with Guttenberg sediments are common in the top of the Quimbys Mill. In parts of the northern outcrop area the Guttenberg has at the top a 1- to 2-foot transition zone to the Buckhorn Member of the Dunleith Formation, but in the southern area, where the Buckhorn is absent, the Guttenberg is overlain with sharp unconformity by St. James strata containing lenses of coarse conglomerate.

Correlation.—The Guttenberg is equivalent to the Napanee Member of the Rockland Formation in New York and Ontario (fig. 30).

Garnavillo Member (new)

The Garnavillo Member is here named for the town of Garnavillo, Clayton County, Iowa, 7½ miles northwest of the type section, which is in the Guttenberg North section (geol. sec. 27). The Garnavillo Member is the basal member of the Guttenberg Formation.

Distribution and Thickness.—The Garnavillo Member is present throughout the area of Guttenberg beds except that in north-central Illinois it does not extend as far east as the overlying Glenhaven Member. It is commonly from 2 feet to 3½ feet thick in the southern outcrop area and the southern part of the northern outcrop area. It thins northward and is only 1 foot 9 inches thick in the type section and 2 to 6 inches in Minnesota.

Lithology.—In the type section, the Garnavillo Member consists of gray, fine-grained to lithographic limestone containing a 5-inch green shale layer 7 inches from the top and phosphatic nodules at the base. Although to the south it becomes gray-buff and has thin brown shale partings, it is consistently grayer, more argillaceous, thicker bedded, and contains less shale than the Glenhaven above. Phosphatic nodules are widely present in the lower foot of the member in the northern outcrop area and are more persistently concentrated in that zone than in uppermost Spechts Ferry beds, as shown by Agnew et al. (1956, p. 268, 288).

Glenhaven Member (new)

The Glenhaven Member is named for Glenhaven, Grant County, southwestern Wisconsin, 2½ miles northeast of the type section, which is in the Guttenberg North section (geol. sec. 27). The Glenhaven Member is the upper member of the Guttenberg Formation.

Distribution and Thickness.—The Glenhaven Member has the same general distribution as the Guttenberg Formation, but the upper part is locally absent in the northern outcrop areas, as at Bloomington, Wisconsin. The upper beds appear to have been generally eroded along the basal Dunleith unconformity in the southern outcrop area. The member thins southward from 14 feet 10 inches thick in the type section to 10 to 12 feet in northern Illinois and 7 to 9 feet in southern Illinois.

Lithology.—The Glenhaven Member consists of tan, white-weathering, lithographic limestone in wavy, smooth-faced beds from 1 to 4 inches thick, separated by layers of dark brown-red, carbonaceous shale, mostly less than a quarter of an inch thick but locally as much as 2 inches thick.

In some areas the upper 1 to 2 feet of the Glenhaven is a transition zone that has dark blue-gray, medium-grained layers, like some layers in the Buckhorn above, and also some fine-grained beds and brown shale partings characteristic of the Guttenberg.

The Glenhaven is subdivided into two widely recognized submembers, which are not named. The lower submember is more lithographic, more shaly, thinner bedded, and has more wavy bedding than the upper. The upper unit is purer, slightly thicker bedded, and is characterized by more fossil debris and calcarenite layers than the lower. Lenses of chert are widely present in a single layer 1 to 2 feet above the base of the upper submember in the northern area and are scattered through the lower 1 foot in the southern area. However, in subsurface in west-central Illinois, between the outcrop areas, the entire Guttenberg Formation is locally cherty.

The upper submember is 6 feet thick in the Guttenberg North section and is commonly 5 to 6 feet thick in the northern outrop area. It is only 2½ feet thick where exposed in the northern part of the southern outcrop area. The lower submember is 8 feet 10 inches thick at Guttenberg but thins southward to about 6½ feet thick in northern Illinois and in the southern outcrop area.

At the base of the Glenhaven a bentonite up to 1 inch thick is widely present in both the northern and southern outcrop areas. In places the bentonite occurs as 2 or 3 separate thin layers in 1 to 2 inches of shale. The bentonite is an excellent key bed that extends northward from the limestone to the shale facies of Minnesota. It is equivalent to a bentonite that Stauffer and Thiel (1941, p. 81,188) called the "putty layer" and put at the top of the *Stictoporella* bed or Spechts Ferry. It was noted also by Sardeson (1928, p. 113) and called the "third bentonite."

KIMMSWICK SUBGROUP

Ulrich, 1904

The Kimmswick Subgroup was named for the town of Kimmswick, in Jefferson County, Missouri, near which it is well exposed (Ulrich, *in* Buckley and Buehler, 1904, p. 111). It consists of the dominantly pure carbonate formations that compose the middle part of the Galena Group, excluding the shaly strata of the Dubuque Formation at the top and the shaly formations of the Decorah Subgroup at the base.

In Illinois the Kimmswick Subgroup consists of the Dunleith (below) and Wise Lake Formations. This follows the broad usage of Kimmswick to include strata higher than those present in the type section, which does not include the uppermost Dunleith and Wise Lake strata. It extends the usage of the term to equivalent, relatively pure dolomite strata in northern Illinois instead of restricting it to the limestone facies.

The name Kimmswick is particularly useful in subsurface in Illinois where it is commonly convenient to consider the Dunleith and Wise Lake Formations as a unit. This is especially true in northeastern Illinois where the entire sequence becomes unusually pure, and the upper part of the Dunleith does not contain the chert nodules and only a few of the argillaceous bands that distinguish it in most areas.

The Kimmswick is well exposed in a quarry about a mile west of Kimmswick, Jefferson County, Missouri, on the north side of Rock Creek just west of the mouth of Black Creek (Kimmswick Quad.). The exposures at Cape Girardeau (geol. sec. 34) and at the New London type section (geol. sec. 31) are typical of the limestone facies, and the Dunleith and Wise Lake type sections (geol. secs. 28, 32) are typical of the dolomite facies.

Distribution and Thickness.—The Kimmswick Subgroup occurs throughout essentially the same areas as the Galena Group, previously described. It is about 250 feet thick in northern Illinois, but it thins rapidly in a belt through the central part of the state and is only 90 to 125 feet thick throughout most of the southern half of Illinois.

Lithology.—The Kimmswick is dominantly pure limestone in the southern two-thirds of Illinois and dominantly pure dolomite in the northern third. The lower part of the limestone is mostly medium- to coarse-grained calcarenite with abundant crinoid and bryozoan debris. The upper part consists of finer grained calcarenite interbedded with fine-grained to lithographic limestone. The dolomite is fine to medium grained. The lower part is alternately pure and slightly argillaceous and is generally cherty. The upper part is pure, massive, and vesicular.

Correlation.—The Kimmswick is equivalent to strata from the base of the Hull to the top of the Steuben Member of the Cobourg Formation in New York. The base of the Kimmswick is somewhat higher than shown by Twenhofel et al. (1954), because it overlies the Guttenberg, and its top is much higher in the Trentonian.

Dunleith Formation (new)

The Dunleith Formation is here named for Dunleith Township, Jo Daviess County, Illinois, which contains the type section, an exposure in the Mississippi River bluffs at East Dubuque (formerly Dunleith), Illinois (geol. sec. 28). The section is at and above the Illinois Central Railroad tunnel, and continues north of the tunnel for a quarter of a mile to a ravine at the first culvert beneath the railroad. The top of the St. James Member is exposed only at the east end of another culvert beneath the railroad, a quarter of a mile north of the ravine section. The two lowest members (St. James and Buckhorn) are exposed 2 miles north in the Eagle Point quarry in Dubuque, Iowa, but their type section is at Buena Vista, Illinois (geol. sec. 29).

In the northern outcrop area the Dunleith Formation is differentiated into the following members: Wyota (top), Wall, Sherwood, Rivoli, Mortimer, Fairplay, Eagle Point, Beecher, St. James, and Buckhorn. In the southern outcrop area the member sequence is: New London (top), Moredock, Eagle Point, Beecher, St. James, and Buckhorn (fig. 18).

Classification.—The sequence of alternating pure and argillaceous, partly cherty, limestone and dolomite strata, previously the lower part of the Prosser Member of the Galena Formation and the Ion Member of the Decorah Formation, is differentiated as a new formation, the Dunleith. The Dunleith Formation overlies the Guttenberg Formation and underlies the Wise Lake Formation.

The top of the cherty dolomite has long been recognized as an important marker in the Galena, but it has not been used in classification previously because of uncertainty as to continuity of the chert. Our studies have shown that the cherty zone is widely present and that the top of the cherty dolomite is also the top of a zone that is more argillaceous and thinner bedded than the one above. This zone commonly contains beds with distinctive argillaceous flecks, and in many areas it has abundant corrosion surfaces. Consequently, the top of this zone generally can be recognized where chert is absent. The persistence of a bentonite about 15 feet above the chert top and another bentonite about 30 feet below the chert top, demonstrates the uniformity of the chert top.

A prominent bedding plane at the top of the slightly argillaceous zone generally makes a marked reentrant in weathered exposures and we use this reentrant as the Dunleith-Wise Lake contact. Although this is the top of the cherty dolomite in a broad sense, scattered nodules of chert occur 1 to 2 feet above the contact in a large area, and rarely a few nodules occur higher. In some areas none can be found for several feet below the contact. In parts of central and northeastern Illinois where the Dunleith becomes exceptionally free from argillaceous material and chert, the Wise Lake and Dunleith cannot readily be differentiated in well samples.

As neither the upper nor the lower boundaries of the Dunleith correspond to those of the Prosser, use of the name Prosser for this unit would cause confusion. The lithologic change from the Decorah Shale to the Prosser Limestone is distinct in their type areas in southeastern Minnesota and northeastern Iowa, but the change at this position is relatively minor east, south, and north from the type area. In subsurface to the west, it continues to be a position of major change.

Recently the Prosser has been restricted in Minnesota by differentiation of about the lower half as the Cummingsville Member (Weiss, 1955; Weiss and Bell, 1956, p. 58, 67; Weiss, 1957, p. 1037). This change recognizes a useful subdivision of the Galena section in southeastern Minnesota, but it limits the usefulness of the name Prosser to a small area and makes the extensive usage of the name in other areas (Agnew et al., 1956, p. 268) out of agreement with usage in the Minnesota type area.

Because the limestone and calcarenite that constitute Dunleith equivalents in Missouri represent a facies distinct from the dolomite of the type Dunleith, consideration was given to substitution of the name Kimmswick for Dunleith. This was rejected because such usage of Kimmswick would correspond neither to the Kimmswick of the type section (Ulrich, *in* Buckley and Buehler, 1904, p. 111), which represents only the coarse-grained lower Dunleith calcarenite, nor to the more general use of Kimmswick for all the limestone between the Maquoketa Shale and the Decorah limestone and shale. As Kimmswick in the latter usage embraces both the Dunleith and Wise Lake Formations, it seems preferable to retain the name Kimmswick for the larger unit.

Strata equivalent to the Ion Member of the Decorah are included in the Dunleith because in Illinois and in many other areas they are more closely related in lithology to overlying beds than to Guttenberg strata below. From the type area in northeastern Iowa, the Ion grades southward to pure Galena-type dolomite. As Ion beds are present in the base of the calcarenite facies in southern Illinois and Missouri, and as they overlap lower beds, the break at the base of the Ion is regionally more important than that at its top. The name Ion is not needed in Illinois because the unit there consists of two readily differentiated members, the St. James and Buckhorn Members, which are comparable to other units differentiated as members of the Dunleith Formation.

Distribution and Thickness.—The Dunleith Formation is present throughout the Mississippi Valley. It is about 132 feet thick at the type section (the lower 20 feet is not exposed) and 140 to 150 feet thick at Guttenberg and Decorah, Iowa, but it thins to about 125 feet in southeastern Minnesota. It thins eastward from the type section and is commonly from 120 to 125 feet thick in northern Illinois. The Dunleith is about 135 feet thick at the north end of the southern outcrop area, in Ralls County, Missouri, but farther south between Calhoun and Alexander Counties, Illinois, it is overlain unconformably by the Maquoketa Shale and as a rule is only about 100 feet thick. Many outcrops of the Dunleith Formation mentioned in other sections of this report are listed in the index.

Lithology.—In the type section the Dunleith consists of an alternating sequence of pure and impure beds, largely fine-grained and mostly cherty dolomite. The lower 27 feet is dolomite-mottled lithographic limestone. South and east of the type section, the Dunleith grades to relatively pure but mainly cherty dolomite. North of the type section it grades to limestone, becoming more argillaceous and less cherty. The transition is accomplished by a gradual rise in the base of the dolomite until only the Wyota Member is dolomite at Guttenberg, Iowa (geol. sec. 27). At Decorah, Iowa, the entire formation is limestone, except the St. James and Buckhorn Members (Ion) which there and farther north are predominantly shale with thin limestone beds.

A complete section of the limestone facies is well exposed at Decorah. The lowest limestone beds (Beecher) are exposed in the type section of the Decorah Shale along the "Dugway," a road immediately west of Decorah (SW SW 16, 98N-8W, Decorah Quad.); the middle beds are exposed in two stream-diversion channels, one of which is 1½ miles west of Decorah (NE SE 18, 98N-8W), and the other half a mile southwest of Decorah (cen. NE 20); and the highest beds are to be seen in a quarry on the south side of Decorah (SE SW 21). The sequence from the top is: *Wise Lake 26′, Dunleith 139′6″ (Wyota 18′, Wall 12′, Sherwood 20′6″, Rivoli 20′, Mortimer 11′6″, Fairplay 19′, Eagle Point 13′6″, Beecher 15′), Decorah (St. James) 10′.* These sections may be tied together by a prominent bentonite that occurs 7 feet below the top of the Rivoli Member and is the lower of two bentonites 13 feet apart.

In southern Minnesota the Dunleith contains little chert and the lower part grades to shaly limestone and shale. Upper Dunleith strata, composed of relatively nonshaly limestone, are well exposed at the Prosser type section described under *Stewartville Member.* Shaly lower Dunleith beds are typically exposed in cliffs on the north side of the Root River, 1½ miles southeast of Simpson, Olmstead County, Minnesota (SW SE 9, 105N-13W), where the sequence from the top is: *Wise Lake 13′, Dunleith 103′6″, (Wyota 10′4″, Wall 14′7″, Sherwood 16′, Rivoli 11′6″, Mortimer 8′4″, Fairplay 21′6″, Eagle Point 7′9″, Beecher 10′2″), Decorah (St. James) 3′4″.* In this section a 1-inch bed of bentonite lies 1 foot 10 inches below the top of the Wyota. The base of the Sherwood marks the lowest occurrence of relatively pure crinoidal beds. The top of the shaly facies is 4 feet 9 inches below the top of the Rivoli, and the underlying zone of strong sawtooth weathering marks the Mortimer and Fairplay Members. Beds of pyritic oolite occur in the upper part of the St. James, which is shale.

South of Rock Island and Dixon the Dunleith grades into coarse-grained calcarenite and lithographic limestone that is partly dolomite mottled and mostly pure. The upper 35 to 40 feet, however, contains nodular chert and some argillaceous beds. Red-brown shale films occur in zones throughout the formation. In the dolomite and calcarenite facies the uniform grain size distinguishes the Dunleith from the more variable but generally fine-grained strata of the underlying Decorah and Platteville.

Fauna.—Fossils are abundant in the limestone facies but, except for *Receptaculites oweni* Hall, are only locally common in the dolomite facies. *Receptaculites* is present locally in all parts of the formation, but it is particularly abundant in the Fairplay Member and is common also in the Mortimer immediately above the Fairplay Member. This interval of abundant *Receptaculites* has long been called the Lower *Receptaculites* Zone. In many places *Receptaculites* also is abundant in a zone about 20 feet thick, here called the Middle *Receptaculites* Zone, consisting of the upper half of the Rivoli Member and most of the Sherwood Member. The Upper *Receptaculites* Zone is in the overlying Wise Lake Formation.

The Dunleith is equivalent to the *Subretepora* (=*Chasmatopora*=*Phylloporina*), Fucoid, *Clitambonites*, and *Nematopora* beds and most of the *Fusispira* bed of Minnesota (Winchell and Ulrich, 1897, p. xcvi-ci), but these faunas are well developed only in the northern limestone-shale facies.

Stratigraphic Relations.—In the northern outcrop area the Dunleith is conformable on the Guttenberg and is overlain by the Wise Lake. The contact with the Guttenberg commonly is marked by a transition zone from 1 to 2 feet thick. This zone generally is more like the Guttenberg and is included in that formation, although in places it more closely resembles the overlying Buckhorn Member of the Dunleith. In the southern outcrop area, where the Buckhorn Member generally is missing, the Dunleith is separated by a diastem or unconformity from the underlying beds, which range from Guttenberg to Plattin in age. Except for a minor break at the top of the Buckhorn Member, the Dunleith members are all conformable.

Correlation.—The Dunleith Formation appears to be equivalent to beds extending from the base of the Hull Formation to the top of the Rust Member of the Cobourg Formation in the standard New York section (fig. 30).

Subdivisions.—The problem of differentiating members in the Dunleith Formation has received much attention because the unit is about 125 feet thick and is the only formation exposed in a large area in northern Illinois. In general, the more argillaceous beds have been found to maintain relatively greater argillaceousness from southern Minnesota, where most of the strata are argillaceous and some are shaly, to north-central Illinois, where the impure units are represented by only faint argillaceous streaking in relatively pure dolomite. Maximum argillaceousness is reached near the middle of the formation, except in Minnesota where the lower part becomes very shaly.

The persistent alternation of pure and argillaceous units provides the best regional basis for subdivision of the Dunleith Formation into members. Some of the contacts between the pure and argillaceous units are gradational and some are sharp. The pure and argillaceous units could be differentiated as separate members or combined so that an argillaceous unit is either at the top or bottom of a member. Classification of each argillaceous or pure unit as a separate member would make thinner subdivisions than is desirable.

Because the base of the formation is a relatively pure unit and the top of the formation is an argillaceous unit, the Dunleith has been divided into members consisting of a relatively pure unit at the base and a generally much thinner argillaceous unit at the top. This paired arrangement produces a sequence of ten members roughly cyclic in character (fig. 18). Many minor variations occur within the members.

The member classification as a whole is most distinct in the area of intermediate purity from Galena, Illinois, to Decorah, Iowa. Some members are easily recognized in the more argillaceous facies. All are relatively indistinct in the pure limestone and dolomite facies, and to trace them very detailed matching of sequences at close intervals is necessary. Only a few are as easily identified as are members in other Champlainian formations.

As shown by Herbert (Willman et al., 1946) a differentiation based on cherty and noncherty zones permits very close correlation in local areas. Variations in amount, size, color, and arrangement make the chert nodules useful markers. However, in certain areas almost every bed has some chert, whereas in others the same beds do not contain chert. Even where the chert zones are well developed they are not sharply defined. As chert is commonly more abundant in the argillaceous beds than in the pure beds, there is local agreement between the chert zones and the argillaceous units. However, where the beds become strongly argillaceous or shaly, chert commonly does not occur. The lowest of the chert zones (Eagle Point) is one of the most persistent. Although it is generally a little more argillaceous than adjacent units and is differentiated as a member, it can be recognized by the presence of chert in some areas where the argillaceous content does not distinguish it.

Consideration also has been given to naming certain distinctive key beds in the Dunleith Formation, such as bentonites, distinctive chert bands, zones of shale partings, beds with argillaceous streaking, and calcarenite beds, instead of differentiating members. Such a classification is useful for local correlation purposes, but it does not provide names for intervening units or differentiate units of similar gross lithology. In the Dunleith Formation, it would result in an almost endless accumulation of names.

The Dunleith Formation in Missouri and southern Illinois consists of an upper cherty, partly argillaceous, lithographic, and calcarenitic limestone, and a lower coarse-grained calcarenite. As elsewhere in the Mississippi Valley region, the top of cherty argillaceous limestone in the Galena Group marks the top of the Dunleith Formation.

This correlation, based on subsurface tracing, is supported by the presence of a bentonite 40 to 45 feet below the top of the Dunleith Formation in Ralls and Pike Counties, Missouri. The bentonite appears to be equivalent either to a persistent bentonite at the base of the Sherwood Member in the northern outcrop belt, or to a bentonite about 4 feet above the base of the Sherwood. In exposures near New London, Ralls County, and in outcrops south of St. Louis this bentonite is at the top of the coarse-grained calcarenite in the lower part of the Dunleith, and in the Main Street section at Cape Girardeau, Missouri, it is also at the top of the coarse calcarenite, the contact between the *Receptaculites* (below) and *Echinosphaerites* Zones (McQueen, 1939, p. 61-62). The prominent zone of *Receptaculites* is almost continuously present just below the bentonite from New London to Cape Girardeau and is believed to correspond to the persistent Middle *Receptaculites* Zone in the lower Sherwood and Rivoli strata of northern Illinois.

The Eagle Point, Beecher, and St. James Members are recognizable at least as far south as Valmeyer, Monroe County, southern Illinois, but the Buckhorn Member appears to be generally overlapped by the St. James south of Sangamon County, central Illinois. Although all three members consist of coarse-grained calcarenite in southern Illinois, the Eagle Point is distinguished by nodular chert bands and slight argillaceousness and the St. James by weak argillaceous streaks and numerous *Dalmanella rogata* (Sardeson). In the St. Louis area a bentonite found locally 3 feet above the base of the St. James probably is equivalent to a bentonite at approximately the same horizon in parts of Ogle County, northern Illinois.

The northern Illinois members of the Dunleith Formation above the Eagle Point Member have not been differentiated in the southern outcrop area. These strata are divided into two distinct units separated by the bentonite previously mentioned. The lower unit consists of massive, pure, coarse, calcarenite, which contains rare, large, white, chert nodules. The name Moredock Member is proposed for this unit. For the upper unit, which consists of cherty, partly argillaceous, lithographic and calcarenitic limestone with some beds of medium calcarenite, the name New London Member is proposed. Where the bentonite is absent between the two members, a sharp reentrant generally marks the contact. The Moredock is essentially equivalent to the Fairplay, Mortimer, and Rivoli Members, and the New London to the Sherwood, Wall, and Wyota Members of the northern outcrop area.

Buckhorn Member (new)

The Buckhorn Member is here named for the village of Buckhorn Corners, in Stephenson County, northern Illinois, 2 miles east of the type section in a quarry at Buena Vista (geol. sec. 29).

Classification.—The Buckhorn Member is the basal member of the Dunleith Formation and is overlain by the St. James Member. It previously was considered the lower part of the Ion Member of the Decorah Formation. Herbert (*in* Willman et al., 1946, p. 12) correlated these beds with strata called the "Blue" in the lead-zinc district. They are equivalent to the *Glyptorthis bellarugosa* Zone of Kay (1929, p. 660) and approximately equivalent to the *Subretepora* bed in Minnesota.

Distribution and Thickness.—The Buckhorn is present throughout the northern outcrop area. It is present in subsurface from LaSalle County, northern Illinois, to Sangamon County, central Illinois. It is overlapped by the St. James Member south of Sangamon County and is generally absent in the southern outcrop area. It is commonly from 7 to 8 feet thick, but is 5 to 6 feet thick in north-central Illinois.

Lithology.—In the type section the Buckhorn consists of dolomite that is argillaceous, blue-gray, slightly sandy (especially near the top), and medium to coarse grained. It is heavily speckled with dark gray, carbonaceous, pyritic, partly phosphatic material and contains green shale partings. It is cherty in wells in western Illinois. Floating fine sand grains are of well sorted St. Peter type. The Buckhorn is differentiated from the St. James Member above by its greater argillaceousness, darker color, and a persistent shaly zone at the top. In central northern Illinois it contains several thin layers of bentonite, the most prominent 3 feet above the base. The Buckhorn is a distinctive unit in outcrops from LaSalle, north-central Illinois, to Guttenberg, Iowa, but farther north it is largely shale similar to that above and below (fig. 22).

Fauna.—*Dalmanella rogata* (Sardeson) is especially abundant. A small species of *Receptaculites* is common near the middle of the unit in central northern Illinois.

Stratigraphic Relations.—The uniform thickness of the Buckhorn suggests that no important disconformity occurs at the top, although the upper surface is locally wavy with 2 to 4 inches of relief, as shown in the type section. The fact that the Buckhorn contains sand grains and is overlapped southward suggests that it was deposited during a period when the Ozark Dome was undergoing uplift and erosion.

St. James Member (new)

The St. James Member is here named for St. James Cemetery, Stephenson County, northern Illinois, 3 miles northwest of the type section at Buena Vista (geol. sec. 29).

Classification.—The St. James Member of the Dunleith Formation overlies the Buckhorn Member and underlies the Beecher Member. These beds previously were undifferentiated upper beds of the Ion Member of the Decorah Formation. Herbert (*in* Willman et al., 1946, p. 12) correlated these beds with strata called the "Gray" in the lead-zinc district. The St. James is approximately equivalent to the Fucoid bed in Minnesota.

Thickness.—The St. James is commonly about 14 feet thick in northern Illinois, but it locally is 28 feet thick in Ogle County. From the type area it thins northward to about 8 feet at Guttenberg, Iowa, and southward to between 8 and 12 feet in the southern outcrop area.

Lithology.—In northern Illinois the St. James is similar to the underlying Buckhorn Member, but it is lighter in color, less argillaceous, less shaly, and less gray specked. The lower part is relatively pure and medium bedded, but green shale partings are abundant in the upper 2 to 4 feet. It becomes more shaly northward and in Minnesota it is similar to beds above and below. In Minnesota a persistent zone of pyritic oolites marks the top (Stauffer and Thiel, 1941, p. 85). In the subsurface of western Illinois the St. James is very cherty. In the southern outcrop area it consists mainly of pure medium- to coarse-grained, gray to brown, faintly gray-specked calcarenite that locally is conglomeratic at the base. At the top it is fine grained, laminated, dense, and slightly argillaceous. A thin bentonite is locally present along a prominent, persistent bedding reentrant about 3 feet above the base. The St. James is exposed 1½ miles northwest of Batchtown, Calhoun County, at the mouth of Dixon Hollow (SE NE 6, 12S-2W, Hardin Quad.), where the sequence from the top is: *Dunleith 40′5″ (Moredock 12′, Eagle Point 9′1″, Beecher 11′6″, St. James 7′10″), Guttenberg 8′7″ (Glenhaven 8′5″, Garnavillo 2″).*

Fauna.—*Batostoma humile* Ulrich and *Dalmanella rogata* (Sardeson) are common in the St. James, but the latter is less abundant than in the Buckhorn below. *Prasopora simulatrix* Ulrich is common in the shaly upper beds of the northern limestone facies but not in the shale facies. In the dolomite facies it seems confined to a thin, slightly shaly zone at the top, which extends eastward to Rockford, Illinois. In many areas the bedding surfaces are covered with large stem-like fucoids. In the southern outcrop area bryozoans are abundant throughout.

Beecher Member (new)

The Beecher Member is here named for Beecher Street in East Dubuque, Illinois, near the type section (geol. sec. 28). The upper 5 feet 6 inches is exposed in the ravine section and the lower 2 feet 9 inches is exposed above the contact with the St. James, a quarter of a mile north. A supplementary section showing the Beecher in the dolomite facies is exposed near Millbrig, section 2 of the Galena Group type section.

Classification.—The Beecher Member of the Dunleith Formation overlies the St. James Member and underlies the Eagle Point Member. It consists of previously undifferentiated basal beds of the Prosser Member. It is equivalent to zone D of Agnew et al. (1956, p. 280, 296) and to the lower part of the *Clitambonites* bed of Minnesota (Winchell and Ulrich, 1897, p. xcviii-xcix).

Thickness.—The Beecher commonly is about 8 feet thick in northwestern Illinois, but it thickens northward to about 15 feet in northeastern Iowa. It is about 12 feet thick in the southern outcrop area.

Lithology.—The Beecher Member is distinguished as a relatively pure, noncherty, thick-bedded limestone or massive dolomite. Thin, slightly argillaceous beds that are weakly developed at the top in northern Illinois become prominent and shaly northward. In the type section the Beecher is lithographic to fine-grained, dolomite-mottled limestone characteristic of the northern limestone facies, but farther east in Illinois it is bluish gray to buff, medium-grained dolomite with persistent strong bedding-breaks at top and bottom. In the southern area it is coarse-grained, gray to pink or buff calcarenite that is almost wholly massive. Its relatively high purity and massiveness differentiate it from the more argillaceous St. James below and the thinner bedded, cherty Eagle Point above.

Eagle Point Member (new)

The Eagle Point Member is here named for Eagle Point, a prominent bluff in a park of the same name on the north side of Dubuque, Iowa, 2 miles north of the type section in East Dubuque, Illinois (geol. sec. 28). It consists of 11 feet 10 inches of limestone with bands of chert in the ravine at the north end of the type section. A supplementary section showing the Eagle Point in the dolomite facies occurs near Millbrig, section 2 of the Galena Group type section.

Classification.—The Eagle Point Member of the Dunleith Formation overlies the Beecher Member and underlies the Fairplay Member. It previously has been recognized as the lowest cherty zone in the Prosser (Willman and Reynolds, 1947, p. 10). It is equivalent to zone C of Agnew et al. (1956,

p. 280, 296) and to the upper part of the *Clitambonites* bed of Minnesota.

Thickness.—The Eagle Point is commonly about 12 feet thick in the lead-zinc district but thickens eastward to 17½ feet at Rockford and northward to 15 feet at Guttenberg. In the southern outcrop area it varies from 8½ feet to 10½ feet thick.

Lithology.—The Eagle Point Member consists of cherty limestone or dolomite, usually more argillaceous than members above and below. The chert commonly is in well defined nodular bands. The Eagle Point generally lacks an argillaceous zone at the top. In the type section it is dolomite-mottled limestone, but it changes southward and eastward to dolomite. It grades northward to limestone and shaly limestone, the chert disappearing in the shaly facies. In the southern outcrop area it is fine- to medium-grained, gray to buff calcarenite containing many bands of nodular chert and a few weak shale partings. It normally is fine grained, denser, and more argillaceous than adjacent members. Although only weakly argillaceous, the member can be differentiated by this character in the few areas where chert is absent.

Fairplay Member (new)

The Fairplay Member is here named for the town of Fairplay, Grant County, southwestern Wisconsin, 6 miles northeast of the type section in East Dubuque, Illinois (geol. sec. 28). In the type section the argillaceous zone at the top is exposed just above the railroad tracks at the north tunnel entrance. The lower beds are exposed in the bluffs farther north and the complete section is exposed in the ravine.

Classification.—The Fairplay Member of the Dunleith Formation overlies the Eagle Point Member and underlies the Mortimer Member. It previously has been referred to as the Lower *Receptaculites* Zone in the Prosser Member. It is equivalent to zone B of Agnew et al. (1956, p. 280, 296). In Minnesota it is equivalent to the *Nematopora* bed and the basal part of the *Fusispira* bed, which are equivalent to the lower part of the *Camarella* bed (Sardeson, 1896b, p. 29-30).

Thickness.—The member is commonly from 14 to 20 feet thick and is 19 feet 7 inches thick in the type section.

Lithology.—The Fairplay consists of relatively pure limestone or dolomite and is largely chert-free, except for scattered nodules in zones 2 to 4 feet thick at the top and bottom. The upper 1 to 3 feet is persistently argillaceous or shaly, and locally is strongly cherty. In many places a strong bedding-break occurs at or just above the base of the argillaceous zone, and another is present locally at the top. A third prominent bedding-break commonly lies from 4 to 8 feet below the top and in places contains thin lenses of gray clay, which probably represent a bentonite. The Fairplay becomes more argillaceous northward. In Minnesota it consists of relatively pure limestone beds from 1 to 3 feet thick alternating with layers of shaly limestone or calcareous shale having a similar thickness; it has a distinctive sawtooth profile in a weathered face, and has several relatively pure and thick limestone beds in the upper 10 feet.

Fauna.—*Receptaculites oweni* Hall is abundant in both limestone and dolomite facies and in the limestone beds in the northern shaly facies.

Mortimer Member (new)

The Mortimer Member is named for Mortimer Street in East Dubuque, Illinois, near the type section (geol. sec. 28). It is well exposed at the north entrance to the railroad tunnel, where it consists of strata between the top of the prominent argillaceous bed at the base of the tunnel and the top of the argillaceous bed at the top of the tunnel.

Classification.—The Mortimer Member of the Dunleith Formation overlies the Fairplay Member and underlies the Rivoli Member. In Minnesota it is equivalent to the lower part of the *Fusispira* bed, and with the overlying Rivoli Member is equivalent to the upper part of the *Camerella* bed.

vine section in southern Minnesota (see *Wise Lake Formation, Stewartville Member*).

Wyota Member (new)

The Wyota Member is here named for Wyota Street in East Dubuque, Illinois, near the type section (geol. sec. 28). It is best exposed above the abandoned highway incline where it is 19 feet 9 inches thick, and its top, marked by a 2-inch shaly parting, is 6 feet 9 inches above the floor of the quarry at the top of the section.

Classification.—The Wyota is the top member of the Dunleith Formation, overlying the Wall Member and underlying the Wise Lake Formation.

Thickness.—The member commonly is 18 to 20 feet thick.

Lithology.—The Wyota Member consists of thick-bedded limestone at Decorah, Iowa, and northward, but it grades into dolomite farther south. It is purer than the Wall Member below but less pure than the Sinsinawa Member of the Wise Lake Formation above. From Guttenberg, Iowa, southward it is distinguished by the persistence of thin beds with argillaceous flecks, particularly in the upper 8 to 10 feet, and by an abundance of chert, which is mostly in well defined bands of nodules. At Guttenberg the member also contains many corrosion surfaces, which become particularly abundant in southern Minnesota where the beds with argillaceous flecks and chert nodules are absent. The corrosion surfaces commonly underlie, but in places overlie, thin calcarenite beds. In most exposures the upper 2 to 4 feet of the Wyota is relatively dense and slightly argillaceous, with thin, local, shaly partings. A 1- to 6-inch argillaceous-to-shaly bed commonly occurs at the top. Northwestward this bed is represented by as much as a foot of shaly limestone, which in southern Minnesota locally has a distinctive layer of conglomeratic calcarenite at the base.

Moredock Member (new)

The Moredock Member is here named for Moredock Lake at Valmeyer, Monroe County, southwestern Illinois, below the type section in the Mississippi River bluff just north of the crushing plant of the Columbia Quarry Company (geol. sec. 30).

Classification.—The Moredock Member of the Dunleith Formation overlies the Eagle Point Member and underlies the New London Member. It is a previously undifferentiated part of the Kimmswick Limestone and is equivalent to the Fairplay, Mortimer, and Rivoli Members of the northern outcrop area.

Distribution and Thickness.—The Moredock Member is confined to the southern outcrop area, where it commonly is 60 to 70 feet thick.

Lithology.—The Moredock consists mostly of coarse-grained calcarenite. It is exceptionally pure, massive, cross-bedded, crinoidal, and generally light gray to nearly white or light buff. It is locally banded with pink, buff, and light to medium gray beds. Although it is generally noncherty, large chert nodules or large lenses of chert occur locally, and both are common in exposures near Castlewood, St. Louis County, Missouri. Where the Moredock is cherty, it is easily distinguished from the underlying Eagle Point which is more cherty, finer grained, and slightly argillaceous. In the northern part of the southern outcrop belt, several zones contain very thin partings of red-brown shale. The upper 12 feet in Pike and Ralls Counties, Missouri, is fine- to medium-grained calcarenite with coarse-grained lenses and a few chert nodules. This part is transitional to the New London above and might be included with it, except that the same strata farther south are coarse grained, like those below. Furthermore, a persistent bentonite at the top and the change to finer textured, cherty, less pure beds above make it possible to recognize the upper contact of the transition zone consistently.

Fauna.—Many beds of the Moredock contain much crinoidal debris and some are a coquina of bryozoans. *Receptaculites oweni* Hall is scattered throughout and is abundant in the upper 10 to 15 feet.

Stratigraphic Relations.—The Moredock Member is conformable with the Eagle Point

Member below and the New London Member above. Where the New London is missing, the Moredock is overlain unconformably by Cincinnatian strata, either the Cape Limestone or, where the Cape is missing, by the Elgin Shale or the Thebes Sandstone. In the type section, where the Moredock is overlain unconformably by the Cape Limestone, the upper few feet of the Moredock probably are absent. However, the abundance of *Receptaculites* at the top of the type Moredock, as in places where the Moredock is overlain by New London strata, suggests that less than 5 feet is missing. The uppermost Moredock beds are exposed at Glen Park, Missouri, 4 miles west of the type section, where the basal beds of the New London Member are present.

New London Member (new)

The New London Member is here named for the town of New London, Ralls County, northeastern Missouri, 2 miles south of the type section in a roadcut on U.S. Highway 61 and in the bluff east of the highway on the north side of Salt River (geol. sec. 31). The top of the formation is exposed in a section half a mile southeast of Frankford, compiled from roadcuts and a ravine along U. S. Highway 61 and a bluff on the north side of Peno Creek (SE NE and NE SE 2, 54N-4W, Vandalia Quad.), where the sequence from the top is: *Wise Lake (Sinsinawa) 28′, Dunleith 70′ (New London 32′, Moredock 38′)*. The New London here is faulted and the thickness probably is greater than measured.

Classification.—The New London Member of the Dunleith Formation overlies the Moredock Member and underlies the Wise Lake Formation. It is a previously undifferentiated part of the Kimmswick Limestone, and appears to be essentially equivalent to the middle cherty member of the Kimmswick (McQueen and Greene, 1938, p. 41), which is 55 feet thick in northwestern Missouri. It is equivalent to the Sherwood, Wall, and Wyota Members of the northern outcrop area.

Distribution and Thickness.—The entire member is present in only the extreme northern part of the southern outcrop area where it appears to be 35 to 45 feet thick. South of Calhoun County, Illinois, the New London is overlapped by the Cape Limestone and the Elgin Shale of the Maquoketa Group. However, the lower 3 to 5 feet occurs locally, as at Glen Park, Brickeys, and Cape Girardeau, Missouri. In the vicinity of Cape Girardeau and Thebes, Illinois, as much as 30 feet of cystoid-bearing limestone, possibly all New London, is reported to be present at places (Ulrich, 1911, p. 309-310), but it was not found during our study. In the section at Cape Girardeau (geol. sec. 34), the New London Member is 8 feet thick and has a bentonite at the base.

Lithology.—The New London consists of fine- to medium-grained calcarenite and fine-grained to lithographic, calcarenitic limestone in medium beds, moderately pure, mostly cherty, with some thin argillaceous and weakly shaly beds. It is finer grained than the Moredock below but coarser than the Wise Lake above and less pure and thinner bedded than either. Red-brown shale partings occur locally, especially near the base at Cape Girardeau and 10 feet above the base near New London. A bed of bentonite, up to 2 inches thick, commonly marks the bottom of the member from the type area southward to Cape Girardeau, but it is missing in some exposures.

Fauna.—*Receptaculites oweni* Hall is present to common throughout the member but is less abundant than in the upper part of the underlying Moredock strata. The New London is distinguished faunally by the presence of the cystoids *Comarocystites obconicus* Meek & Worthen, *Comarocystites shumardi* Meek & Worthen, and *Echinosphaerites aurantium* (Gyllenhahl).

Wise Lake Formation (new)

The Wise Lake Formation is here named for Wise Lake, a small lake on the Mississippi River floodplain just southwest of the type section, the north end of a prominent bluff

6 miles south of Galena, Jo Daviess County, Illinois (geol. sec. 32). The lower 9 feet of the formation is not exposed at Wise Lake but is exposed on the southeast side of Galena, Illinois, in the type section of the Sinsinawa Member (geol. sec. 33). The 1- to 2-inch bed of bentonite 8 feet above the base of the exposure at Wise Lake is 17 feet above the top of the Dunleith Formation in the Sinsinawa type section. The interval of 17 feet was confirmed in a temporary excavation for a bridge abutment at the Wise Lake type section.

Classification.—The Wise Lake Formation overlies the Dunleith Formation and underlies the Dubuque Formation. It previously has been differentiated as the "upper massive noncherty zone" of the Galena Formation (Trowbridge and Shaw, 1916, p. 49). It consists of two members, the Stewartville (above) and strata previously included in the upper part of the Prosser, herein differentiated as the Sinsinawa Member.

Distribution and Thickness.—The Wise Lake Formation is present throughout the northern outcrop area and in subsurface southward to outcrops in Ralls and Pike Counties, Missouri, but it is absent farther south. It is commonly 70 to 80 feet thick. As much as 50 feet may be present in the Missouri outcrop area. McQueen and Greene (1938, p. 41) report 45 feet of limestone above the cherty zone in the Kimmswick in northwestern Missouri. Outcrops of the Wise Lake Formation are listed in the index.

Lithology.—The Wise Lake consists of noncherty, thick-bedded dolomite or limestone. It is characterized throughout the Mississippi Valley and other regions by high purity.

Fauna.—*Receptaculites oweni* Hall is common throughout and is persistently very abundant in the lower 10 to 15 feet of the Stewartville, which is called the Upper *Receptaculites* Zone. The Stewartville Member was called the *Maclurea* bed in early Minnesota reports and is characterized by a gastropod-cephalopod fauna. The Sinsinawa lacks the Stewartville cephalopod fauna as well as the gastropods *Lophospira augustina* Billings, *Maclurites cuneata* (Whitfield) and *Maclurites subrotunda* (Whitfield) but contains all other reported Stewartville species, generally in a similar degree of abundance. The Sinsinawa is the uppermost part of the *Fusispira* and *Lingulasma* beds in Minnesota (Winchell and Ulrich, 1897, p. ci; Sardeson, 1896b, p. 30).

Stratigraphic Relations.—The basal contact is sharp, but continuity of the thin argillaceous zone at the top of the underlying Dunleith indicates it is conformable. In the type region a thick transitional zone shows the conformity to the Dubuque Formation above. The Sinsinawa and Stewartville Members are conformable.

Correlation.—The Wise Lake Formation is correlated with the Steuben Member of the Cobourg Limestone in New York and Ontario (fig. 30).

Sinsinawa Member (new)

The Sinsinawa Member is here named for the Sinsinawa River, Jo Daviess County, northwestern Illinois. The member is completely exposed in roadcuts along U.S. Highway 20 on the east side of the Sinsinawa River (SE NE 4, 28N-1W, Galena Quad.), but because the contact with the underlying Dunleith Formation is not well exposed and heavy traffic makes the section dangerous to study, the roadcut 4 miles southeast along the same highway on the east side of the Galena River at Galena is taken for the type section (geol. sec. 33). A thin bed of bentonite occurs along a prominent reentrant 17 feet above the base of the Sinsinawa. The uppermost 3 to 5 feet of the Sinsinawa Member, lacking in the type section, is exposed in the Wise Lake type section.

Classification.—The Sinsinawa Member of the Wise Lake Formation underlies the Stewartville Member and overlies the Dunleith Formation. It previously has been referred to as the upper noncherty zone of the Prosser Member. It is equivalent to zone P of Agnew et al. (1956, p. 280, 296).

Thickness.—The member commonly is 35 to 40 feet thick in the type area and about

30 feet in southern Minnesota and in Pike and Ralls Counties, Missouri.

Lithology.—The Sinsinawa consists of relatively pure medium-grained dolomite or of fine-grained to lithographic limestone. It is considerably purer than underlying strata but is slightly less pure than the Stewartville above. It consists of dolomite between LaSalle County, north-central Illinois, and Decorah, Iowa, but north of Decorah it is dolomite-mottled limestone, the proportion of dolomite increasing upward. In the southern outcrop belt it is limestone.

In the northern outcrop area a 1- to 2-inch bentonite is widely present from 16 to 19 feet above the base. In the northern limestone facies 6 to 8 inches of shaly limestone with red-brown shale partings, overlies the bentonite. A similar shaly zone occurs 12½ feet above the base of the member in the section near Frankford, Missouri, described under *Dunleith Formation, New London Member.*

Beneath the bentonite a few thin, dense, very slightly argillaceous beds, locally containing argillaceous flecks like the beds in the Wyota below, are present in the dolomite facies, and a few thin calcarenite beds are present at the same horizon in the limestone facies. Above the bentonite the limestone or dolomite is more uniform and much like the Stewartville above. The top is placed at a prominent bedding-plane above which *Receptaculites* becomes very abundant and above which the strata are slightly more massive and almost entirely without siliceous impurities.

Correlation.—The Sinsinawa is equivalent to the lower part of the Steuben Member of the Cobourg Formation in New York and Ontario.

Stewartville Member
Ulrich, 1911

The Stewartville Member was named for Stewartville, Olmstead County, southeastern Minnesota (Ulrich, 1911, pl. 27). The type section is a quarry on the north bank of the Root River (Kay, 1935b, p. 567), where 28 feet is exposed with neither top nor bottom shown. A typical exposure in Illinois is in the Wise Lake type section (geol. sec. 32).

Classification.—The Stewartville Member of the Wise Lake Formation overlies the Sinsinawa Member and underlies the Dubuque Formation. It previously has been a member of the Galena Formation in Illinois. It is equivalent to the *Maclurea* bed as differentiated in Prosser's ravine and in cliffs extending downstream to Deer Creek, 2 miles west of Wykoff, Fillmore County, Minnesota, where the sequence from the top is correlated with the Illinois section as follows: *Dubuque 20′, Wise Lake 95′ (Stewartville 63′ or possibly slightly more, Sinsinawa 31′8″), Dunleith 65′ (Wyota 12′, Wall 8′6″, Sherwood 19′6″, Rivoli 10′9″, Mortimer 7′10″, Fairplay 6′6″).* In this section a 2-inch bentonite overlain by 6 inches of shaly limestone is present 19 feet above the base of the Sinsinawa. Weiss (1957, p. 1054) called this the Mahood's Creek section.

Our differentiation of the Stewartville or *Maclurea* bed in the Prosser's ravine section is similar to that of Winchell and Ulrich (1897, p. lxxx), and Kay (1935b, p. 565), and not to that of Stauffer and Thiel (1941, p. 38), who used the bentonite as the Stewartville-Prosser contact, or Weiss (1957, p. 1054-1055), who put the base of the Stewartville 19 feet 8 inches below the bentonite (feldspathized shale). The redefinition proposed by Weiss would expand the Stewartville to equal the Wise Lake Formation of this report. The redefinition of Stewartville to include the lower strata (Sinsinawa), also suggested but not adopted by Agnew et al. (1956, p. 267, 268), is not favored because the original Stewartville is a widely traceable lithologic unit that needs a name.

Thickness.—The Stewartville is 60 to 65 feet thick in the type area. It thins southward to between 30 and 35 feet in northwestern Illinois. It is over 25 feet thick at places in Ralls and Pike Counties, Missouri.

Lithology.—The Stewartville consists of medium-grained dolomite or lithographic to fine-grained limestone that is pure and mainly very thick bedded. The Upper *Receptaculites* Zone at the base of the Stewartville is the most massive part of the Wise Lake and is so pure that many samples have almost no insoluble residue. *Receptaculites* is sufficiently abundant and persistent to be an effective aid in differentiation of the Stewartville from the Sinsinawa. Although the Stewartville-Sinsinawa contact is not prominently exposed in the Prosser's ravine section, Weiss (1957, p. 1055) noted a change in color at the position we take to be the contact (in his unit 62), 12 feet above the bentonite or feldspathized shale (his unit 60). The differentiation is stronger in other areas, and the contact generally can be placed within an interval of about 5 feet.

In the northern outcrop area south of Decorah, Iowa, the top of the Stewartville is marked by the first strong shaly parting, and the zone of transition to strongly shaly Dubuque above is included in the Dubuque Formation. The contact is distinct in many weathered exposures where the change from very thick-bedded Stewartville to much thinner bedded Dubuque is accentuated. Farther north in Minnesota the top contact is sharp, and the massive dolomitic Stewartville is in strong contrast to the thin-bedded crinoidal limestone with prominent shale partings that constitutes the Dubuque. In Minnesota the upper 10 feet of the Stewartville is strongly crinoidal and has a few weak bedding-breaks. The limestone facies commonly weathers thin bedded in both northern and southern outcrop belts. A 6-inch shaly bed occurs from 10 to 12 feet above the base in northwestern Illinois, and thin red-brown shale partings occur in the upper part of the member near McCune's Station, Pike County, Missouri.

Stratigraphic Relations.—The presence of an unconformity between Prosser and Stewartville strata (the Sinsinawa-Stewartville contact of this report), along which strata equivalent to the Sherman Fall and lower Cobourg of New York are missing, has been shown on many correlation charts (Kay, 1937, p. 294; Twenhofel et al., 1954). No physical evidence of an unconformity at this position has been found in the Mississippi Valley. The entire Galena sequence, above a minor break near the base of the Dunleith, appears to be conformable. The many corrosion surfaces of the upper Dunleith are essentially surface characteristics of the beds, and probably no more than a few inches of beds are missing. In our suggested correlation with the New York sequence (fig. 30) Sherman Fall strata are equivalent to part of the Dunleith and there is no need for an unconformity within the sequence.

Correlation.—The Stewartville has been correlated faunally with the McCune Limestone in Missouri (Kay, 1935a, p. 292) but the name McCune (Keyes, 1898) was applied to the entire sequence between the Plattin (Bryant) and Maquoketa (Buffalo). Only the upper part, about 14 feet thick in exposures near McCune's Station, Ralls County, northeastern Missouri, is equivalent to the Stewartville.

The Stewartville is correlated with the upper part of the Steuben Member of the Cobourg Limestone in New York and Ontario.

Dubuque Formation

Sardeson, 1907

The Dubuque Formation was named for Dubuque, Dubuque County, Iowa, (Sardeson, 1907, p. 193). The type section is a quarry east of Columbia College at the top of West Fourteenth Street hill in Dubuque, where, according to Kay (1935b, p. 571), 25 feet of Dubuque strata was underlain by 9 feet of Stewartville. We interpreted the upper 33 feet, exposed in 1950, as Dubuque with the top eroded and the lower 3 feet as Stewartville. In northern Illinois the Dubuque is well exposed in the Wise Lake section (geol. sec. 32).

Classification.—The Dubuque previously has been classified in Illinois as a member of the Galena Formation, but it is classified here as a formation in the Galena Group, following Kay (1935a, p. 292).

The Dubuque is equivalent to the *Oxoplecia* Zone in Minnesota, where it was considsidered a member of the Maquoketa Formation (Stauffer and Thiel, 1941, p. 90) until it was classified as a separate formation between Galena and Maquoketa Formations (Weiss, 1955, p. 765; 1957, p. 1040).

Distribution and Thickness.—The Dubuque is present throughout the northern outcrop area. It is 40 to 45 feet thick in northern Illinois. It extends southward in subsurface to Galesburg, Knox County, western Illinois, where it is 32 feet thick, but farther south it is truncated by the Maquoketa Shale and disappears before reaching Quincy, Adams County, Illinois. It is reported to thin northward to as little as 15 feet (Kay, 1935b, p. 565).

Lithology.—The Dubuque consists of pure to argillaceous dolomite or limestone in beds, mostly less than 1 foot thick, with strong shale partings. In northern Illinois the dolomite ranges from porous and medium grained at the base to dense and fine grained or chalky in the midde and upper portions. An abundance of fossil debris in a chalky matrix gives the upper beds a characteristic uneven or mixed texture. The beds gradually decrease in thickness and increase in impurity, and the shale partings generally increase in thickness upward to the middle of the formation. In the lower 10 feet the beds are as much as 2 feet thick. In the upper part the dolomite has 1- to 6-inch beds interlayered with 1- to 8-inch beds of dolomitic shale. A thin bed of red-brown shale occurs 20 feet below the top. The formation is cherty in the subsurface of western Illinois.

Fauna and Age.—*Dalmanella, Sowerbyella, Pseudolingula iowensis* (Owen) and crinoid debris are common to abundant in the shaly beds constituting the upper 15 feet of the Dubuque in northern Illinois, but farther north these elements are common in the entire formation. A large number of more typically Cincinnatian species, such as *Streptelasma rusticum* Billings, *Onniella quadrata* Wang, *Rafinesquina kingi* Whitfield, and *Rafinesquina sardesoni* Salmon, first appears in the Dubuque, although the transitional relations to the Stewartville below and the unconformable relations to the overlying Elgin Shale of Edenian age suggest that the Dubuque is Champlainian. In northern Illinois common Wise Lake fossils such as *Hormotoma trentonensis* Ulrich & Scofield occur in lower Dubuque beds. Although *Pseudolingula* is locally present in shaly partings in the transitional zone at the base of the Dubuque, the partings separate pure dolomite beds that contain typical Stewartville fossils.

Some beds contain numerous minute, brown-red, unicellular, spore-like forms believed to be algae.

Stratigraphic Relations.—Fauna and lithologic evidence accord in indicating that Stewartville-Dubuque relations in the Dubuque type area are conformable and transitional. The major problem has been the selection of a boundary between them. In the type area of the Dubuque there is a gradual transition in lithology from the pure massive dolomite of the Stewartville, through a zone 20 to 30 feet thick, to the impure dolomite with shaly interbeds of the Dubuque. The contact originally selected by Sardeson (1907) is accepted here in preference to a position about 15 feet higher chosen by Kay (1935b). Kay moved the contact to a position within the transition zone. The base of the transition zone has been used as the contact in Illinois (Willman et al., 1946, p. 12) because the lowest strong shaly parting can be more consistently differentiated in both outcrops and well samples.

In the Stewartville type area, where the Stewartville is dolomite or dolomitic limestone and the Dubuque is limestone, the contact is sharper but the upper Stewartville strata show gradational characteristics and no evidence of unconformity was noted.

In the northern outcrop area the contact of the Dubuque with the overlying Maquoketa is sharp, the top of the Dubuque is locally a ferruginous pitted surface, phosphatic pellets and fossils are common in the depauperate zone at the base of the overlying Maquoketa Shale, and the Cape Limestone is missing. Although these data suggest the presence of an unconformity, the uniform thickness of the Dubuque Formation indicates that no appreciable erosion occurred in the northern region at this time. Farther south Maquoketa strata, with the

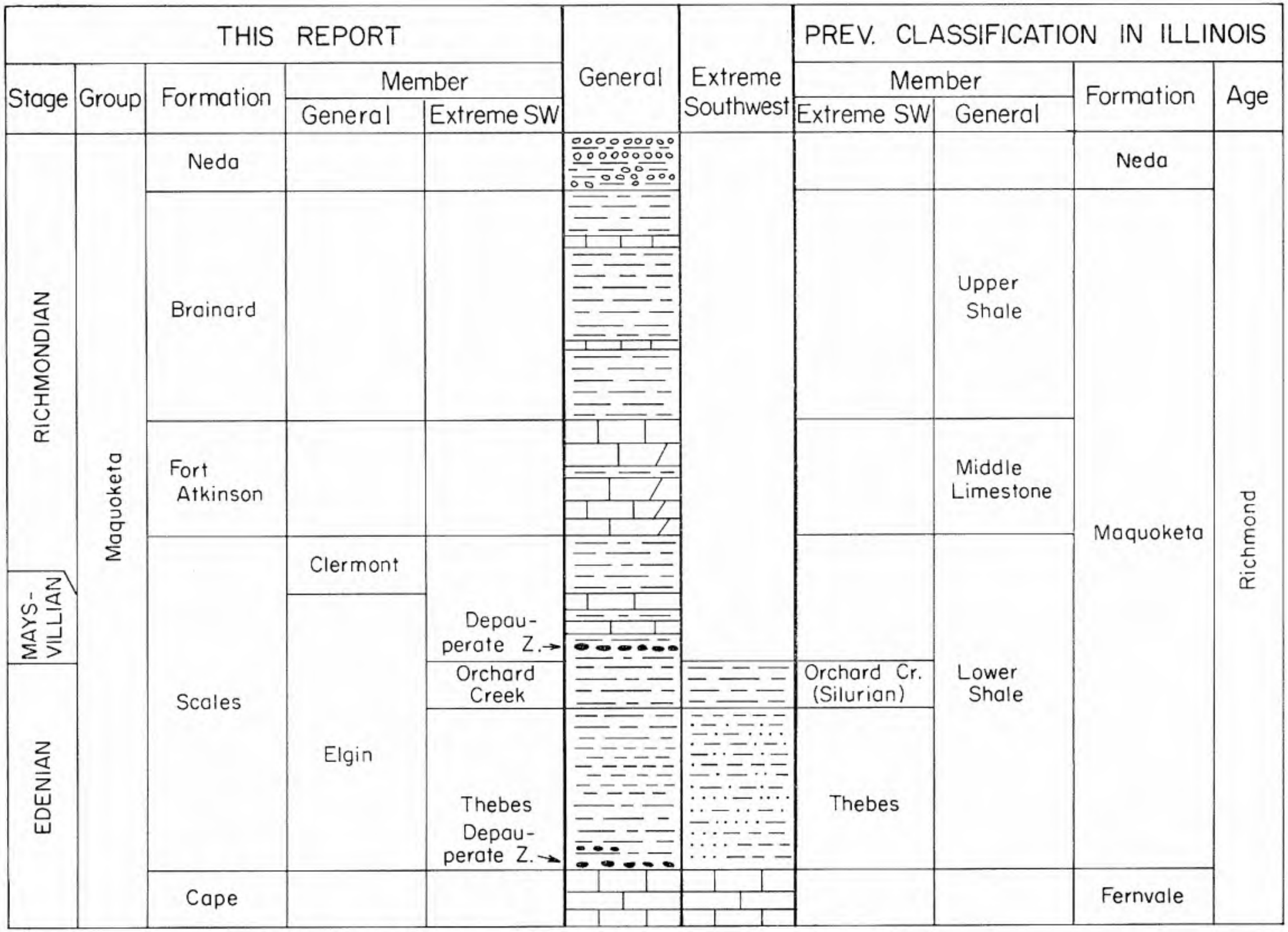


FIG. 25.—Classification of the Cincinnatian Series in Illinois.

depauperate zone at the base, deeply truncate the Galena Group, indicating an important unconformity.

Correlation.—The Dubuque is correlated with the Hillier Member at the top of the Cobourg Formation in New York. Twenhofel et al. (1954) correlated the Dubuque with the Collingwood (upper Utica), as discussed under *Regional Correlations, New York* and *Ontario.*

Rock Stratigraphy of the CINCINNATIAN SERIES

MAQUOKETA GROUP

In the Mississippi Valley the Champlainian Series is progressively truncated to the south by the Maquoketa Group of the Cincinnatian Series (fig. 20). The Maquoketa strata previously have been correlated with the Richmond Group at the top of the Cincinnatian Series in the type area, but information accumulated during this study suggests that equivalents of the other Cincinnatian groups also are represented, as well as strata possibly older and younger than those present in the Cincinnatian type area. Certain changes in the rock-stratigraphic classification of strata of Cincinnatian age in Illinois are proposed in this report (fig. 25).

The Fernvale Limestone of Illinois and Missouri is now believed to be an initial Cincinnatian deposit that may be equivalent to or older than basal Cincinnatian beds in the Cincinnatian type area. (See *Regional Correlations, Kentucky.*) It appears to be much older than the type Fernvale Limestone of the Richmond Group in Tennessee, and is herein renamed the Cape Limestone.

In Illinois the succeeding Maquoketa strata range from 200 to 350 feet thick where they have not been notably affected by pre-Silurian erosion. They consist of the following units in ascending order:

(1)) Gray, brown, and black shale containing subordinate proportions of interbedded limestone and having a depauperate faunal zone at the base and a second depauperate zone, previously unreported, about 10 feet below the top. It ranges from 70 to over 100 feet thick and is equivalent to the Elgin Shale Member of the Maquoketa Formation in Iowa (Calvin, 1906, p. 97-109; Ladd, 1929, p. 329-339; Templeton, 1940, p. 57-77). In southwestern Illinois and southeastern Missouri, on the flanks of the Ozark Dome, part or all of this unit grades laterally into the dark brown sandstone, siltstone, and shale called the Thebes Sandstone (Worthen, 1866; Savage, 1909).

(2) Greenish gray to brownish gray partly dolomitic shale, with only a few thin layers or lenses of argillaceous limestone. The shale is normally 15 to 20 feet thick, but it thickens greatly in central and southeastern Illinois. This unit is correlated with the Clermont Shale Member of Iowa (Calvin, 1906).

(3) Dolomite and limestone, which is argillaceous to pure, partly cherty, chalky to coarse grained, dense to porous, and in medium to thick beds separated by thin shale partings. In northeastern Illinois this unit is mostly pure and consists of vuggy dolomite and crinoidal limestone. It ranges from 15 to 40 feet thick and corresponds to the Fort Atkinson Limestone Member of Iowa (Calvin, 1906). In Illinois it has been called the Divine Limestone (Lamar and Willman, 1931) and the "middle limestone zone" (DuBois, 1945, p. 9, 15).

(4) Greenish gray to green partly dolomitic and silty shale containing a few limestone layers and having a thickness of from 75 to 100 feet or more. This unit is equivalent to the Brainard Shale Member of Iowa (Calvin, 1906). The *Cornulites* Zone (Ladd, 1929, p. 338-339, 344-345) is present near the top in both Iowa and Illinois.

The four units described above appear to be widespread in Illinois, although locally they are obscured by facies changes. Therefore, we extend the use of the Iowa nomenclature to Illinois, with some modifications. The Fort Atkinson Limestone and the Brainard Shale warrant formational rank because of their extent, thickness, and distinctive lithology. The Elgin and Clermont Shales are not readily separated at many places in Illinois and we therefore recognize them as members of a new formation—the Scales Formation. The name Elgin is accepted, even though it is used also for a sandstone of Pennsylvanian age in Kansas (Haworth, 1898; Moore et al., 1951, p. 67), and the latter use has priority. The name Elgin has been used for both units for 50 years, and it appears that introduction of a new name would cause more confusion than has resulted from the duplicate usage.

Studies of exposures and well cores in northeastern Illinois have shown the presence of subdivisions within the Scales and Brainard Formations, and the following tentative correlations with the type Cincinnatian Series are suggested:

(1) The basal division of the Elgin Member of the Scales is a black to dark brown shale that contains a few thin limestone layers and ranges from 20 to 70 or more feet thick. In northwestern Illinois the shale is interbedded with gray argillaceous limestone. The unit is very similar to the Fulton Shale, the basal dark colored shale of the Eden Group of the Cincinnatian type area. A phosphatic depauperate zone found throughout most of Iowa and Illinois at the base of the Elgin also is present, although weakly developed, at Kentland, Indiana, and in central Kentucky. Two bentonite layers are present just below the top of the Fulton at Kentland, Indiana.

(2) The next Elgin division, about 20 feet thick, is a gray to light brown shale containing more numerous limestone layers than the shale below. This upward change to a lighter colored, more calcareous unit parallels the change from the basal dark shales to lighter colored shales in the Eden Group in Ohio (Stout, 1941, p. 28-31, table facing p. 46).

(3) The succeeding and highest Elgin division, from 10 to 20 feet thick, consists of argillaceous limestone and greenish gray shale interbedded in about equal proportions. It is separated from the underlying light colored shale unit by a strongly developed phosphatic pyritic depauperate zone that is believed to mark a diastem. This unit may represent a greatly thinned Maysville Group, which generally is distinguished lithologically by having a higher percentage of limestone than adjacent strata.

(4) The Clermont Member, which overlies the Elgin with apparent conformity, seems to be similar in its light color, dominant shale lithology, and stratigraphic position to the Arnheim Formation at the base of the Richmond Group in the Cincinnati area.

(5) In northeastern Illinois the Fort Atkinson Limestone is remarkably similar in fauna (Savage, 1924, 1925), lithology, and stratigraphic position to the Waynesville Limestone of southern Indiana and northern Kentucky and to the Fernvale Limestone of Tennessee. The Cape Limestone of southern Illinois formerly was thought to occupy the same stratigraphic interval because the Fort Atkinson, Waynesville, and Fernvale Limestones represent a recurrence of the lithology and fauna found in the Cape Limestone.

(6) In southeastern Illinois the Fort Atkinson is overlain conformably by a greenish gray shale that is the basal unit of the Brainard Formation and is thought to correspond to the Liberty Formation of the Cincinnatian type area. The unit thins out northward, where its absence is reflected in the strongly pitted, ferruginous surface on the top of the Fort Atkinson Limestone.

(7) The next younger Brainard unit is a greenish gray laminated shale about 45 feet thick, which is dolomitic, micaceous, and silty. It is thought to be a western facies of the Saluda Limestone of the Cincinnatian type area, which is silty and sandy and which in turn seems to be a faint western reflection of the Sequatchie facies in the Appalachian region. The silty shale is overlain by some 15 feet of gray-green laminated shale having black carbonaceous flecks in the lower portion. This unit is tentatively correlated with the Whitewater Formation, which generally is regarded as a northern facies of the Saluda Formation.

(8) The topmost 20 to 25 feet of the Brainard Formation consists of massive green shale that is very dolomitic in the middle. A

strongly developed phosphatic zone at the base probably indicates a diastem. Two bentonite layers are found just above the phosphatic zone. At or near the top is the *Cornulites* Zone. The shale is correlated with the Elkhorn Formation at the top of the Richmond Group because the Elkhorn shows a similar lithologic sequence and has a similar fauna. A bentonite has been found near the top in Ohio (Caster and Kjellesvig-Waering, 1951).

The Scales and Brainard subdivisions whose occurrences in eastern Illinois are described above, extend westward to central Illinois, but with the exception of the persistent dark shale of the Elgin, it is not yet known whether they persist in other parts of the state. For this reason, and because differentiation of many units in the Cincinnatian type area seems to be based more on faunal zones than on lithologic unity, application of the Iowa nomenclature to Maquoketa strata in Illinois appears preferable at present.

The uppermost Cincinnatian unit in the Mississippi Valley, found only in northeastern Iowa, southeastern Wisconsin, and northeastern Illinois, is the Neda Formation, which consists of goethite oolites in a matrix of red hematitic shale or dolomite (Workman, 1950). It is patchy in distribution because of pre-Silurian erosion, but is about 10 feet thick in Illinois and has a maximum thickness of 55 feet in Wisconsin (Thwaites, 1923, p. 536). Although it has a Richmondian fauna (Savage and Ross, 1916), it is missing in the Cincinnatian type area and is believed to be younger than the Elkhorn Formation. The lithology and distribution of the Neda suggest that it is a westernmost, and probably uppermost, tongue of the Queenston red shale in New York and Ontario.

In southernmost Illinois the Thebes Sandstone Member of the Scales Formation is overlain, in ascending order, by the Orchard Creek Shale (Savage, 1909) and the Girardeau Limestone (Shumard, *in* Swallow, 1855). In lithology the Orchard Creek and Girardeau resemble Maquoketa strata more closely than they do the overlying Alexandrian limestones, but their faunas are a mixture of Ordovician forms, Silurian forms, and species known only from these beds. They have long been considered Silurian (Savage, 1917), although their transfer to the Ordovician has been suggested (Weller and Ekblaw, 1940, p. 8-9; Twenhofel et al., 1954).

Near Thebes Pryor and Ross (1962) noted that the basal part of the Orchard Creek Shale grades downward into Thebes Sandstone and that only the upper few feet contains limestone beds. The fossils listed from the Orchard Creek Shale and interpreted to be of early Silurian age probably came from these limestone beds. The presence of an unconformity between the Orchard Creek and the Girardeau does not appear to be well demonstrated. However, the unconformity at the top of the Girardeau is prominent at several places.

As the combined thickness of the Thebes and Orchard Creek is about half the normal thickness of the Maquoketa, the Girardeau Limestone is essentially at the position of the Fort Atkinson Limestone, if it is the upper half that is missing. The unconformity at the top of the Girardeau may account for the absence of the Brainard Shale.

In this report we assign the Orchard Creek Shale to the Maquoketa on lithologic grounds, but retain the Girardeau in the Silurian on faunal grounds, pending more detailed study. The Orchard Creek and the Thebes are classified as local members of the Scales Formation and are distinct units only in extreme southwestern Illinois and adjacent parts of Missouri.

Elevation of the Scales, Fort Atkinson, and Brainard units to formational status in Illinois requires the elevation of the Maquoketa to a group. Although the Cape and Neda Formations are not present at the Maquoketa type locality, they show many lithologic and faunal resemblances to Maquoketa beds and are not separated from Maquoketa strata by important physical breaks. For these reasons they are here included within the Maquoketa Group in Illinois. If the correlations suggested above are correct, the Maquoketa Group is essentially equivalent in age to the Cincinnatian Series.

Gutstadt (1958a, p. 518, 524, 531) accepted the name Cape Limestone from the manuscript of the present report for the limestone previously called Fernvale at Cape Girardeau. However, he correlated it with the middle limestone of the Maquoketa, which is the early correlation on which the name Fernvale was introduced for this limestone. As the Thebes Siltstone, which overlies the Cape Limestone at Cape Girardeau, and the Elgin Shale, which has the depauperate zone at its base and overlies the Cape Limestone in the St. Louis region, appear to be continuous with the shale unit beneath the middle limestone, the correlation suggested by Gutstadt seems improbable. Gutstadt differed from the earlier correlation, however, in relating the middle limestone unit to the Maysville rather than to the Richmond Waynesville or Fernvale Limestone.

Gutstadt (1958a, p. 518, 531) applied the name Orchard Creek to the upper shale of the Maquoketa, specifically to strata from the top of the Cape Limestone to the base of the Silurian, which he places at the base of the Girardeau. Such an assignment is undesirable because it would include in the Orchard Creek the Thebes Siltstone, which is many times thicker than the Orchard Creek, and it would leave the present Orchard Creek without a name.

Cape Limestone (new)

The Cape Limestone is here named for Cape Girardeau, Missouri. The type section is on Main Street north of Broadway in Cape Girardeau (geol. sec. 34, in part after McQueen, 1939, p. 17).

Classification.—The Cape Limestone is the basal formation of the Maquoketa Group in the Mississippi Valley. It is overlain by the Scales Formation. The name is proposed as a replacement for the name Fernvale, which was applied to this unit by Ulrich (Buckley and Buehler, 1904, p. 11, misprinted Fernville) in the belief that it represented the type Fernvale Limestone of Tennessee. The type Fernvale overlies the basal Richmondian Arnheim Formation, underlies Silurian strata, and was considered an upper unit of the Richmond Group. It is tentatively correlated with the middle Richmond Waynesville Limestone of Ohio and the Fort Atkinson Limestone of Illinois and Iowa. The Cape Limestone is an older unit, underlying brown to black shale that represents the Fulton Shale at the base of the Eden in Ohio.

The name Fernvale was first used in Illinois (Savage, 1910, p. 315-318; 1925, p. 233-247) for both the basal Maquoketa (Cape) Limestone in southern Illinois and for the middle Maquoketa (Fort Atkinson) Limestone in the Wilmington region of northeastern Illinois. Fernvale later was restricted to the southern Illinois strata when it became apparent that the latter were stratigraphically lower than the Fort Atkinson. Shideler (*in* Ladd, 1929, p. 368-369) suggested that the basal Maquoketa depauperate zone, which is above the Fernvale in southern Illinois, was the same as that near the top of the Arnheim of Ohio, which is below the type Fernvale of Tennessee. He also questioned the use of the name Fernvale for the limestone in southern Illinois. Although Shideler (1937) proposed the name Ada to replace Fernvale in the Ozark region the name was preempted and the term Fernvale continues to be used in that area. By subsurface tracing, DuBois (1945, p. 15-16) also showed that the Fernvale of southern Illinois could not be equivalent to the Fort Atkinson Limestone. He considered the Fernvale to be a facies of the Maquoketa and suggested that the name Fernvale be dropped in Illinois.

Distribution.—The Cape Limestone has a patchy distribution in the southern outcrop area south of St. Louis, and is absent farther north. It is present in states south and west of the Ozark Dome, as described under *Regional Correlations,* where it is commonly called Fernvale.

Thickness.—The Cape Limestone commonly is 1 to 4 feet thick in the outcrop area. It has a maximum thickness of 8½ feet in the type section, but it is much thicker to the southwest in Arkansas.

Lithology.—The Cape Limestone consists of limestone which, except for scattered, thin, argillaceous laminae, is pure, light gray weathering brownish gray to reddish gray, coarse grained, calcarenitic, very fossiliferous, and medium to thick bedded. It is similar in general character to the underlying Kimmswick Limestone but is distinguished by thinner bedding and argillaceous laminae.

Fauna.—The fauna has been listed by Branson (1944, p. 92-93). It is characterized by large brachiopods, particularly *Lepidocyclus capax* (Conrad). It contains much white to red crinoidal debris.

Stratigraphic Relations.—In the Mississippi Valley the Cape Limestone is present only in the area where Cincinnatian strata truncate the Wise Lake and Dubuque Formations of the Galena Group, so that it unconformably overlies the Dunleith Formation. It lies on different beds within the Dunleith, commonly resting directly on the Moredock Member but in places separated from it by a few feet of basal New London strata. It is overlain unconformably and is locally cut out by the Elgin Shale or Thebes Siltstone Members of the Scales Formation (Weller and St. Clair, 1928, p. 118-119).

Scales Formation (new)

The Scales Formation is here named for the town of Scales Mound in Jo Daviess County, northwestern Illinois. The type section is in a railroad cut in Scales Mound in which 30 feet of the Scales Formation overlies 10 feet of the Dubuque Dolomite (geol. sec. 35). The top of the Scales Formation is exposed about 5 miles farther east in another railroad cut (SW SW SW 15, 29N-3E, Elizabeth Quad.), where 20 feet of Fort Atkinson Limestone overlies 18 feet of the Scales Formation.

Classification.—The name Scales Formation is applied to the unit which has been referred to in many reports as the lower brown shale member (Willman and Payne, 1942, p. 66) or the lower shale zone (DuBois, 1945, p. 9) of the Maquoketa Formation. It is classified here as a formation in the Maquoketa Group underlying the Fort Atkinson Limestone and overlying the Cape Limestone. As the latter is confined in Illinois to the extreme southwestern part of the state, the Scales more commonly rests directly on formations of the Galena Group. In places the Scales is subdivided into the Elgin Shale Member (below) and the Clermont Shale Member. In southwestern Illinois it is subdivided into the Thebes Sandstone Member (below) and the Orchard Creek Shale Member.

Distribution and Thickness.—The Scales Formation is present throughout the area of the Maquoketa Group (DuBois, 1945, p. 8). It generally is 75 to 100 feet thick, but it ranges from 50 to 150 feet thick.

Lithology.—The lower part of the Scales Formation most commonly consists of brown to black shale. In some areas it is calcareous and interbedded with dark gray to brown argillaceous limestone, and in others it consists of dark brown sandstone, siltstone, and shale. Somewhat higher, the shale is generally medium gray and contains varying proportions of interbedded limestone, but in places this interval also is largely dark colored. This variable sequence is differentiated as the Elgin Member in areas where it is separated from the Fort Atkinson Limestone above by 10 to 20 feet of light to medium gray or greenish gray shale that is referred to the Clermont Member. Frequently this differentiation cannot be made. In the Thebes area in Alexander County, Illinois, the Scales is largely dark brown sandstone, siltstone, and shale (the Thebes Sandstone Member), 75 to 100 feet thick, overlain by greenish gray shale (the Orchard Creek Shale Member), 20 to 30 feet thick (Weller, 1940, p. 19). The distribution of various facies of the Scales has been shown by DuBois (1945, p. 10, map C in figure 3). The dark gray to black facies of the basal Scales is well shown just east of the Illinois line at Kentland, Indiana.

A bed of small fossils, mostly gastropods and pelecypods, usually pyritic or phosphatic, mixed with phosphatic pellets, and called the "depauperate zone," is commonly present at the base of the Scales, not infrequently in two layers 1 to 6 inches thick. One layer is at or close to the base of the shale, the other is from 3 to as much as 12 feet above the base.

An almost identical bed with the same types of fossils occurs near the top of the Scales in northeastern Illinois in a clay pit at Goose Lake, 3 miles south of Dresden Island lock and dam on the Illinois River. The depauperate bed is only intermittently exposed in the floor of the pit, but it occurs about 60 feet above the base of the shale, as shown by drilling, and only 15 to 20 feet below the Fort Atkinson Limestone exposed in the hills north of the pit. This depauperate bed is also found in borings near Kankakee. The basal depauperate bed of the Scales is encountered in wells in the same region.

Stratigraphic Relations.—The Scales Formation rests unconformably on the Dubuque, Wise Lake, and Dunleith Formations of the Galena Group. In southwestern Illinois it overlaps and truncates the Cape Limestone, which probably was originally much thicker. The Scales appears to be conformable to the overlying Fort Atkinson Limestone.

Correlation.—The Scales Formation is Edenian and probably Maysvillian in age, rather than Richmondian as long classified (Twenhofel et al., 1954). The continuity of the Eden Shale through Indiana to Illinois seems well established (Gutstadt, 1958a, 1958b). The previous correlation of a depauperate zone near the top of the Arnheim (lower Richmond) with the basal Elgin depauperate zone made the entire Maquoketa equivalent to the Richmond. If instead it is equivalent to the depauperate zone in eastern Illinois a short distance below the Fort Atkinson Limestone, the Scales is equivalent to all the Cincinnatian strata older than the Richmondian.

In consequence of this correlation, the Eden black shales and associated gray shales of the type Cincinnatian region are probably equivalent to black shales of the Upper Utica (Collingwood and Gloucester) of New York, a correlation advanced many years ago (Miller, 1881; see Weiss and Norman, 1960). In both regions these strata directly overlie essentially contemporaneous uppermost Champlainian strata, as indicated by tracing through Illinois, Michigan, and Ontario. The widely accepted belief that Edenian-Maysvillian strata are absent throughout a large part of the eastern United States (Twenhofel et al., 1954) is contradicted by these correlations.

STRUCTURAL MOVEMENTS

Repeated uplift took place during the Champlainian Epoch on many of the structures in the Mississippi Valley, such as the (1) Canadian Shield, (2) Savanna Anticline, Oregon Anticline, Ashton Arch, and LaSalle Anticline in northern Illinois (Willman and Templeton, 1951, p. 121-124, figs. 1, 4, 9), (3) Ozark Dome, (4) an unnamed structural nose projecting northeastward from the Ozark Dome into western Illinois, and (5) Waterloo Anticline in Monroe County, southwestern Illinois.

A major unconformity separates Champlainian strata from the underlying Canadian Series. Lesser unconformities reflecting three periods of crustal disturbance during Ancell time are believed to separate (1) the Everton Group and the St. Peter Formation in southwestern Illinois and southeastern Missouri, (2) the St. Peter and Glenwood Formations in northern Illinois and southern Wisconsin, and (3) the Glenwood and Pecatonica Formations in the same area.

Several movements must have taken place during early Platteville time because (1) Pecatonica beds are thin and partly or wholly disappear as the Canadian Shield and the Ozark Dome are approached; (2) Pecatonica or Mifflin strata are missing locally over structures in central northern and western Illinois; and (3) the Mifflin Formation is the most argillaceous and shaly formation in the Platteville Group, becomes very sandy in western Illinois, and shows submarine slumping in part of Ogle County, northern Illinois.

Movement also occurred later in Platteville time in part of southwestern Wisconsin, where the Nachusa Formation is absent and basal Quimbys Mill strata rest directly on upper Grand Detour beds.

A more extensive movement took place between the end of Platteville deposition and the beginning of Galena deposition. The extent of this movement is shown by the facts that (1) the Spechts Ferry Formation, the basal unit of the Galena Group, rests on strata as old as Grand Detour in Minnesota, northeastern Iowa, southwestern Wisconsin, and northwestern Illinois; (2) the Quimbys Mill Formation is truncated at places, and over much of central and eastern Illinois the Spechts Ferry and Kings Lake Formations, and to a lesser extent the Guttenberg Formation, are absent, probably due to nondeposition; and (3) in part of northeastern Missouri, Joachim and Platteville strata have been stripped away (Grohskopf, 1948, figs. 2 and 3) so that beds of lower Galena age rest directly on St. Peter Sandstone.

During the Buckhorn interval of early Galena time, uplift of the Ozark Dome resulted in removal by erosion of Guttenberg and Kings Lake strata from part of southeastern Missouri and southwestern Illinois.

A final regional uplift at the close of Champlainian time caused truncation of the Dubuque and Wise Lake Formations in southern Illinois and southern Missouri, so that in this area the basal Cincinnatian Cape Limestone directly overlies the middle Galena Dunleith Formation.

The thinness of all Platteville formations in western Illinois, and the absence of some, suggests repeated Champlainian uplift in that area.

Middle Ordovician bentonites commonly occur just above unconformities, diastems, or abrupt changes in sedimentation, which suggests that, in many cases, the diastrophism responsible for the break or change in sedimentation was accompanied by volcanic activity.

Periods of movement that were approximately contemporaneous with the disturbances outlined above seem to have taken place in most of the eastern United States, and, judging from the clastic nature of Ancell, Platteville, and lower Galena equivalents in western states, likewise affected that region. The evidence of repeated relatively minor uplift, together with the gradual increase in argillaceousness toward the source areas of clastic sediments, strongly supports the interpretation that diastrophism was the major factor in the origin of the alternations of pure and argillaceous sediments.

Although some of the uplifts appear to have resulted in subaerial erosion of parts of the region, others may have resulted only in shallowing of the sea. The evidence does not require complete withdrawal of the sea from the interior region at any time during the Champlainian Epoch.

To account for the resumption of sedimentation, the intervals of uplift presumably were followed by depression. Regional variations in thickness of the sediments suggest that depression was not uniform. In the Ancell and Platteville Groups in southern Illinois the great thickening of many units with only minor change in lithology, the evidence of shallow-water deposition in some units, and the presence of minor breaks in sedimentation, indicate repeated intervals of depression and a much greater amount of depression than elsewhere in the Mississippi Valley.

REGIONAL CORRELATIONS

Revisions in the Illinois classification of Champlainian strata introduced in this report have been based partly on regional correlations that were needed to show (1) the best unit boundaries from a regional viewpoint, (2) the regional importance of units differentiated in Illinois, (3) the comparison between the rank assigned to units in Illinois and that used in other states, and (4) regional trends in sedimentation.

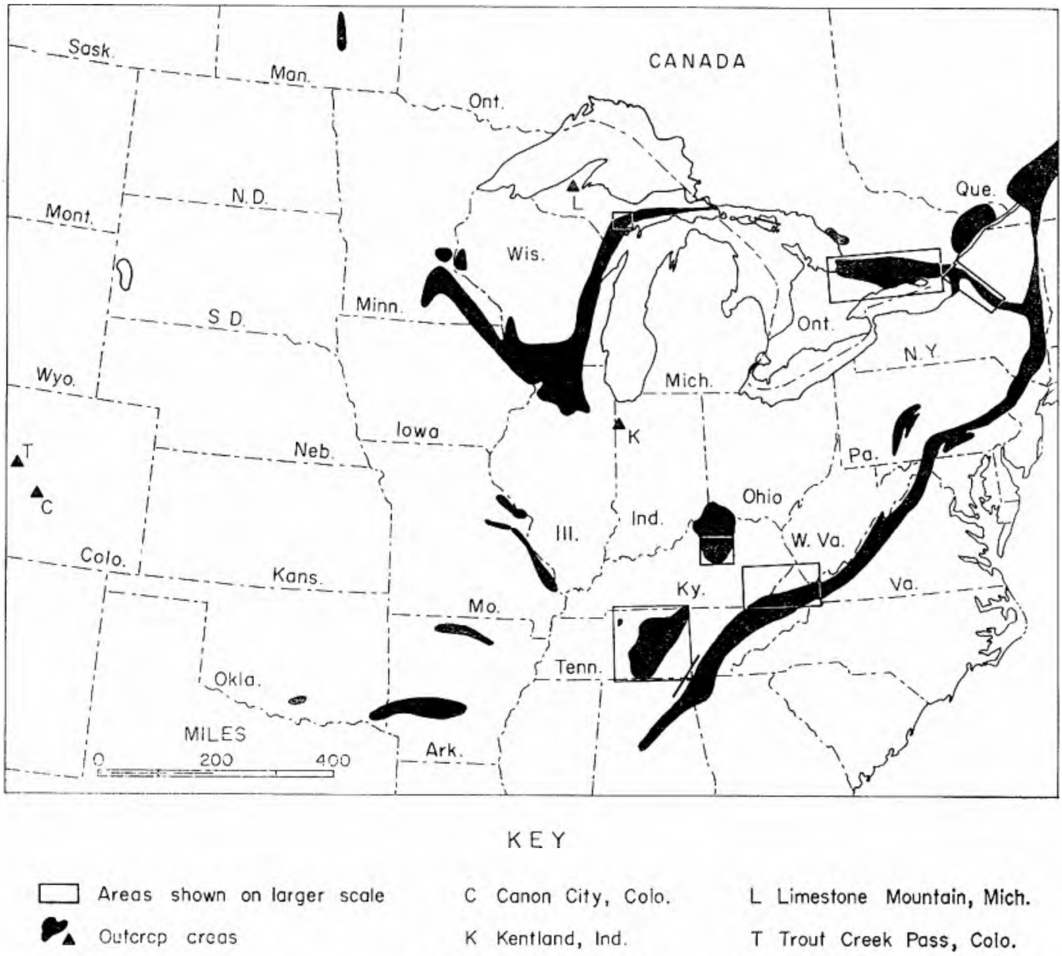


FIG. 26.—Major areas of outcrop of Champlainian strata in central and eastern United States and southern Canada, C—Canon City, Colorado; K—Kentland, Indiana; L—Limestone Mountain, Michigan; and T—Trout Creek Pass, Colorado. Areas covered by more detailed maps are outlined, except those in the Mississippi Valley (see figs. 6-11).

The sequence found in Illinois was compared with type sections and important exposures in other states in the Mississippi Valley (Iowa, Minnesota, Missouri, and Wisconsin). The comparison revealed so much uniformity in the sequence throughout the region that the possibility of even broader regional continuity was apparent. An attempt, therefore, was made in a limited time to match the Illinois sequence with those in regions at a considerable distance. Detailed studies were made of several typical exposures in Colorado, Indiana, Kentucky, Michigan, New York, Ontario, Tennessee, and Virginia (fig. 26). Published descriptions of the sequence in several other states have been used as a basis for preliminary correlations with the Illinois sequence.

The correlations (fig. 27) suggest a remarkable continuity of almost the entire lithologic sequence throughout a large part of the eastern and central United States and Canada. Most of the sequence extends even into the Appalachian geosyncline (Champlain miogeosyncline of Kay, 1951), and distinctive lithologic features of Trentonian strata extend westward to Colorado. The matching of sequences in the upper Platteville, youngest Blackriveran, from northern Illinois to southwestern Virginia (fig. 28) is an example of the degree of continuity of Champlainian strata.

The matching of lithologic sequences suggests regional correlations that differ in many respects from those previously made and that are considerably more detailed. Although we consider these long-range correlations tentative, they are presented at this time because (1) they suggest changes in correlations of the Champlainian of the Mississippi Valley with other regions which should be available to others and open to discussion, (2) they indicate the usefulness of lithologic sequences in regional correlations and show their potentialities for more precise matching, and (3) they indicate a continuity of thin rock units that is at variance with other interpretations postulating major facies changes (e.g., Winder, 1960).

The study of other exposures and particularly of well samples in the long distances between outcrop areas is needed to confirm many of the correlations suggested. Modifications of some correlations will result from more detailed lithologic studies in intervening areas and from more accurate fossil zonation.

It commonly has been assumed that regional continuity of minor lithologic units in the carbonate sequences was lacking because of changes in facies. Consequently, previous regional correlations have been based largely on fossils. Some miscorrelations resulting from inadequate knowledge of fossil ranges have made differences in facies appear much greater than they are.

Gradual changes in facies are evident in all regions, and sharp changes occur locally. Both facies change and wedging are especially common over the axes of uplifts where intermittent movement has modified sedimentation. The transition zones between facies are marked by gradation, mottling, or interfingering, depending on the type of sediments involved. Without such evidence, abrupt changes in sequence are more logically interpreted as resulting from lenticularity, rather than from changes in facies. Even where there are major changes in facies, many rock units based on relative differences in argillaceousness, or other criteria, can be traced from one facies to another.

The continuity of recognizable lithologic units is particularly evident on the relatively stable platforms (cratons), in troughs or basins within the stable platforms (autogeosynclines), and in the marginal parts of geosynclines adjacent to the platforms (miogeosynclines). The magnitude and rapidity of facies changes at many places within the miogeosynclines cannot be discounted. Because of such facies complexity, stratigraphic tracing is accomplished more easily via the bordering stable platform than along the miogeosyncline itself. For example, the correlation of the Champlainian rocks of southwestern Virginia with those of New York appears to be more clearly established by way of the outcrop belts in Tennessee, Kentucky, Illinois, northern Michigan, and Ontario than by direct tracing through Pennsylvania. The distinctive platform sequence can be traced into the basins and the marginal portions of the miogeosyncline even though it thickens from 5 to 10 times. Some units thicken much more. Ordinarily only a few new units appear as the section thickens.

The recent publication of regional correlations, based largely on fossils, by Twenhofel et al. (1954) and Cooper (1956) offers a basis for comparison with the correlations based largely on lithology suggested in this report (fig. 29). The differences between the two correlations based on fossils are at least as great as differences between them and our lithologic correlations.

The continuity of the units perhaps justifies the inference that, under conditions like those in the Champlainian, time-stratigraphic differentiation can be extended widely on lithologic criteria, and over broad regions a much finer time-stratigraphic differentiation can be established on lithologic continuity than on faunal zonation. The present study by no means indicates the lateral extent or the degree of differentiation to which lithologic criteria can be used in time-stratigraphic classification. Many of the gross lithologic aspects of the systems, and even series, span the oceans.

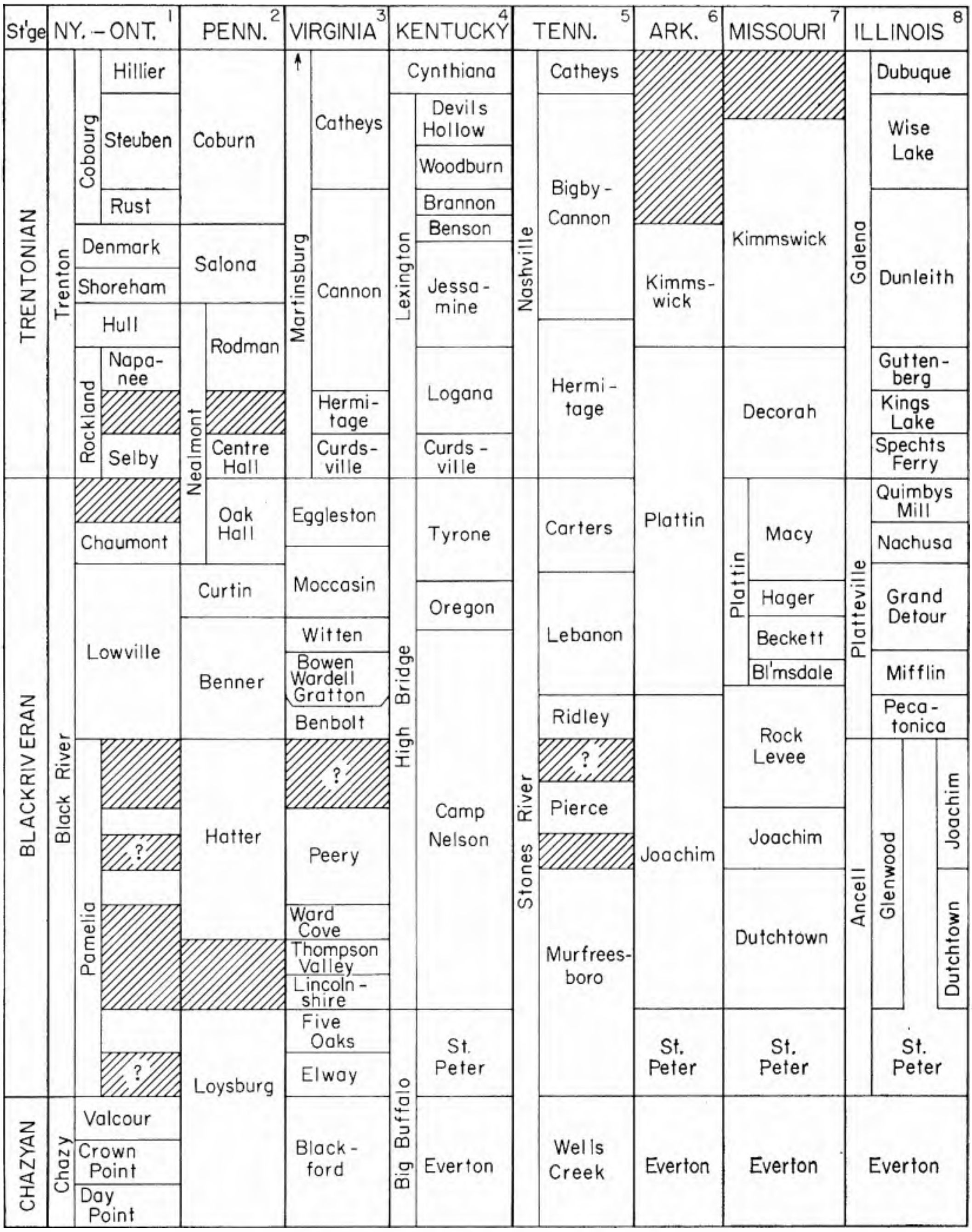
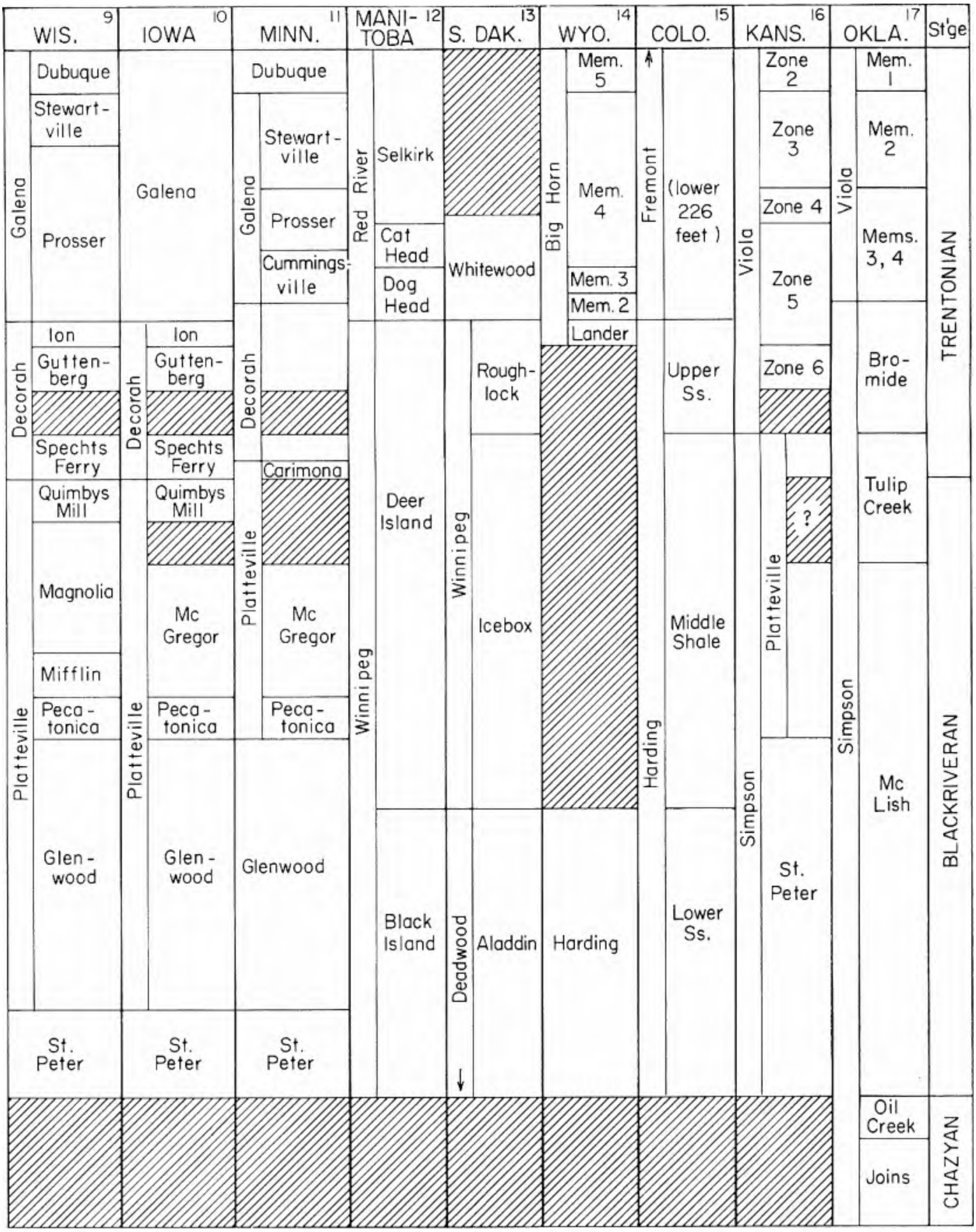


FIG. 27.—Champlainian correlation chart.

References for figure 27: (1) Kay, 1937, 1943, 1948; Young, 1943; Oxley, 1951. (2) Kay, 1944, 1956. (3) Cooper and Prouty, 1943; Huffman, 1945; Prouty, 1948. (4) Freeman, 1945, 1949; McFarlan and White, 1948. (5) Bentall and Collins, 1945; Wilson, 1949. (6) Giles, 1930, p. 12; McKnight, 1935. (7) Branson, 1944; Grohskopf, 1948; Larson, 1951. (8) This report. (9) Bays and Raasch, 1935; Bays, 1938; Agnew and Heyl, 1946; Agnew et al., 1956. (10) Hershey, 1948, p. 9;



Agnew, 1955. (11) Stauffer and Thiel, 1941; Weiss, 1955; Weiss and Bell, 1956. (12) Goudge, 1945; Kerr, 1949; Genik, 1954. (13) Darton and Paige, 1925; Furnish, Barragy, and Miller, 1936; McCoy, 1952; Carlson, 1960. (14) Tomlinson, 1917; Miller, 1930; Kirk, 1930. (15) Johnson, 1945; Maher, 1950. (16) Taylor, 1947; Moore et al., 1951; McQueen and Greene, 1938. (17) Decker and Merritt, 1931; Decker, 1952, p. 135; Wengerd, 1948; Harris, 1957. (Big Horn should be Bighorn.)

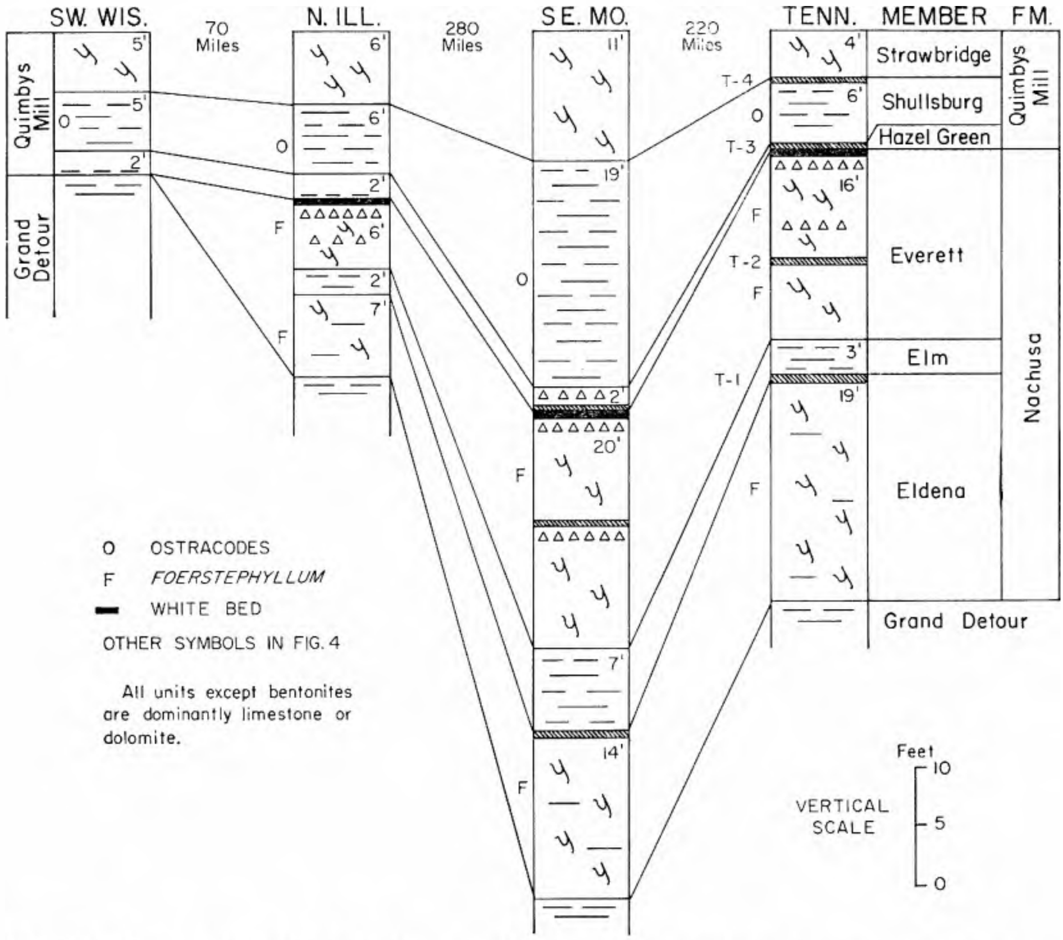


FIG. 28.—Cross section of the Nachusa and Quimbys Mill equivalents from Illinois to Virginia. A. From Quimbys Mill, Wisconsin, through Dixon, Illinois, and Ste. Genevieve, Missouri, to Nashville, Tennessee.

Many authors thoroughly familiar with the continuity of units throughout their own region do not consider the possibility of regional correlations on a lithologic basis. If they lack up-to-date faunal studies they do not discuss potential equivalence with other areas, and in many cases reject previous regional correlations, seemingly in the belief that time-stratigraphic interpretations are valid only if based on biostratigraphic zonation.

Both fossils and lithology should be used as fully as possible to evaluate the time-equivalence of strata. However, the faunal approach is time consuming, is restricted by the limited number of paleontologists, and is handicapped by the fact that many units are sparsely fossiliferous, or are without fossils. Under these circumstances, time-stratigraphic differentation should not wait for biostratigraphic zonation but should proceed on lithologic criteria, anticipating refinement and broader application when the additional faunal evidence becomes available.

In the following discussion of correlations with other regions, Illinois nomenclature has been used solely to show equivalence. We do not suggest that the Illinois classification should be adopted in the other regions. In

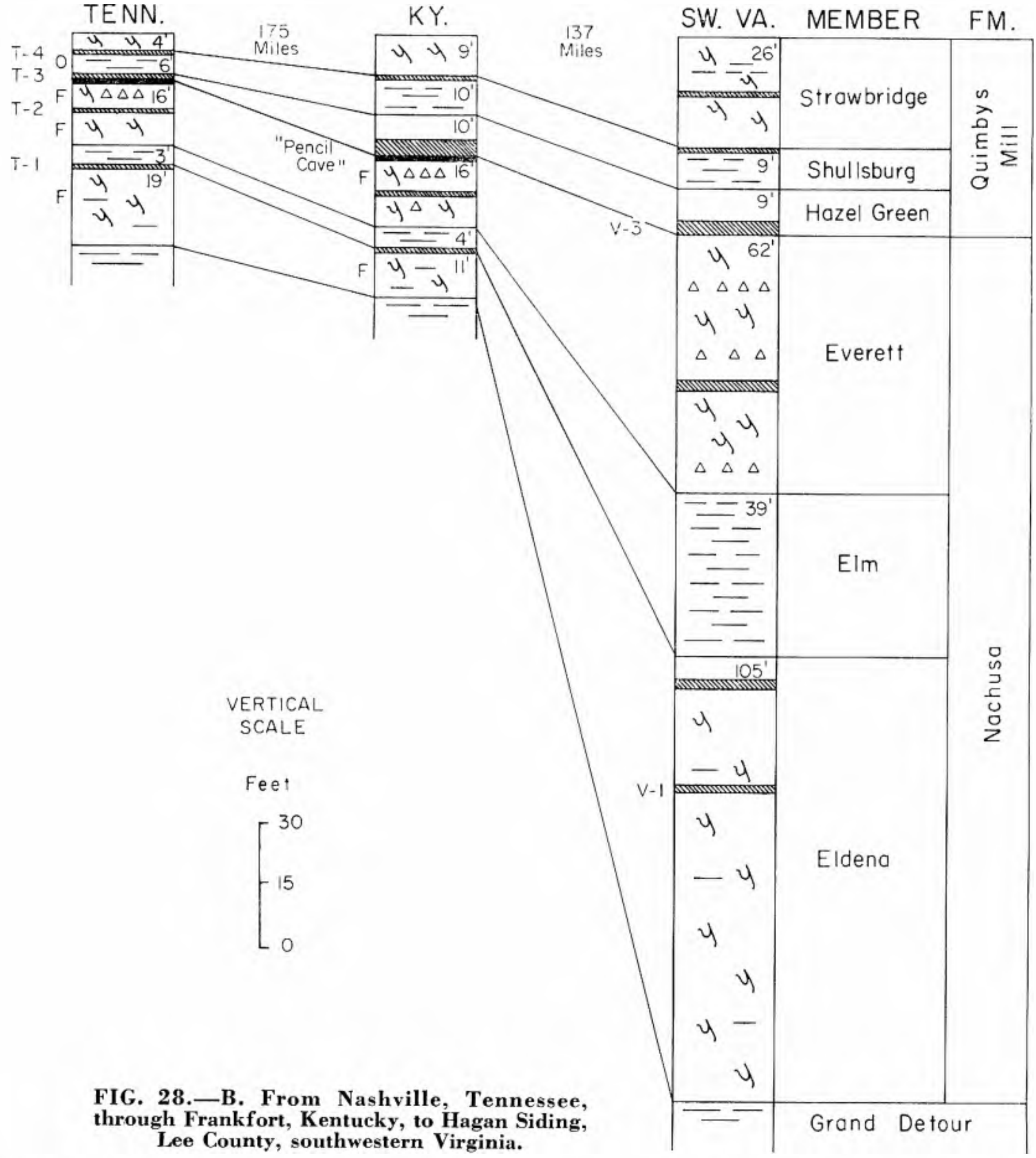


FIG. 28.—B. From Nashville, Tennessee, through Frankfort, Kentucky, to Hagan Siding, Lee County, southwestern Virginia.

some regions the Illinois classification is unsuitable because changes in thickness and lithology make the Illinois units impractical for routine recognition, but in a few areas the Illinois units seem to us to be more distinctive than those currently recognized. Some provincial classifications have resulted largely from the long distance between outcrop areas rather than from important changes in sedimentation. Where the lithologic sequences can be matched in detail, establishment of a uniform nomenclature is desirable. However, the use of local nomenclature should be continued until correlations are more certain and until the merits of various alternative classifications have been studied.

In the following discussion of the correlation of the Illinois sequence with other areas, the New York and Ontario sequence is described first because it is the standard of comparison for the North American Ordo-

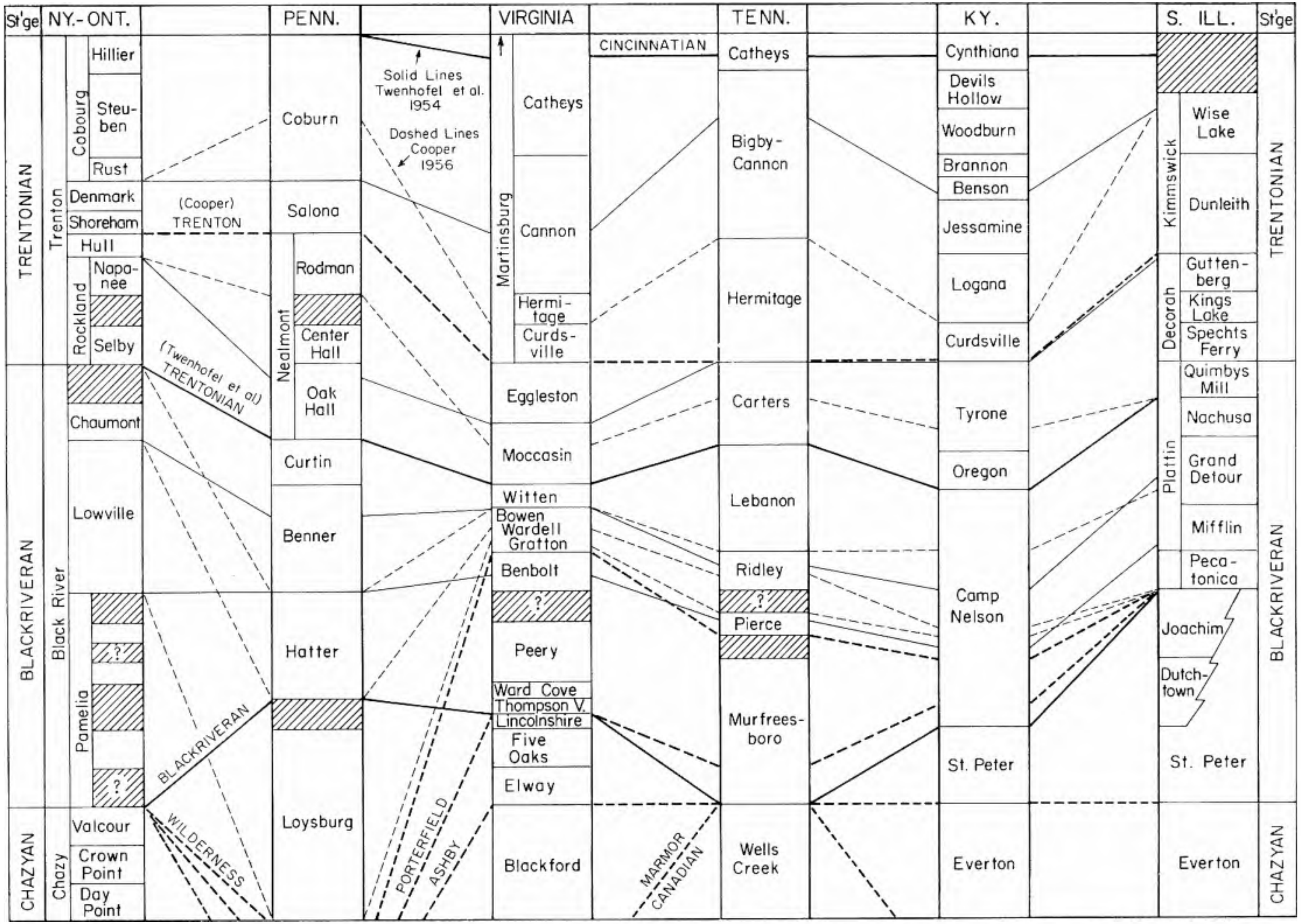


FIG. 29-A.—Comparison of correlations of this report with those of Twenhofel et al. (1954) and Cooper (1956). New York and Ontario through Pennsylvania, Virginia, Tennessee, and Kentucky to southern Illinois. The columns are matched according to our correlations. The correlations of Twenhofel and others are shown in solid lines and those of Cooper in dashed lines. Stage boundaries are in heavy lines. (Center Hall, in the Pennsylvania column, should be spelled Centre Hall.)

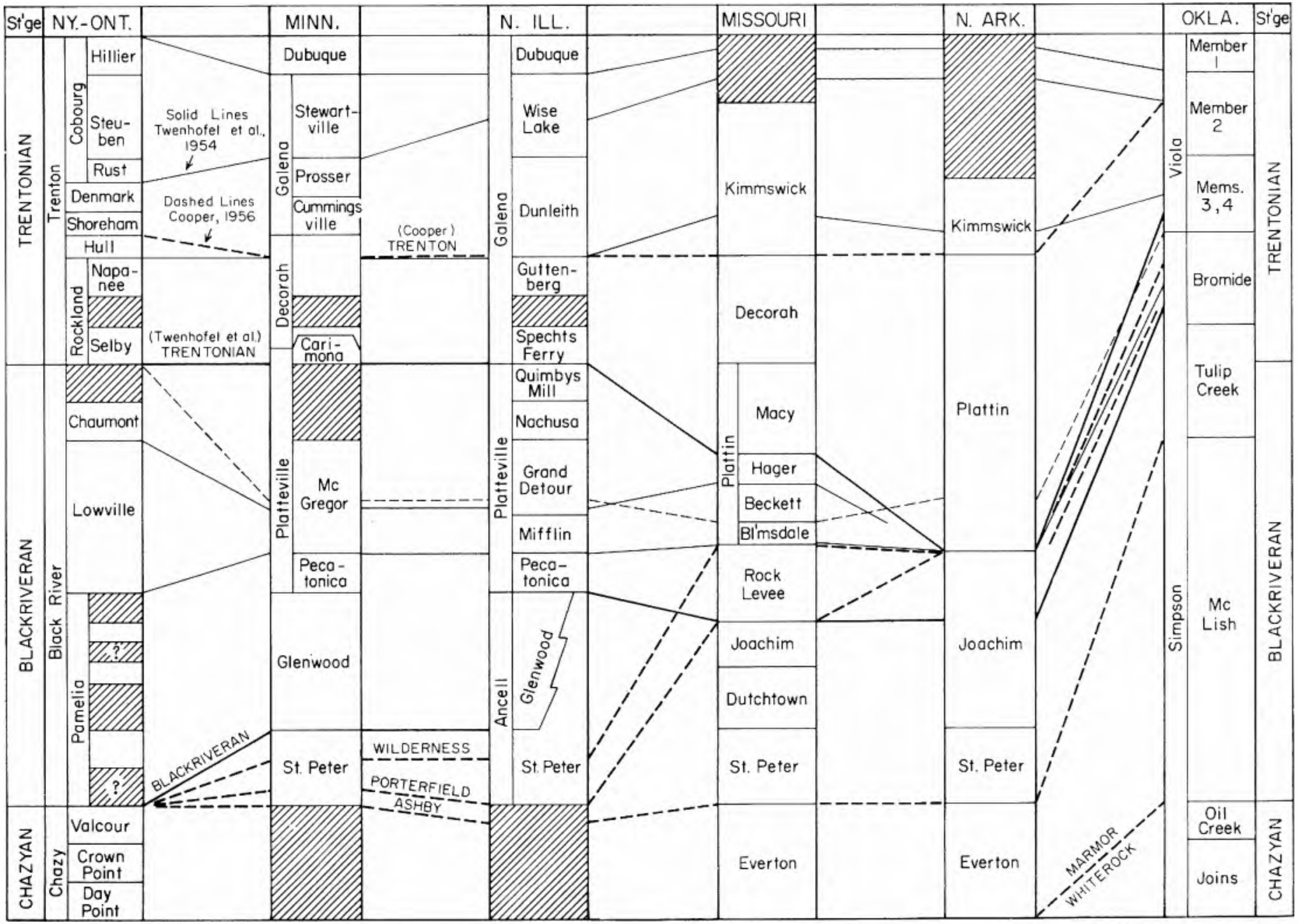


FIG. 29-B.—Comparison of correlations of this report with those of Twenhofel et al. (1954) and Cooper (1956). New York and Ontario through Minnesota, northern Illinois, Missouri, and northern Arkansas to Oklahoma.

vician and is mentioned frequently in the descriptions of the other areas. The correlations with other areas are described by states in alphabetical order.

NEW YORK AND ONTARIO

The sequence in this region has long been a standard of reference for Ordovician strata elsewhere in North America. The Champlainian or Middle Ordovician Series has commonly been divided into the Chazy, Black River, and Trenton Groups, in ascending order (e.g., Schuchert, 1943, p. 10, 43). These groups have served as the bases for time-stratigraphic subdivision of the series, as previously noted. The section compiled for New York and Ontario (fig. 30) is based on publications available at the time of our visit to the region in 1950. (See also Kay, 1953; Fisher, 1957; Oxley and Kay, 1959.)

Our correlation of the New York-Ontario sequence with that in Illinois and other states is shown in figure 27, and a comparison with recent correlations by Twenhofel et al. (1954) and Cooper (1956) is given in figure 29.

Chazy Group

The type Chazy strata of the Lake Champlain area, New York and Vermont (Oxley, 1951; Oxley and Kay, 1959), were not examined during this study. Correlations via Virginia, Tennessee, and Arkansas (fig. 27) indicate that in the Mississippi Valley the Chazy probably is equivalent to the Everton Group. Although the possibility that the uppermost Chazyan Valcour Formation is a facies of the basal Black River Pamelia Formation has been suggested (Neuman, 1951, p. 305-306), the evidence is not conclusive.

Black River Group

The Black River Group consists, in ascending order, of the Pamelia, Lowville, and Chaumont Formations and is equivalent to the Ancell and Platteville Groups in Illinois. Ten Black River sections examined in detail are exposed at Coboconk, Victoria County, at Point Anne, Hastings County, at Napanee, Lennox and Addington Counties, and near Kingston, Frontenac County, Ontario; and at Depauville and Perch Lake, Jefferson County, and at Lowville and along Roaring Brook at East Martinsburg, Lewis County, New York (Cushing et al., 1910; Kay, 1942; Young, 1943) (figs. 31, 32). The following discussion of Black River strata is based chiefly on the easily accessible and excellently exposed Roaring Brook section.

St. Peter Equivalents

The Pamelia Formation has been separated into a lower and upper division (Cushing et al., 1910, p. 69). The lower division includes two units, the lower of which is about 19 feet thick at Roaring Brook and 32½ feet thick at Perch Lake and consists of conglomerate, sandstone, and shale derived from weathered Precambrian crystallines, overlain by light gray, dolomitic limestone which is argillaceous and partly sandy. On the basis of similarities in lithology and in stratigraphic position beneath Dutchtown equivalents, we believe that the limestone represents the Five Oaks Limestone of southwestern Virginia, the basal part of the Murfreesboro Limestone of Tennessee, and the type St. Peter Sandstone of the Mississippi Valley. *Tetradium syringoporoides* Ulrich appears first in these strata. *Eoleperditia fabulites* (Conrad) has not been reported below these beds, except for an occurrence in the uppermost Blackford of Virginia. The basal Pamelia clastics appear to be a shoreline facies of the limestone.

Dutchtown Equivalents

The upper part of the lower division of the Pamelia Formation, as used by Cushing and Young, ranges from about 9 feet thick at Roaring Brook to 33½ feet thick at Perch Lake and consists of limestone that is black to dark gray, partly argillaceous, lithographic to very fine grained, and mostly thick bedded. Except for the lack of chert, it is almost identical in lithology with the lower part of the Peery Limestone (Zone 8) of Virginia, with the upper part of the Murfreesboro Limestone of Tennessee, and with the Dutchtown Limestone of Missouri. It contains among several other forms *Tetradium syringoporoides* Ulrich, *Helicotoma declevis* Ulrich, *Lophospira perangulata* (Hall), *Raphistomina modesta* Ulrich, and ostracodes, all of which are present or even common in lower Peery and upper Murfreesboro strata. A hiatus representing the Lincolnshire, Thompson Valley, and Ward Cove Formations of Virginia may be present at the base of the unit.

Joachim Equivalents

The upper division of the Pamelia Formation also consists of two units. The lower unit ranges from nearly 26 feet thick to 35 feet thick on the Chaumont River one mile southwest of Depauville. It is composed mainly of greenish buff chalky dolomite and gray lithographic limestone which are argillaceous, silty, partly sandy, thin to medium bedded, and shaly, but have a few interbeds of dolomitic siltstone. The upper unit ranges from nearly 22 feet thick on the Chaumont River to over 24 feet thick at Roaring Brook. It consists of gray, very fine grained limestone which is dolomitic, somewhat argillaceous, and thin to thick bedded, has dark gray-blue carbonaceous laminae, and contains some interbeds of brown-gray lithographic Lowville-type limestone. In lithology and stratigraphic position the upper Pamelia division corresponds to the Joachim Formation at the top of the Ancell Group in the Mississippi Valley. The two units within the upper division probably represent one of the argillaceous members and one of the pure members of the Joachim Formation. The Pamelia-Lowville contact marks the boundary between the Hatterian Group below and the Hunterian Group above in the Bolarian Series of Kay (1948, fig. 2).

Thirty feet of the lower Pamelia division (Dutchtown) overlain by nineteen feet of the upper division (Joachim) also are exposed on the north side of a roadcut just east of the Kingston-Battersea highway, 4½ miles north-northeast of Kingston, Frontenac County, Ontario.

Pecatonica Equivalents

The dark brown-gray lithographic Lowville Limestone bears many resemblances to the Pecatonica-Grand Detour sequence of eastern Missouri. However, the more frequent occurrence of oolitic beds, the presence of numerous intra-formational conglomerates, the relative thinness of the members, and the absence of some members all suggest that the New York section was deposited in shallower, more agitated water.

The basal unit of the Lowville Formation ranges from a little more than 8 feet thick at Roaring Brook to 12 feet thick on the Chaumont River and in the cut on State Highway 12 just northwest of Depauville. Although the entire section at Depauville has been called Pamelia (Young, 1943, p. 228, locality 30) we assign the lower 38 feet to the Pamelia and the upper 28 feet to the Lowville (compare Neuman, 1951, p. 305). The basal Lowville unit consists of comparatively pure, mostly conglomeratic, chiefly medium- to thick-bedded limestone that is similar to the Pecatonica Formation in purity and bedding. *Öpikina minnesotensis* (N. H. Winchell), *Lophospira oweni* Ulrich & Scofield, and *Trochonema umbilicatum* (Hall) first appear in Pecatonica and basal Lowville strata, and the long-ranging *Cyrtodonta huronensis* Billings, *Lophospira bicincta* (Hall) and *Lophospira perangulata* (Hall) are common in both units. The presence of argillaceous streaks, zones with shale partings, and *Öpikina minnesotensis* (N. H. Winchell) in the lowermost 5 feet at Roaring Brook and the lowermost 4 feet 9 inches at Depauville indicate that these strata may represent the Dane Member. The occurrence of shale partings at widely separated intervals in the overlying beds is suggestive of the Medusa Member. Equivalents of the other Pecatonica members seem to be missing.

Mifflin Equivalents

The Lowville beds for about 12 to 14 feet above the Pecatonica equivalents are more argillaceous than the adjacent units and consist of an alternating series of shaly and mass-

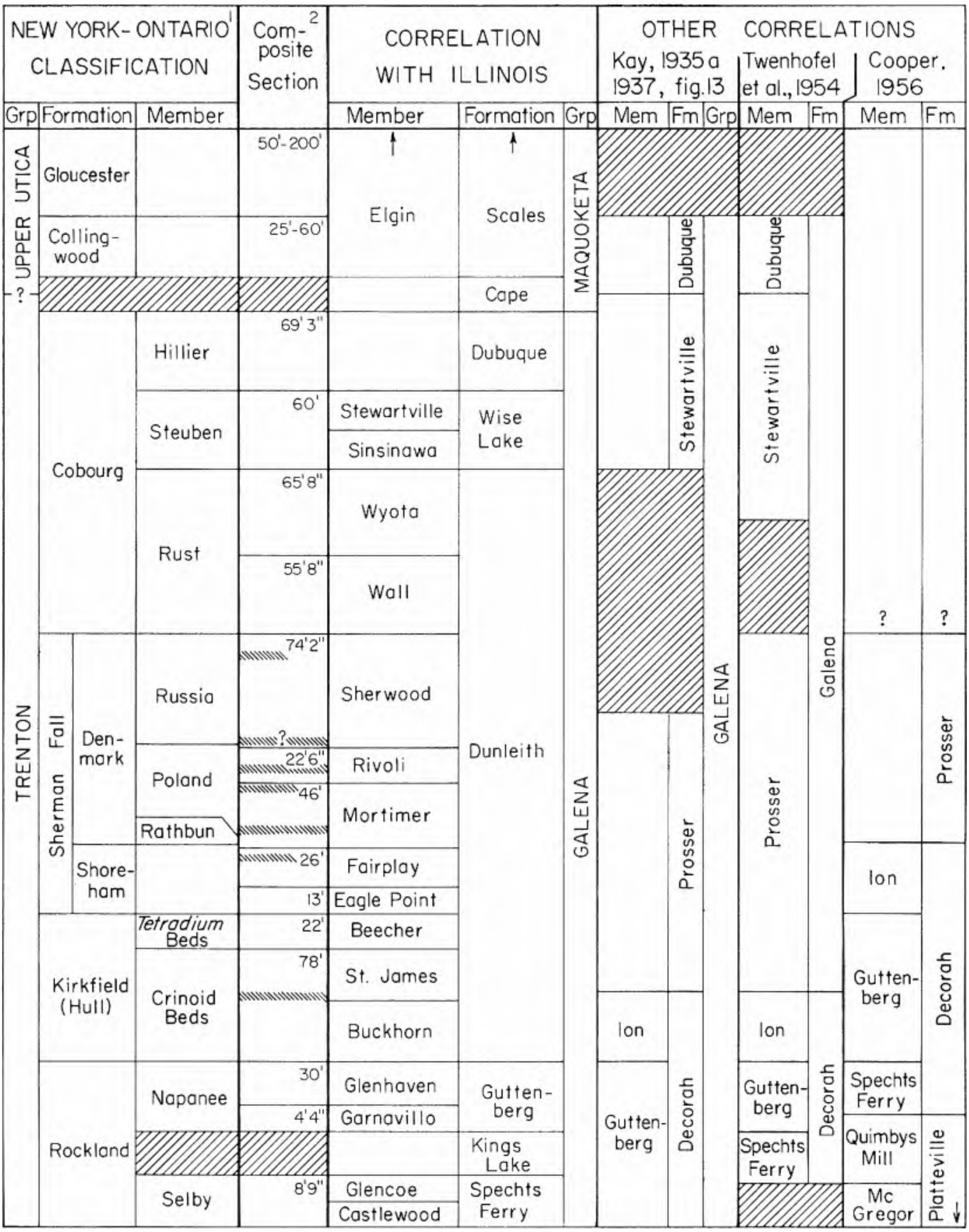


FIG. 30.—Correlation of the Champlainian Series in New York and Ontario with Illinois. Footnotes are on page 150.

(Continued) NEW YORK-ONTARIO CLASSIFICATION			Composite Section	CORRELATION WITH ILLINOIS			OTHER CORRELATIONS: Kay, 1935a; 1937, fig.13			Twenhofel et al., 1954		Cooper 1956	
Grp	Formation	Member		Member	Formation	Grp	Mem	Fm	Grp	Mem	Fm	Mem	Fm
BLACK RIVER				Strawbridge	Quimbys Mill	PLATTEVILLE	Spechts Ferry	Platteville	BLACK RIVER			↑ Mc Gregor	↑ Platteville
			1'8	Shullsburg									
				Hazel Green									
	Chaumont	Watertown	14'9"	Everett	Nachusa					Magnolia / Mc Gregor	Platteville		
		Glenburnie	4'4"	Elm								Peca-tonica	
		Leray	11'4"	Eldena			Mc Gregor						
	Lowville	Upper Division	11'10"	Forreston	Grand Detour		Peca-tonica						Glenwood
			1'	Victory									
			4'6"	Hely									
			10"	Clement									
			5'4"	Stillman									
		Lower Division	3'10"	Walgreen			Glen-wood			Mifflin			
			5'2"	Dement									
			6'6"	Briton	Mifflin								
			2'2"	Hazelwood									
			9"	Establishment									
			1'	Brickeys									
			4'	Blomeyer									
				Oglesby	Pecatonica								
			7'5"	Medusa									St. Peter
				New Glarus									
			4'9"	Dane									
				Chana									
	Pamelia	Upper Division	50' ?		Joachim / Glenwood	ANCELL				Pecatonica			
		Lower Division	8'9"		Dutchtown					Glen-wood			
			19'7" ?		St. Peter								
CHAZY	Valcour		202'										
	Crown Point		350'			EVERTON		St. Peter			St. Peter		
	Day Point		338'								Ever-ton		

ive units that seem to match the members of the Mifflin Formation, in ascending order, as follows: (1) Blomeyer—limestone, argillaceous, thin bedded, shaly, 2 feet 8 inches thick at Depauville, 4 feet thick at Roaring Brook; (2) Brickeys—limestone, pure, partly conglomeratic and oolitic, medium bedded to massive, 1 foot thick; (3) Establishment—shale with layers of argillaceous calcarenite or limestone, 2 inches thick at Roaring Brook, 9 inches thick at Depauville; (4) Hazelwood—limestone, pure, massive, 2 feet 2 inches thick; and (5) Briton — limestone, argillaceous, slightly shaly to shaly, thin to medium bedded, 6½ feet thick; a one-foot pure, oolitic bed 15 inches from the top may correspond to the pure bed in the middle of the type Briton.

Tetradium cellulosum (Hall), *Rhinidictya mutabilis* (Ulrich) and *Bumastus milleri* (Billings) seem to make their first appearance in the Mifflin and equivalent Lowville beds. *Tetradium cellulosum* (Hall) and *Bathyurus extans* (Hall) first appear in the Mifflin in outcrops west of New York and first become common to abundant in correlative Lowville strata. A number of long-ranging species also are common in this interval in both Illinois and New York.

Grand Detour Equivalents

Above the probable Mifflin equivalents in the Lowville is about 5 feet of mostly pure and massive limestone thought to represent the basal Dement Member of the Grand Detour Formation of Illinois. The upper half is conglomeratic, and a 4- to 9-inch shaly layer lying 10 inches below the top of the Depauville section occurs near the middle of the unit. The massive Dement equivalent is overlain by about 4 feet of thin-bedded and shaly limestone, which has a 10-inch massive oolitic layer near the middle and is believed to correspond to the Walgreen Member of the Grand Detour Formation. The top of this unit marks the top of the lower division of the Lowville, which is more argillaceous and thinner bedded than the upper division (Young, 1943, p. 156-157). Overlying the Walgreen strata is 5 feet 4 inches of massive fucoidal limestone capped by 10 inches of purplish brown massive calcarenite. These beds seem lithologically identical with the Stillman-Clement sequence of Illinois. The calcarenite is overlain by 4½ feet of limestone with highly argillaceous bands that is similar to the Hely Member at Cape Girardeau, Missouri. Above the Hely strata on Roaring Brook, in the midst

Footnotes for figure 30.

[1]/Kay, 1937, 1943, 1948, fig. 2; Schuchert and Dunbar, 1941, p. 154; Young, 1943; Caley, 1947, p. 163; Twenhofel et al., 1954.

[2]/Hillier and Steuben Members taken from exposures (a) along Gulf Stream east of Rodman, Jefferson County, New York, and (b) along Deer River between Copenhagen and power plant three-fourths of a mile northeastward, Lewis County (Kay, 1933). Section from top of the Rust to middle of the Poland (base of Rivoli equivalent) taken from Trenton Falls exposure between top of Mohawk Valley Power Company dam and Sherman Fall, 1¾ miles south, Herkimer and Oneida Counties. Bentonite near top of Russia projected into Trenton Falls section from stream exposure 14 miles southeastward and a quarter of a mile south of Herkimer County Home. Section from middle of the Poland to base of Shoreham taken from exposures along Rathbun Brook, on west side of West Canada Creek, 1¾ miles northwest of bridge to Newport, Herkimer County. Hull Formation taken from exposures in Deer River gorge 3 miles northeast of Copenhagen, Lewis County, extending from top of Kings Fall to bridge a quarter of a mile northeast. Member names from Hull (Ontario) type area. Thickness of St. James-Buckhorn equivalents approximate because of faulting. Bentonite in the Hull projected from Rathbun Brook section. Napanee Member is from type section along stream 1 mile north of Napanee railroad station, Lennox and Addington County, Ontario. Selby and Chaumont strata are from Canada Cement Company quarry at Point Anne, Hastings County, Ontario, 3 miles southeast of Belleville. Grand Detour equivalents are from section on Roaring Brook at East Martinsburg, Lewis County, New York. Section from top of Mifflin equivalents to base of Pamelia taken mainly from Roaring Brook exposure. Establishment and Pecatonica equivalents taken from roadcut on State Highway 12 just northwest of Depauville, Jefferson County, New York. Chazy Group from exposures along Valcour Island in Lake Champlain, Clinton County, New York (Goldring, 1931, p. 276-278; Oxley, 1951).

of a dark brown-gray argillaceous sequence, is a striking 1-foot bed of gray, pure, massive, calcite-flecked limestone that seems identical to the Victory Member of the Mississippi Valley. This unit is overlain by alternating argillaceous and pure beds that extend upward for nearly 12 feet to the top of the Lowville Limestone and correspond in sequence and number with similar units of the Forreston Member. The conspicuous argillaceous banding of the lowest Forreston unit also is well developed in equivalent beds on Roaring Brook.

Lambeophyllum profundum (Conrad) is first reported in the upper Lowville of New York and first becomes abundant in the Forreston Member in Illinois. Lowville and Grand Detour strata appear to mark the upper limit of *Subulites regularis* Ulrich & Scofield, *Centrocyrtoceras bondi* (Safford), *Bathyurus extans* (Hall) and *Phytopsis tubulosum* Hall.

Nachusa Equivalents

Conspicuous lithologic and faunal similarities exist between the Chaumont and Nachusa Formations. Both are relatively pure, cherty, fucoidal, and massive, and in each the lowermost member (Leray in the Chaumont and Eldena in the Nachusa) is more argillaceous than the uppermost member (Watertown in the Chaumont and Everett in the Nachusa). Both have a thin, argillaceous to shaly middle member (Glenburnie in the Chaumont and Elm in the Nachusa), although the base of the Elm is drawn at a slightly higher horizon. The bentonite in the Glenburnie (Kay, 1935c, p. 229-230) is believed to be the same as the bentonite at or just below the top of strata equivalent to the Eldena Member in Virginia, Kentucky, and Missouri. *Foerstephyllum halli* (Nicholson) and *Tetradium fibratum* Safford first become common to abundant in Chaumont and Nachusa strata. In both formations these species are associated with the long-ranging *Lambeophyllum profundum* (Conrad), *Tetradium cellulosum* (Hall), *Hesperorthis tricenaria* (Conrad), *Öpikina transitionalis* (Okulitch), and *Eoleperditia fabulites* (Conrad). The long-lived *Clathrospira subconica* (Hall), whose occur-

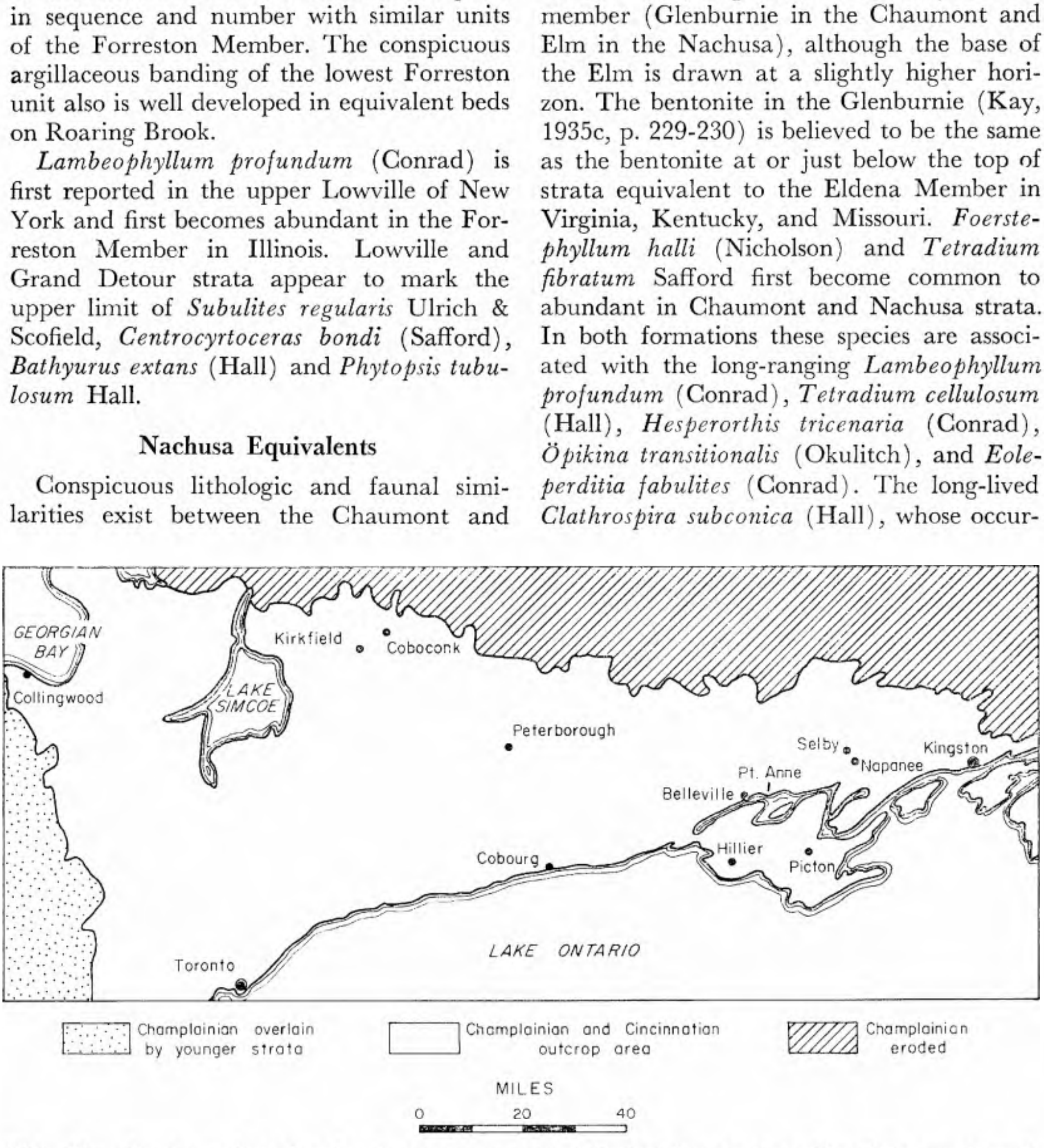


FIG. 31.—Southern Ontario, showing outcrop area of Ordovician strata and localities mentioned. Geologic boundaries from *Geological Map of Province of Ontario*, Ontario Department of Mines.

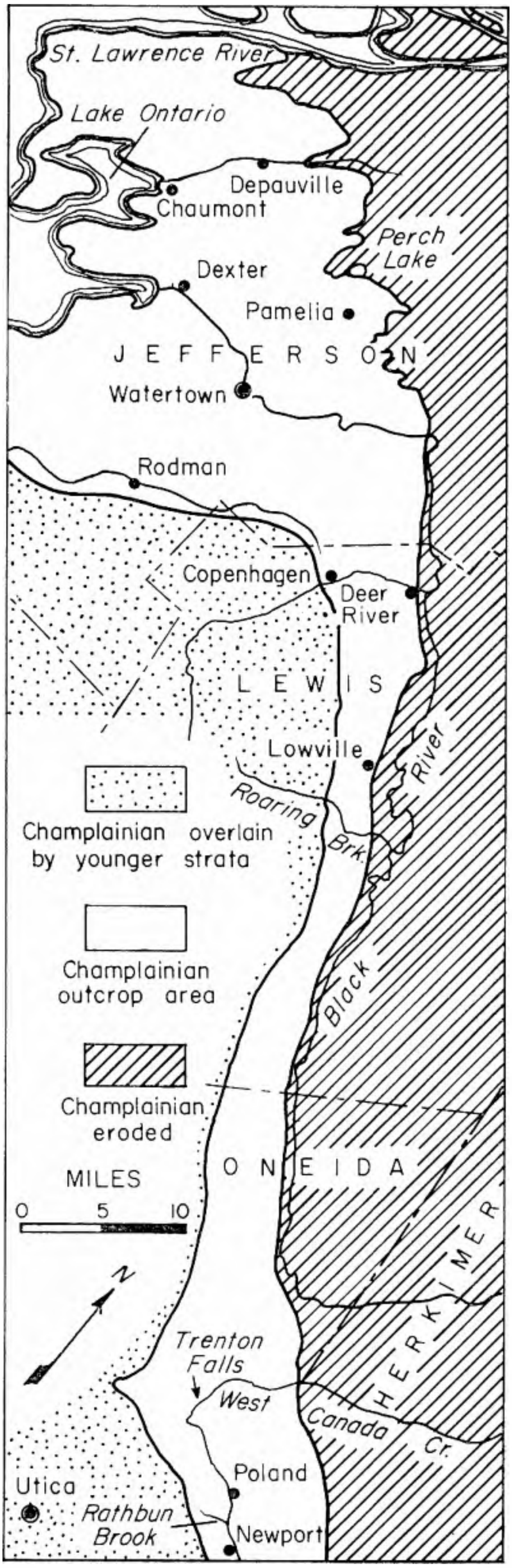


FIG. 32.—Western New York, showing outcrop area of Champlainian strata and localities mentioned. Geologic boundaries from *Geologic Map of New York*, New York State Museum, and from Young (1943).

rence in the Black River strata of New York seems limited to the Leray Member, is most abundant in the Eldena Member in the Mississippi Valley. A strong faunal correlation between Chaumont and Nachusa strata also can be made via the Carters and Tyrone Formations of Tennessee and Kentucky.

At Coboconk, Ontario, the sequence called the Coboconk Limestone underlies Rockland equivalents and has many lithologic and faunal similarities to the Nachusa and Chaumont sequence (see following discussion of Spechts Ferry), supporting the correlations of Okulitch (1939) and Sinclair (1954) rather than Kay (1937, 1942, 1956) and Cooper (1956).

Quimbys Mill Equivalents

Probably because of the unconformity at the top of the Black River Group (Young, 1943, p. 219; Kay, 1948, p. 1411), Quimbys Mill strata seem to be absent in New York exposures. However, in the Canada Cement Company quarry at Point Anne, Hastings County, Ontario, 20 inches of brown, lithographic limestone ("glassrock") with black to brown shale layers, which appears to be a wedge-edge of the Shullsburg Member of the Quimbys Mill Formation, lies between the Chaumont and Rockland Formations.

Trenton Group

In northwestern New York and eastern Ontario the Trenton Group consists, in ascending order, of the Rockland, Hull, Shoreham, Denmark, Cobourg, Collingwood, and Gloucester Formations (Kay, 1948, fig. 2; 1960), but Twenhofel et al. (1954) put the Collingwood and Gloucester Formations in the Utica Shale above the Trenton. We correlate Rockland-Cobourg strata, composed of limestone that is mostly shaly, with the Galena Group of the Mississippi Valley, but believe that the black, brown, and blue shales of the Collingwood and Gloucester Formations belong to the overlying Cincinnatian Series. Twelve Trenton sections were studied between Collingwood, Simcoe County, southern Ontario, and Trenton Falls, Oneida and Herkimer Counties, northwestern New York.

Kay (1953, p. 42; 1956, p. 96) replaced the name Hull (Raymond, 1914) with Kirkfield (Johnston, 1911) on the basis of priority, but Sinclair (1954) believed that the type Kirkfield includes the Rockland. Sinclair's interpretation is supported by our correlations. Cooper (1956, chart 1) accepted Kay's correlation but retained the name Hull. The long use of Hull for the interval between the Rockland and Shoreham would seem to outweigh the 3-year priority of Kirkfield, particularly as Kirkfield would require redefinition.

Kay (1953, p. 43) classified the Rathbun as the upper member of the Shoreham, rather than the basal member of the Denmark. He considered the Shoreham and Denmark as formations (1956), but they are treated as members of the Sherman Fall Formation in other recent reports (Twenhofel et al., 1954; Cooper, 1956).

Spechts Ferry Equivalents

In the Canada Cement Company quarry at Point Anne, 3 miles southeast of Belleville, Hastings County, Ontario, the basal Selby Member of the Rockland Formation, lying 8 feet 4 inches below the quarry rim, is a coarse brown calcarenite 8 feet 9 inches thick, which has blue to brown shale partings, and contains green clay mottlings and fucoidal bands in the lower 17 inches. In lithology it closely resembles the limestones of the Spechts Ferry and Curdsville. About 77 miles northwestward, in the cut along King's Highway 35 at the south edge of Coboconk, Victoria County, Ontario, and in quarries immediately to the west, the Selby is reduced to a 6-inch layer of light gray, fine-grained, thin-bedded limestone with green shale partings, many bryozoans, and a clay parting at the top possibly representing the Hounsfield Bentonite (Kay, 1935c, p. 239-240). The section from the top downward is as follows, with the Illinois nomenclature in parentheses: *Rockland Formation, Napanee (Guttenberg) Member 13′4″ (Glenhaven 9′, Garnavillo 4′4″), Selby (Spechts Ferry) Member 0′6″; Chaumont (Nachusa) Formation 23′2″, Watertown (Everett) Member 7′4″, Glenburnie (Elm) Member 3′6″, Leray (Eldena) Member 12′4″; Lowville Formation (Grand Detour Formation—Forreston Member) 3′*. The type Hounsfield Bentonite found in the lower part of the Selby near Dexter, Jefferson County, New York, is correlated with the bentonite near the base of the Glencoe Member of the Spechts Ferry Formation, which is the most extensive bentonite in the Champlainian Series.

In Illinois *Eridotrypa, Mesotrypa, Prasopora, Dalmanella, Rafinesquina alternata* (Conrad) emend. Salmon, *Sowerbyella, Carinaropsis,* and *Calymene senaria* Hall first appear in Spechts Ferry strata, and in New York they are first encountered in Selby beds. The abundance of *Doleroides ottawanus* Wilson and *Doleroides pervetus* (Conrad) in the Selby Member is paralleled by the profusion of *Doleroides pervetus* and its homeomorph *Pionodema subaequata* (Conrad) in the Spechts Ferry. Bryozoans are abundant in both units.

Guttenberg Equivalents

If the Selby Member is excluded, Kay's correlation of Rockland and Guttenberg ostracode faunas (1934) is supported by similarities in lithology as well as by many species in the megascopic fauna. The upper Rockland Napanee Member consists of brown to blue-gray lithographic, locally oolitic limestone and medium-grained calcarenite with brown shale partings; it grades laterally to dolomite in places, and is purer than adjacent strata. In these features it resembles the Guttenberg Formation. The lower 4 to 5 feet is less calcarenitic, less oolitic, grayer, and more argillaceous than the beds above, though less argillaceous than the Selby Member below, and it weathers gray-white. In these characteristics it is similar to the Garnavillo Member of the Guttenberg in Illinois.

If the Upper Mississippi Valley and New York-Ontario sections are matched as suggested, the ranges of 33 (21 percent) of the species common to both regions lend support to the proposed correlation. This percentage is considerably higher than that obtainable under any other correlation criteria. Twenty-one species (13 percent) are in doubtful category, with ranges that might match if refined. For example, the upper limit of *Receptaculites oweni* Hall in the west is Stewartville. The species occurs in the lower Cobourg (Rust-Steuben) of New York (Kay, 1935b, p. 580), and if it is present in Steuben strata, its upper limit in the two regions would be the same. Forty-seven species (29 percent) are long-ranging forms useless for correlation. Fifty-nine species (37 percent) have ranges in the two regions that definitely do not match. Species with discordant ranges are interpreted mainly as long-ranging forms sensitive to ecologic factors, some of which are not reflected in lithology. Unusually slow migration from the point of origin and destruction of remains by scavenger action or dolomitization may account for a small part of the discordance. The fact that most species with discordant ranges occur higher in the New York-Ontario sequence than in the Mississippi Valley section suggests an eastward migration of optimum environment for marine life during Trentonian time. The fossil ranges that seem to support the suggested correlations are given below. Most of the species involved are bryozoans and brachiopods.

(1) *Ceramoporella interporosa* Ulrich, *Escharopora recta* Hall, *Graptodictya proava* (Eichwald), and *Trematis ottawaensis* Billings first appear in Beecher and upper Hull strata. *Prasopora insularis* Ulrich dies out at the top of the Beecher and upper Hull, although it recurs in the upper Rust of New York. *Hemiarges paulianus* (Clark) is common in the Beecher and upper Hull Members but rare above them.

(2) The upper limit of *Ceramoporella interporosa* Ulrich, *Gyronema percarinatum* (Hall), and *Bollia subaequata* Ulrich seems to be Eagle Point and Shoreham, and *Eridotrypa aedilis minor* (Ulrich) dies out above Eagle Point and Shoreham strata, although it reappears in Rust strata. If these species are confined to the lower Shoreham their upper limit in Minnesota and New York would coincide.

(3) Fairplay and Shoreham strata mark the first reported appearance of *Prasopora selwyni* (Nicholson) and *Modiolopsis mytiloides* Hall, and the last occurrence of *Macronotella rugosa* (Jones). *Prasopora oculata* Foord seems confined to these units in the Mississippi Valley and in New York and Ontario, but it recurs in upper Michigan in strata we refer to the Rivoli. *Subretepora reticulata* (Hall), *Coeloclema trentonense* (Ulrich), *Eridotrypa exigua* Ulrich, *Mitoclema mundulum* Ulrich, *Nematopora ovalis* Ulrich, *Pachydictya pumile* Ulrich, and *Rhinidictya mutabilis* (Ulrich) all disappear above the Fairplay and the Shoreham, although they reappear in Rust or higher beds in New York. Evidently the unfavorable environment that caused their permanent disappearance from the Mississippi Valley simultaneously caused their temporary disappearance in the east. Although the recorded distribution of six other species also indicates Shoreham and Eagle Point-Fairplay equivalency, these species are not included in the category of fossils supporting the proposed correlation because the accuracy of their reported ranges is doubtful.

(4) *Rafinesquina deltoidea* (Conrad) first becomes abundant in Wyota and upper Rust beds.

(5) Dunleith and Rust strata constitute the upper limit of *Prasopora conoidea* Ulrich, *Glyptorthis bellarugosa* (Conrad), *Ambonychia bellistriata* Hall, *Hormotoma salteri* Ulrich, and *Actinoceras bigsbyi* Bronn. A considerable faunal change, probably caused by the conspicuous lithologic change, takes place at both the Rust-Steuben and Dunleith-Wise Lake contacts; the change in the west is of greater magnitude.

(6) The Wise Lake-Dubuque and Steuben-Hillier contacts mark the upper limit of *Ischadites iowensis* (Owen), *Strophomena trentonensis* Winchell & Schuchert, and *Vellamo trentonensis* Raymond, and the lower limit of *Rafinesquina sardesoni* Salmon.

(7) *Conularia trentonensis* Hall, *Rafinesquina camerata* (Conrad), *Rafinesquina trentonensis* (Conrad), *Dalmanella rogata* (Sardeson), *Rhynchotrema increbescens* (Hall), *Sowerbyella punctostriata* (Mather), *Strophomena trilobata* (Owen), and *Calliops callicephala* (Hall) do not occur above Dubuque and Hillier beds.

Comparable correlations between lower Prosser and upper Hull-Shoreham strata were made by Kay (1935a, p. 290-293; 1935b, p. 577-583), but his correlations of the higher Galena and Trenton beds differ from those suggested here (fig. 30). Kay considered the Stewartville and upper Cobourg (Hillier) Members equivalent because certain gastropods, such as *Fusispira subfusiformis* (Hall), *Hormotoma trentonensis* Ulrich & Scofield, and *Trochonema umbilicatum* (Hall) are most abundant in these strata and had not been reported from the Dubuque Formation. It is now known that these and some other elements of the Stewartville gastropod fauna have long ranges in both east and west and extend into lower Dubuque strata. The abundance of these species in Stewartville and Hillier strata is attributed to the occurrence of optimum environment at different periods of Trenton time in the two regions. The easternmost extent of the typical Stewartville *Receptaculites-Maclurites* fauna is in the limestone constituting the upper 40 feet of the Liskeard Formation at Lake Timiskaming, on the Ontario-Quebec boundary (Hume, 1925, p. 23-25). Some ecologic barrier probably prevented migration of this fauna into southern Ontario and New York. However, the Liskeard contains *Strophomena trentonensis* Winchell & Schuchert, reported only from pre-Hillier (pre-Dubuque) beds in New York.

Champlainian-Cincinnatian Boundary

The position of the Champlainian-Cincinnatian boundary in New York and Ontario and its correlation with the Mississippi Valley has been a controversial problem for many years. In Ontario the Cobourg Limestone of Trentonian age (uppermost Champlainian) is succeeded in ascending order by the Collingwood Shale, the Gloucester Shale, and the Dundas Shale. The Collingwood and Gloucester Formations have been correlated with the Deer River and Atwater Creek Shales, respectively, of New York (Ruedemann, 1925, p. 64) and the upper part of the Gloucester Shale has been correlated with the Blue Mountain Shale of Georgian Bay, Ontario (Parks, 1928, p. 60). Later workers are in agreement with these correlations (Sproule, 1936, p. 100; Kay, 1937, pl. 4; Caley, 1947, p. 163). The Dundas Shale is of undoubted Cincinnatian age, but the Collingwood and Gloucester Formations have been assigned by some authors to the Champlainian, by others to the Cincinnatian, or have been divided between the two series. Kay (1937, p. 283-286; 1956, p. 95; 1960, p. 31) and the Canadian Geological Survey (Caley, 1947, p. 163) have classified the Collingwood and Gloucester as Trentonian. Ulrich (1913, p. 662, pl. facing p. 666), Bassler (1915, pl. 2), Raymond (1921, p. 1), and Parks (1928, p. 60) considered the Collingwood Formation to be Trentonian and the Gloucester to be Cincinnatian. Twenhofel et al. (1954) assigned the two units to a questionable zone between the two series. Foerste (1924, p. 50-58), Ruedemann (1925, p. 147-149), Goldring (1931, p. 289), and Sproule (1936, p. 98-101) regarded both the Collingwood and Gloucester or equivalent formations as Cincinnatian. The last interpretation is accepted for the following reasons:

(1) A regional unconformity of considerable magnitude separates the Collingwood-Deer River Shale from the underlying Cobourg or older formations (Sproule, 1936, p. 98-101; Kay, 1937, pl. 4). No comparable break in sedimentation occurs in the interval between this unconformity and the Cincinnatian Dundas Formation (Parks, 1928, p. 58-59; Kay, 1937, p. 287).

(2) A major lithologic change from limestone to shale takes place at this unconformity, but no sharp or important lithologic changes occur at the contacts between the Collingwood, Gloucester, and Dundas Formations where the complete sequence is present.

(3) Of 127 species reported from the Collingwood-Deer River Shales, 24 (19 percent) are Cincinnatian or most closely related to Cincinnatian forms, 41 (32 percent) are Trentonian, 33 (25 percent) range from Trentonian into Cincinnatian, and 30 (24 percent) are known only from strata of Collingwood-Gloucester age. If the last two groups are eliminated as not bearing on this point, the pertinent part of the Collingwood-Deer River fauna is 37 percent Cincinnatian and 63 percent Trentonian. The appearance of the Cincinnatian species indicates a major faunal break at the Cobourg-Collingwood contact.

Of 63 species reported from the Blue Mountain, Gloucester, and Atwater Creek Shales, only 5 (8 percent) are Trentonian, 30 (48 percent) are Cincinnatian, 11 (17 percent) range from Trentonian, into Cincinnatian, and 17 (27 percent) are confined to strata of Collingwood-Gloucester age. If we eliminate the last two groups, the pertinent part of the Gloucester fauna is 14 percent Trentonian and 86 percent Cincinnatian. Thus a second sharp faunal change takes place at the Collingwood-Gloucester contact, but because it is not accompanied by a significant break in sedimentation or lithology, it is regarded as less important than the Cobourg-Collingwood change.

The contact between the Gloucester Shale and the Cincinnatian Dundas Shale is drawn at the highest occurrence of the trilobite *Triarthrus* (Parks, 1928, p. 59), but it is not marked by any major faunal break.

(4) Regional relations also suggest that the Collingwood and Gloucester Shales are of Cincinnatian age. The Collingwood Shale is black to brown. The Gloucester Shale is black to brown at the base, but grades upward through brown shale into blue shale at the top. Similar black to brown shales are found in the Fulton Formation of Ohio, which is the basal unit of the Cincinnatian Series in its type area (Stout, 1941, p. 28-29, table facing p. 46; Weiss and Norman, 1960), in the Bill's Creek Formation of upper Michigan (Hussey, 1926, p. 121-131; Ladd, 1929, p. 362-367), and in the Elgin Member of the Scales Formation at the base of the Maquoketa Group in the Mississippi Valley (Trowbridge and Shaw, 1916, p. 62-64; Ladd, 1929, p. 342-343; DuBois, 1945, p. 7-14). More or less faunal similarity also is evident between these formations, although the Bill's Creek and Scales Formations probably include strata of Maysvillian age.

A prominent diastem at the Dubuque-Maquoketa contact in Minnesota and adjacent states merges southward into an unconformity in southwestern Illinois and eastern Missouri, along which Dubuque and Wise Lake strata have been removed. This break is regarded as the western continuation of the unconformity at the base of the Collingwood Formation.

Regional lithologic and physical evidence, therefore, as well as considerable faunal data, indicate correlation of the Collingwood and at least the lower and middle portions of the Gloucester with the basal part of the Cincinnatian Series. Hussey (1926, p. 131) and Ladd (1929, p. 366-367) have pointed out the lithologic and faunal similarities between the Bill's Creek and Elgin, and Hussey (1950, p. 23; 1952, p. 15) has suggested possible correlation of the Collingwood and basal Bill's Creek strata.

Although correlation of the Collingwood Shale with the Dubuque Dolomite of the Mississippi Valley has been suggested (Kay, 1935b, p. 580-586), the evidence cited above, together with the conformable, gradational nature of the Stewartville-Dubuque contact, strongly suggests that the Dubuque is pre-Collingwood. Dubuque-Collingwood faunal similarities are attributable to the large relict Trentonian element in the Collingwood fauna and to the early appearance of certain Cincinnatian species in the Dubuque. Dubuque strata exposed near Escanaba, Michigan (see Michigan section), are less shaly than in the type area and show no sign of lateral gradation into Collingwood lithology, although the abundance of Collingwood debris in glacial drift 85 miles northeastward (Ruedemann and Ehlers, 1924) indicates that typical Collingwood strata probably were deposited in upper Michigan.

ARKANSAS

The Champlainian sequence of Arkansas was not studied but tentative correlations with the Illinois section (fig. 27) are suggested on the basis of published data.

NORTHERN ARKANSAS

Everton Group

In northern Arkansas (Croneis, 1930, p. 23-33; Giles, 1930; McKnight, 1935, p. 26-58), the Everton Group, absent to 400 feet thick, lies unconformably between dolomites of Canadian age and the St. Peter Sandstone and appears to consist of the following units in ascending order: (1) Sneeds Dolomite, absent to 50 feet thick, confined to the Harrison Quadrangle, (2) Kings River Sandstone, absent to 40 feet thick, found only west of the Yellville Quadrangle, (3) unnamed sandy dolomite and limestone with sandstone interbeds, absent to 150 feet thick, (4) Newton Sandstone, absent to 150 feet thick, found only west of the Yellville Quadrangle, (5) Calico Rock Sandstone, absent to 150 feet thick, found only east of the Yellville Quadrangle and probably equivalent to the Newton Sandstone, (6) unnamed sandy dolomite with sandstone interbeds, about 100 feet thick, and (7) Jasper Limestone, up to 50 feet thick.

The sandstones of the Everton, like those of the St. Peter, are all well sorted and wedge out eastward or westward. In the Eureka Springs-Harrison folio (Purdue and Miser, 1916, p. 5-8) the Newton Sandstone was called "St. Peter" and the lower part of unit (5) was called "Joachim" (McKnight, 1935, p. 38-41). The complex character of the Everton units along the Buffalo River in Newton County, Arkansas, has been described by Glick and Frezon (1953).

Except in the Jasper Limestone, fossils are rare and poorly preserved. The fauna of the Jasper includes *Girvanella, Whiteavesia?, Raphistomina, Plectoceras* aff. *P. jason* (Billings) and *Leperditia,* an association suggestive of middle Chazyan (Crown Point) age. As described in the Kentucky section, subsurface tracing through Kentucky and Tennessee also points to correlation of the Everton with the strata recognized as Chazyan in southwestern Virginia. The correlation of the Everton subdivisions of Illinois and Missouri with those of Arkansas is unknown.

Farther east in Arkansas the Smithville and Black Rock Formations have been considered latest Canadian because of the stratigraphic relations and fauna reported by Ulrich (Ulrich and Cooper, 1938, p. 34-44; Ulrich et al., 1942, 1943, 1944). However, Decker (1944, p. 379) found graptolites suggesting that the Smithville is Canadian and the Black Rock is Chazyan, and McKnight (1935, p. 28) discovered evidence east of the Yellville Quadrangle indicating that the Smithville and Black Rock may be facies of the Everton.

Ancell and Platteville Groups

In the Yellville Quadrangle (McKnight, 1935, p. 42-47) the St. Peter Sandstone, 0 to 136 feet thick, is divisible into lower and upper members, each composed of white to buff, fine- to medium-grained, massive sandstone, and a middle member consisting of argillaceous, greenish gray sandstone, impure dolomite, and greenish to bluish gray shale. The middle member is thought to reflect the beginning of southward gradation of the St. Peter into dolomite. About 90 miles southwestward, in a well near Ozark, Franklin County, sandstone correlated with the St. Peter (Lantz, 1950, p. 9, 24-25) is dolomite cemented. In the Yellville area the St. Peter rests unconformably on Everton strata, and lies conformably below the Joachim Dolomite. In some areas the St. Peter is overlain unconformably by the Plattin Limestone (Maher and Lantz, 1952).

Near Yellville the strata called Joachim consist of sandy, mostly dark gray, fine-grained, thick-bedded dolomite, are up to 60 feet thick, and are conformable on the St. Peter but unconformable beneath the Plattin (McKnight, 1935, p. 47-48). The stratigraphic relations and color suggest correlation with the Dutchtown Formation of Missouri and Illinois. About 65 miles southeastward, in the Batesville area (Miser, 1922, p. 17-18), the strata called Joachim reach 150 feet in thickness, consist mainly of sandy, buff, fine-grained dolomite, and probably are equivalent to Dutchtown, Joachim, and Pecatonica strata.

The Plattin Limestone is absent in places in northern Arkansas, but attains a thickness of 240 feet near Batesville. In the Yellville Quadrangle a 1-foot bed of blue-green shale 35 to 40 feet above the base of the Plattin probably represents the Establishment Shale of Missouri. The interval between the base of the Plattin and this shale is about 15 feet greater than the same interval in Missouri, suggesting that a complete Plattin sequence is present rather than just the uppermost Plattin (Twenhofel et al., 1954). The common occurrence of dolomite at the base of the Plattin (McKnight, 1935, p. 50) suggests that Pecatonica strata have been included in the Plattin in places.

Galena and Maquoketa Groups

Whether the basal Galena (Decorah Subgroup) is represented in northern Arkansas is unknown. The very sandy limestone at the base of the Kimmswick in the Batesville area (Miser, 1922, p. 19-22) may be of Buckhorn age. The Kimmswick Limestone reaches a maximum thickness of 55 feet, but it is locally missing. The fact that it is cherty, especially in the upper part, suggests that it is equivalent to the Dunleith Formation.

The succeeding "Fernvale" Limestone, equivalent to the Cape Limestone of Missouri and Illinois, is absent in some places but is as much as 125 feet thick in the Batesville area. It rests unconformably on the Kimmswick Formation and in Newton County, northwestern Arkansas, overlaps beds as old as Everton (Croneis, 1930, p. 32). The "Fernvale" Limestone is overlain unconformably by the Cason (lower Maquoketa) Shale with a phosphatic ferruginous conglomerate at the base (Croneis, 1930, p. 32) that probably is equivalent to the phosphatic depauperate bed at the base of the Elgin Shale.

OUACHITA REGION

In the Ouachita geosyncline of south central Arkansas and southeastern Oklahoma (Honess, 1923; Miser and Purdue, 1929; Croneis, 1930; Hendricks et al., 1937) a thick sequence of Ordovician sediments, which probably has been thrust northward from its original place of deposition, bears little resemblance to the Ordovician sequences in either the Arbuckle or Ozark regions. The Ordovician succession in ascending order is: Crystal Mountain Sandstone, 500′-850′; Mazarn Shale, 1000′+; Blakely Sandstone 0′-500′; Womble Shale, 250′-1000′; Bigfork Chert 700′-800′; Polk Creek Shale, 0′-200′. The faunas (Miser and Purdue, 1929; Decker 1935, 1936a, 1936b, 1943, 1952) are almost wholly graptolites, except for *Hindia* and *Cryptolithus tesselatus* Green in the Bigfork.

On the basis of stratigraphic relations and fauna, the Crystal Mountain–Blakely sequence has been classed as Canadian. The same criteria, combined with certain lithologic similarities, suggest to us that (1) the Womble Shale ranges from Chazyan to Trentonian in age, and the upper part is a facies of Member 4 (Wengerd, 1948) of the Viola (Galena) Limestone in central southern Oklahoma, (2) the Bigfork Chert is equivalent to the remainder of the Viola Limestone and the Cape (Fernvale) Limestone, probably including beds as old as Sherwood, and (3) the Polk Creek Shale corresponds to the Cason Shale of northern Arkansas, the Maquoketa Shale of the Upper Mississippi Valley, and the Sylvan Shale of central southern Oklahoma.

COLORADO

Ordovician exposures were examined along Trout Creek, Chaffee County (Vanderwilt, 1948, p. 111) and near Canon City, Fremont County (Maher, 1950, Sec. D, p. 6-9), and a detailed section was made of the Harding and Fremont Formations in the latter area, particularly in Priest Canyon. Correlation of the Colorado sequence with that in Illinois and other states is shown in figure 27.

The fauna of the Ordovician formations has been described by Walcott (1892, p. 159-163), although some species almost certainly were misidentified and others are not recognizable in terms of modern nomenclature. Walcott's list has been supplemented by others (Kirk, 1930, p. 463; Johnson, 1945, p. 26-27) and by the writers. Although fossil molds are scattered throughout the Fremont Dolomite, it is extremely difficult to recover them in identifiable condition because the rock is hard, tough, and massive.

Canadian Series

The oldest of the Ordovician formations, the Manitou Dolomite, is buff to red, mostly fine grained, and thin- to thick-bedded dolomite and limestone, and is partly cherty, glauconitic, oolitic, and shaly. The maximum thickness is about 300 feet at Trout Creek, excluding the thin basal beds differentiated as the Ute Pass Dolomite of Cambrian age (Maher, 1950). The Manitou Formation is similar in lithology to strata in the Canadian (Lower Ordovician) Series of the Mississippi Valley, and contains a Canadian fauna (Johnson, 1945, p. 18; Maher, 1950).

Champlainian Series

The Champlainian Series is represented by the Harding Sandstone and by the lower and middle portions of the overlying Fremont Dolomite.

The Harding Sandstone has a maximum thickness of about 145 feet and rests uncomformably on Manitou or older rocks. In the Canon City area the lower 41 feet consists of white to red or purple, very fine-grained, thin- to thick-bedded sandstone which is partly calcareous, argillaceous, silty, and shaly. Several layers contain coarse sand grains and have bimodal (Glenwood-type) texture. The beds contain fish plates, *Lingula,* and abundant worm-borings resembling *Scolithus.* It is probable that this lower member of the Harding represents a near-shore, brackish-water deposit equivalent to Glenwood or to St. Peter and Glenwood strata in the Mississippi Valley.

The middle 45 feet of the Harding consists principally of green, maroon, and brown, partly sandy, waxy, laminated shale, although 17 feet of very fine-grained sandstone is present 12 feet from the top, and two thin beds of impure limestone occur in the basal 3 feet. The shales contain *Lingula, Ctenodonta, Endodesma, Whitella, Vanuxemia rotundata* (Hall), *Helicotoma, Lophospira, Michelinoceras multicameratum* (Emmons), *Cyrtoceras,* and *Eoleperditia fabulites* (Conrad). The species of *Vanuxemia* and *Michelinoceras* appear limited to the Platteville Group. *Eoleperditia fabulites* is most abundant in Platteville strata, and the remaining species seem most closely related to Platteville forms. However, the same shale member in the Black Hills of South Dakota contains scolecodonts known chiefly from the basal Spechts Ferry Formation of the Galena Group (Furnish et al., 1936, p. 1332-1334). Therefore, although most of the middle member of the Harding probably is of Platteville age, the uppermost beds may be of Spechts Ferry age.

The uppermost 56 feet of the Harding Formation near Canon City is composed of sandstone like that of the lower member, but it generally does not have bimodal texture and is interbedded with dark red shale. *Scolithus* borings, *Lingula,* and fish plates are the only megascopic fossils found, although a conodont faunule has been reported 15 feet below the top (Branson and Mehl, 1933a, p. 22-23; Stauffer, 1935a, p. 128-131; Stauffer and Thiel, 1941, p. 238-245). The conodonts seem older than most Platteville-Decorah forms and most closely related to Glenwood and lower Joachim species. Nevertheless the stratigraphic position of the upper Harding Member suggests a Decorah age. Although the top of the Harding is marked by a sharp contact, the relations do not appear to be unconformable, as Kirk had reported them (1930, p. 463).

On the basis of a conodont fauna compiled for the entire Harding Formation, Sweet (1954) correlated the Harding with the Glenwood of Minnesota and the Plattin of Missouri, which are not equivalent but are both Blackriveran in age.

In sharp contrast to the uncertainties of correlation in the Harding Formation, the overlying Fremont Dolomite shows amazingly close lithologic and faunal similarities to Galena and Maquoketa strata in the Mississippi Valley, 800 miles eastward. In Priest Canyon the basal 104 feet appears to correspond to the post-St. James (post-Ion) portion of the Dunleith Formation. It shows an alternating sequence of pure and argillaceous units and has a prominent chert zone at the top. Beds thought to range from Beecher to lower Rivoli in age are calcarenitic, are partly coarse grained and crinoidal, and strongly resemble the Kimmswick of the Mississippi Valley. The suggested correlation with the sequence of Dunleith members from the top downward follows:

Wyota Member
- Dolomite, argillaceous, cherty 1′
- Dolomite, mostly pure, slightly argillaceous in middle, cherty towards top, 12′10″

Wall Member
- Dolomite, argillaceous, 1′6″
- Dolomite, pure, 5′10″

Sherwood Member
- Dolomite, argillaceous, with mud flakes and red shale partings, 7′
- Dolomite, pure, with a few red shale lenses, 10′8″

Rivoli and Mortimer Members
- Dolomite, argillaceous, with mud flakes and red shale partings, 3′6″
- Dolomite and calcarenite, pure, with some red shale lenses, 18′6″

Fairplay Member
- Dolomite and calcarenite, argillaceous, with numerous red shale lenses, 6′
- Dolomite and calcarenite, pure, with some red shale lenses and many *Receptaculites,* 12′

Eagle Point Member
- Dolomite, pure, with scattered *Receptaculites,* 15′

Beecher Member
- Dolomite, moderately argillaceous and silty, with red shale lenses, 5′
- Dolomite, pure, fossiliferous, with a few red shale lenses, 5′

Significant fossils in the strata equivalent to the Beecher Member are *Receptaculites oweni* Hall, *Streptelasma corniculum* (Hall), *Echinosphaerites, Glyptocrinus, Plaesiomys germana* (Winchell & Schuchert), *Platystrophia trentonensis* McEwan, *Rafinesquina trentonensis* (Conrad) emend. Salmon, *Dalmanella rogata* (Sardeson), *Strophomena filitexta* (Hall), *Ambonychia bellistriata* Hall, *Sinuites cancellatus* (Hall), and *Illaenus americanus* (Billings). Several of these species and a few other common Trentonian forms occur sparsely in the beds correlated with the remainder of the Dunleith Formation.

Conformably succeeding the Dunleith equivalents is 72 feet of exceedingly pure, massive, fine-grained, vuggy dolomite with a honeycombed weathered face, which seems identical with the Wise Lake Formation.

The fauna of this unit includes *Receptaculites oweni* (Hall), *Halysites gracilis* (Hall), *Saffordophyllum franklini* (Salter), *Streptelasma corniculum* (Hall), *Hormotoma trentonensis* Ulrich & Scofield, and *Maclurites cuneata* (Whitfield).

The overlying 50 feet of dolomite is believed to correspond to the Dubuque Formation. It is partly argillaceous, thin to thick bedded, and contains some layers of red shale or red shaly dolomite. *Receptaculites oweni* extends into these strata to form the highest known occurrence of this species.

Sweet (1954) assigns both of the above units to his "massive member" and correlates them with Cincinnatian beds below the Richmondian.

Cincinnatian Series

The uppermost 78 feet of the Fremont appears to be of Cincinnatian age and begins with a 7-foot bed of brown to purple shale with thin chert and dolomite bands. Most of the dolomite above this shale is distinctly more argillaceous and shaly and thinner bedded than the dolomite of Galena (Trentonian) age.

The Cincinnatian fauna is chiefly confined to the 20 feet of dolomite overlying the basal shale of the series and is abundant only in the lower 2½ feet of this dolomite. The fauna includes *Saffordophyllum franklini* (Salter) *Streptelasma rusticum* (Billings), *Lepidocyclus capax* (Conrad), *Plaesiomys bellistriatus* Wang, *Rafinesquina nasuta* (Conrad), *Strophomena nutans* (Meek), *Strophomena planoconvexa* Hall, *Stropho-*

mena planumbona (Hall), *Thaerodonta* Wang, *Colpomya pusilla* Foerste, *Pterinea*, and *Ceraurinus icarus* (Billings). The basal shale resembles the Elgin Shale, the basal unit of the Maquoketa Group in much of the Mississippi Valley, and probably is of Edenian age. The fossils in the overlying dolomite suggest that strata of both Maysvillian and Richmondian age are present.

The upper shale and dolomite have been named the Priest Canyon Member by Sweet (1954) and correlated with the Richmondian Maquoketa Shale. We also correlate the Priest Canyon with the Maquoketa but believe that it includes Edenian and Maysvillian as well as Richmondian equivalents. The presence of early Cincinnatian strata in the Priest Canyon favors Champlainian rather than Cincinnatian age for the underlying part of the Fremont.

The above evidence opposes assignment of the Harding to a short interval of late Blackriveran or early Trentonian age (Johnson, 1945, p. 22) or early Trentonian (Twenhofel et al., 1954), and the Fremont entirely to a late Cincinnatian Richmondian age (Johnson, 1945; Twenhofel et al., 1954).

The Cincinnatian strata are succeeded unconformably by the unfossiliferous Williams Canyon Dolomite, which may be of Silurian, Devonian, or Mississippian age (Oborne, *in* Vanderwilt, 1948, p. 34-35; Maher, 1950, table 1).

INDIANA

Champlainian strata are exposed in Indiana only in a small area near Kentland, Newton County, in the northwestern part of the state and along the Ohio River in southeastern Indiana. However, they have been studied in subsurface throughout the state and, as recently described and classified by Gutstadt (1958b), consist of the following:

- Mohawkian Series
  - Trenton Limestone
  - Black River Limestone
- Chazyan Series
  - Joachim Dolomite
  - St. Peter Sandstone

The St. Peter Sandstone is thin and locally absent in the eastern part of the state but thickens to 135 feet in the western part. It grades eastward to interbedded sandstone and dolomite and in the eastern part of the state is not readily separable from the Joachim. The Joachim is as much as 70 feet thick.

The Black River Limestone of Indiana consists largely of lithographic and very fine-grained limestone and thickens from less than 100 feet in the northwestern part of the state to over 600 feet in the southwest. The Black River Limestone appears to be essentially equivalent to the Platteville Group in Illinois, although there is some possibility that the basal formation of the Platteville, the Pecatonica, has been included with the Joachim in Indiana.

The Black River Limestone of Indiana, by our correlation, is not entirely equivalent to the Black River Group of New York, which includes strata equivalent to the Joachim and St. Peter. As correlated by Twenhofel et al. (1954) and Cooper (1956), it also includes Trentonian strata. It is lithologically similar only to upper Black River strata in the type area.

The Trenton Limestone of Indiana consists of limestone and dolomite thinning from 200 or 225 feet thick in the northwestern part of the state to absent in the southeast where Cincinnatian strata locally rest directly on the Black River Limestone. Although the formation is almost entirely dolomite in the northwest, the dolomite facies thins southeastward (Gutstadt, 1958b, fig. 3). The base of the dolomite rises southward, transecting the formation, so that south of the central part of Indiana the formation is entirely limestone. This change in facies extends westward across Illinois and Iowa and eastward into Ohio.

In the extreme southeastern part of the state, interbedded limestone and shale at the position of the Trenton Limestone are referred to the Lexington-Cynthiana Formation, also of Trentonian age, but these strata may include some beds equivalent to the Eden Shale. The Trenton Limestone of Indiana is equivalent to the Galena Group in

Illinois and probably largely to the Kimmswick Subgroup. By our correlation it is also Trentonian in age, but both Twenhofel et al. (1954) and Cooper (1956) place the base of the Trentonian lower in the sequence.

KENTLAND DISTURBANCE

Just east of Kentland, in northwestern Indiana, quarrying has exposed an intensely disturbed Champlainian sequence that has been the subject of detailed stratigraphic and faunal studies by Shrock (1937) and Shrock and Raasch (1937). The extreme deformation and localization has led many geologists to favor a cryptovolcanic origin (Bucher, 1936, p. 1072-1074). More recently evidence has been accumulating to support origin by meteorite impact (Dietz, 1960; Cohen et al., 1961).

The sequence at Kentland is notable in the following respects: (1) The interval between the lower Tonti Member of the St. Peter Sandstone and Platteville strata is occupied in ascending order by the Starved Rock Sandstone Member of the St. Peter and by the Joachim Formation of Missouri and southern Illinois, rather than by the Glenwood Formation of northern Illinois. (2) The Platteville strata consist chiefly of brown, lithographic, relatively pure limestone that in gross lithology has a greater resemblance to the Platteville of southeastern Missouri than to the blue-gray, more dolomitic and shaly Platteville of northern Illinois. (3) Galena strata are intermediate in character to the northern Illinois dolomite facies and the southern Illinois limestone facies. (4) The basal Cincinnatian shales are blacker and less calcareous than the equivalent Elgin Shale of northeastern Illinois, but seem identical with the Fulton Shale of Ohio (Stout, p. 28-29, table facing p. 46).

Subsurface data indicate that the dividing line between the northern Illinois and Missouri facies in the Ancell and Platteville Groups trends northeastward from Adams County, western Illinois, to a point a short distance northwest of Kentland.

The correlation with the Kentland succession is as follows:

Illinois	Kentland (Shrock, 1937)	Thickness (ft.)	(in.)
Cincinnatian Series			
Maquoketa Group	*Division 11 (Utica or Richmond)*		
Scales Formation			
Elgin Member	Unit 29	70	
Champlainian Series			
Galena Group	*Division 10 (Galena)*		
Dubuque Formation	Absent		
Wise Lake Formation			
Stewartville Member	Absent		
Sinsinawa Member	Unexposed, 1937	32	
Dunleith Formation			
Wyota Member	Faulted out		
Wall Member	Faulted out		
Sherwood Member	Unexposed, 1937	15	4
Rivoli Member, Mortimer Member	Unexposed, 1937	26	3
Fairplay Member	Unit 28	16	3
Eagle Point Member, Beecher Member	Unit 28	29	6
St. James Member, Buckhorn Member	Unit 28	31	6
Guttenberg Formation	Absent		
Kings Lake Formation	Absent		
Spechts Ferry Formation	Absent		
Platteville Group			
Quimbys Mill Formation			
Strawbridge Member	Unit 28	10	10
Shullsburg Member	Unit 28; basal 4′		

(Continued)

Illinois	Kentland (Shrock, 1937)	Thickness (ft., in.)	
	Division 9 (Black River-Trenton)		
Shullsburg Member (cont.)	Unit 27	19	
	Unit 26; upper 1′		
Hazel Green Member	Unit 26; middle 2′	2	
Nachusa Formation			
Everett Member	Unit 26; basal 1′	27	5
	Unit 25		
Elm Member	Unit 24		
	Unit 23; upper 16″	2	10
Eldena Member	Unit 23; remainder	18	8
Grand Detour Formation	*Division 8 (Black River)*		
Forreston Member	Unit 22	10	
	Unit 21	6+	
	Unit 20; upper part	22	6+
Victory Member	Unit 20	4	
Hely Member	Unit 20	2	4
Clement Member	Unit 20		4
Stillman Member	Unit 20; basal part	1	8
	Unit 19; upper part	10	
Walgreen Member	Unit 19; lower part	2	
Dement Member	Absent		
Mifflin Formation			
Briton Member	Unit 18	7	6
	Unit 17	4	6
Hazelwood Member	Unit 16	4	6
Establishment Member	Unit 15	9	
Brickeys Member	Absent		
Blomeyer Member	Absent		
Pecatonica Formation	*Division 7 (Carters)*		
Oglesby Member	Unit 14	8	
	Unit 13		7
	Unit 12	2	6
	Division 6 (Platteville)		
Medusa Member	Unit 11	6	
New Glarus Member	Unit 10; upper part	7	7
Dane Member	Unit 10; lower part	22	5
	Division 5 (Platteville)		
Chana Member	Unit 9	20	
	Division 4 (Platteville)		
Hennepin Member	Unit 8	5	
Ancell Group			
Joachim Formation			
Pure member	Unit 7	3	
	Unit 64	8	
Argillaceous member	Unit 5	20+	
Pure member	Unexposed, 1937	33+	
Dutchtown Formation	Absent		
	Division 3 (Glenwood)		
St. Peter Formation			
Starved Rock Member	Unit 4	15+	
	Division 2 (St. Peter)		
Tonti Member	Unit 3	30+	
	Division 1 (Prairie du Chien)		
Kress Member	Unit 2	2	
Canadian Series			
Prairie du Chien Group			
Shakopee Formation	Unit 1	6+	

Blackriveran Stage

Ancell Group Equivalents

Unit 2 of Shrock's sequence at Kentland is residual clay derived from pre-St. Peter weathering of the Shakopee Dolomite and partly reworked by the St. Peter sea. In Illinois this clay is classified as the Kress Member of the St. Peter. Unit 4 is correlated with the Starved Rock Sandstone Member of the St. Peter because it is coarser grained than the underlying part of the St. Peter and lies between St. Peter and Joachim strata. It is unusual in that it contains argillaceous mottlings and fossils (Shrock, 1937, p. 484-485). The fossils represent genera and species found also in the higher Platteville Group. The only other known occurrence of Starved Rock fossils is in southeastern Missouri.

The Starved Rock at Kentland is overlain by 33 feet of brown, fine grained, dense, hard, massive, pure limestone that in places has closely spaced carbonaceous streaks and red-brown shale films. This unit, unexposed at the time of Shrock's study in 1937, probably represents one of the comparatively pure members in the Joachim Formation. It is overlain, across a fault contact, by at least 20 feet of badly sheared, white, chalky dolomite in thin regular beds with occasional blue-gray shale partings. This unit (5) seems equivalent to one of the argillaceous Joachim members. The overlying strata (Units 6 and 7) consist of relatively pure, brown dolomite showing the disturbed dark blue-gray argillaceous and carbonaceous laminae and penetration marks so typical of certain Joachim strata in Missouri. Units 6 and 7 appear to correspond to a second and higher pure member in the Joachim Formation.

Platteville Group Equivalents

The Hennepin Member (Unit 8) at the base of the Pecatonica Formation at Kentland consists of dolomitic, mainly medium-grained, well sorted sandstone that has local dolomite interbeds and green shale partings towards the base. The Dane Member exhibits conspicuous argillaceous bands next to the bedding surfaces, but the overlying New Glarus Member is pure, vuggy, and thicker bedded. At Shrock's section 2 in the McCray quarry, now quarried away, Dane strata seem to have been thrust into or above the stratigraphic position of the New Glarus Member. The Oglesby Member (Units 12-14) is much finer grained calcarenite than that in the type exposure, resembles the member in Missouri and Kentucky, and locally grades to calcarenitic lithographic limestones. A thin shaly bed (Unit 13) near the middle of the member is regionally persistent. *Cryptophragmus antiquatus* Raymond is common in the Oglesby at Kentland. It also occurs in equivalent strata in Kentucky, but there has a longer range.

Because of the absence of the Blomeyer and Brickeys Members, the thin-bedded shaly strata of the Establishment Member (Unit 15) form the base of the Mifflin Formation. The relatively pure Hazelwood Member (Unit 16) has red fucoids in the upper part and a corrosion surface at the top, just like the member in the Dixon and Forreston areas of northern Illinois. The succeeding 4½ feet of nearly white, lithographic, finely brecciated limestone (Unit 17) is considered a local facies at the base of the Briton Member, and is overlain by typical thin-bedded shaly Briton strata (Unit 18).

The basal strata of the Grand Detour Formation at Kentland are medium bedded and moderately shaly and seem to belong to the Walgreen Member. The Stillman Member is typically dolomite mottled, cherty, fucoidal, and thick bedded. A single thin bed of limestone at the top of the Stillman is calcarenitic in the lower half and probably represents the Clement Member. Hely equivalents are weakly argillaceous and medium bedded. The Victory Member consists of nearly white, lithographic, massive limestone strikingly similar to the type Victory of southwestern Illinois. In the Means quarry Clement and Hely strata have been faulted out, so that the Victory Member rests directly on the Stillman. The Forreston Member consists of dolomite-mottled, mostly cherty, partly fucoidal, thin- to medium-bedded limestone containing many calcarenite streaks and having thin brown-red shale partings in some intervals. As in the type area it shows an alternating sequence of relatively pure and argillaceous or shaly units. An additional 17½ feet of Forreston strata belonging to Unit 20 has been exposed by quarrying since Shrock's study.

Most of the Nachusa and Quimbys Mill Formations at Kentland are so similar to the same beds from central Illinois to southeastern Missouri that summary descriptions are unnecessary. Above the smooth-faced bed at the top of the Nachusa, 14 inches thick at Kentland, is a 10-inch shaly bed that probably is the same as the basal shaly unit of the Hazel Green Member of the Quimbys Mill Formation near St. Louis, Missouri. The presence of ***Foerstephyllum halli*** (Nicholson) in the Shullsburg Member at Kentland is, aside from a reported occurrence in the Spechts Ferry of Minnesota (Stauffer and Thiel, 1941, p. 238), the only known occurrence of that fossil in post-Nachusa strata in the Mississippi Valley. In contrast with the underlying Ancell-Platteville beds, which are the most similar to the Missouri facies, the Strawbridge Member is a medium-grained porous dolomite with a prominent chert band at the top, like the Strawbridge in much of central northern Illinois, and in gross lithology resembles the overlying Galena Dolomite. As in Illinois, silicified colonies of *Homotrypa minnesotensis* Ulrich are common in upper Shullsburg and in Strawbridge strata.

Trentonian Stage

Galena Group Equivalents

Strata belonging to the Decorah Subgroup are missing at Kentland, as in much of eastern Illinois. Overlying the Quimbys Mill Formation is about 119 feet of dolomitic limestone divisible into alternating pure and argillaceous or shaly units that seem to match part of the member sequence within the Dunleith Formation. Some members have not been completely differentiated, and the two upper members appear to be absent because of faulting. Subsurface data from nearby in Illinois suggest that the missing interval is about 25 feet thick. The limestone is mostly gray to brown, buff weathering, fine to medium grained, dense, and thick bedded to locally thin bedded, but many thin layers of light colored, coarse-grained calcarenite are present. Bands of nodular chert are present 8½ feet above the base of the Buckhorn, at the top of the St. James, and in a 4½-foot layer 2 feet above the base of the Fairplay. Chert also is common in parts of Illinois at about these positions. We saw no identifiable fossils.

The uppermost 32 feet of the Galena sequence consists of dolomitic limestone that is purer and finer grained than the underlying Dunleith strata, lacks calcarenite and chert, has only occasional shale films, is uniformly thick bedded when fresh, and weathers to a finely vuggy face. Layers of gray lithographic limestone are present in places. Crinoidal debris is common in some beds, but no other identifiable fossils were found. This unit is correlated tentatively with the Sinsinawa Member of the Wise Lake Formation.

Stewartville and Dubuque strata appear to be missing. The regional unconformity between the Champlainian and Cincinnatian Series is shown by the ferruginous, pyritic, pitted, and undulating upper surface of the Sinsinawa Limestone.

Cincinnatian Series

Maquoketa Group Equivalents

Above the Galena Group at Kentland is 70 feet of shale that is mainly dark brown and dark gray to black, moderately to slightly calcareous, and strongly laminated. It contains thin layers of gray to buff, argillaceous, dolomitic, chalky limestone, and in places has a phosphatized depauperate fauna in a 7-inch limestone bed near the base, but otherwise seems unfossiliferous. We consider this unit to be equivalent to the Elgin Shale of Illinois and the Fulton Shale of Ohio.

KANSAS AND NORTHWESTERN MISSOURI

Blackriveran Stage

Ancell Group Equivalents

McQueen and Greene (1938, p. 42-43, pls. VI, VII) have traced the "St. Peter Sandstone" from St. Louis through northwestern Missouri to southeastern Nebraska, and Lee (1943, p. 27-30) and Leatherock (1945, p. 10-12, pl. 1) have carried this unit westward into north-central Kansas (fig. 27). The sandstone rests unconformably on rocks ranging from Everton (?) to Precambrian in age (Moore et al., 1951). In much of the region it is divisible into three irregularly distributed zones, described by Leatherock. The lower and upper zones consist of fine to coarse, rounded, frosted grains, but the middle zone is composed of green sandy shale or comparatively fine and angular sand and locally is glauconitic. These zones probably are equivalent to a similar sequence in western Illinois where the upper sandstone is believed to be the Starved Rock Sandstone Member of the St. Peter, the middle zone is the Kingdom Sandstone Member which farther north is the basal member of the Glenwood Formation, and the lower sandstone is the Tonti Sandstone Member of the St. Peter Sandstone. Though the St. Peter in northwestern Missouri normally ranges from 10 to 105 feet thick, it reaches 403 feet thick in Johnson County, eastern Kansas (McQueen and Greene, 1938, pp. 42-43), probably filling a pre-St. Peter depression like those of northern Illinois.

Platteville Group Equivalents

Between strata that probably are equivalent to the St. Peter Sandstone and others probably equivalent to the Dunleith Dolomite in Kansas and northwestern Missouri is a series of dolomites, limestones, shales, and sandstones, absent to 105 feet thick, which is believed to range in age from Harmony Hill (upper Glenwood) to St. James (lower Dunleith). The units within this series seem to undergo major facies changes in short distances and are very irregularly distributed because of numerous minor unconformities or diastems. These beds apparently have not been treated consistently in respect to nomenclature and boundaries, and they still pose many unsolved problems.

From southeastern to northwestern Missouri, the thick Dutchtown to Quimbys Mill sequence thins out and is overlapped by Decorah and Dunleith strata, which then rest unconformably on St. Peter Sandstone (McQueen and Greene, 1938, pls. VI, VII; Grohskopf, 1948, fig. 3).

In northeastern Kansas, Lee (1943, p. 32-35) applied the name Decorah to all strata between the St. Peter Sandstone and the Kimmswick Limestone although he recognized that beds of Platteville age probably extended southward into the area from southeastern Nebraska. A widely distributed black to red-brown shale near the base of the Decorah probably is the Guttenberg, and its position suggests that the Platteville thins out southward against the Chautauqua Arch. The top of the Decorah has been drawn at the top of the Ion in the northernmost part of the area and probably at the top of Spechts Ferry or older shales in the southern part. Lee noted that the top of the Decorah as drawn might be a facies line and not a time line.

In north-central Kansas Leatherock (1945, p. 12-14) applied the name "Platteville" to all beds between the St. Peter Sandstone and the Kimmswick Limestone, noting that the upper part was equivalent to the Decorah of Missouri. It is probable that a persistent dolomite from 5 to 35 feet thick at the base of the "Platteville" corresponds to the widespread Pecatonica Formation of the Mississippi Valley. A green shale unit found below this dolomite in some wells was correlated with the middle zone of the St. Peter but may be Harmony Hill (upper Glenwood). In southernmost Nebraska the top of the Platteville has seemingly been drawn at the top of the St. James (upper Ion), there composed of sandstone and shale, but in the southern part of north-central Kansas the top of the Platteville apparently has been placed at the top of Spechts Ferry or older shales.

Trentonian Stage

Galena Group Equivalents

A detailed study by Taylor (1947) of the Viola (Kimmswick) Limestone of central Kansas may provide a key to Decorah correlation. The shale underlying the Viola contains Trentonian fossils (Udden, 1926, p. 635) and we provisionally correlate it with the Spechts Ferry Shale of the Mississippi Valley. The basal Viola unit (Zone 6), 0 to 20 feet thick, consists of tan, lithographic to fine-grained, sandy limestone containing light brown chert with abundant dark brown flecks. This unit probably is equivalent to the tan, lithographic limestone and brown-flecked chert of the Guttenberg Formation in Illinois and adjacent states. The presence of sand agrees with its abundance in western Iowa (Agnew, 1955, p. 1725) and may be related to the postulated westward gradation of the Guttenberg into the upper part of the Harding Sandstone of Colorado.

The lower part of the overlying unit (Zone 5) is sandy, gray flecked, and partly fine grained, and locally contains layers of bentonite or bentonitic shale. All of these features are diagnostic characteristics of the Buckhorn and St. James Members of the Dunleith Formation in the Mississippi Valley. It appears that the Ion Shale of southeastern Nebraska grades southward into Kimmswick-like limestone in Kansas. A similar facies change occurs from north to south in the Mississippi Valley. The base of the limestone facies apparently has been followed in drawing the top of "Decorah-Platteville" strata in Kansas. In part of the area this procedure accounts for the reported unconformity at the base of the Kimmswick.

In central Kansas, Viola Zone 5 of Taylor, absent to 50 feet thick, is overlain by Zone 4, absent to 100 feet thick, and the combined zones are thought to correspond to the Dunleith Formation. The upper part of Zone 5, above the Ion equivalents, is noncherty, corresponds approximately to the 70 to 90 feet of noncherty dolomite of the Dunleith above Ion strata in Nebraska, and may range from Beecher to early Sherwood in age. Zone 4 is distinguished mainly by dark-flecked chert and is correlated tentatively with upper Sherwood, Wall, and Wyota strata. The zone has been divided into four subzones, based chiefly on differences in quantity and type of chert. The absence of chert above the top of Dunleith equivalents is a conspicuous marker, as elsewhere in the central United States.

Zone 3, overlying Zone 4, consists of relatively pure, medium-grained to lithographic, chert-free limestone that is as much as 40 feet thick in some places but absent in others. In stratigraphic position and major lithologic features this unit corresponds to the pure chert-free Wise Lake Formation in the limestone facies of the Mississippi Valley.

Zone 2, absent to 25 feet thick, consists of cherty, lithographic to very fine-grained limestone that is correlated tentatively with the Dubuque Formation. The decrease in grain size from Zone 2 matches the decrease in grain size from Wise Lake to type Dubuque strata and is related to increase in clay content. Though chert is not found in Dubuque exposures in the Mississippi Valley, it is present in Dubuque strata in the subsurface of western Illinois. Chert is a common constituent in the purer off-shore facies of many shaly units.

Zone 1, at the top of the Viola, consists of gray coarse-grained limestone that appears identical to the Cape ("Fernvale") Limestone of Illinois and Missouri, and is overlain unconformably by the Sylvan (Maquoketa) Shale.

Similar but less detailed zonations of the Kimmswick Limestone have been observed in northeastern Kansas and northern Missouri, and approximate correlations with the Mississippi Valley have been suggested (McQueen and Greene, 1938, p. 40-41; Lee, 1943, p. 37-40; Taylor, 1947, p. 1251-1252).

It seems significant that the distribution of Zones 1 through 4 of the Viola in central Kansas (Taylor, 1947, fig. 12) parallels the distribution of Dunleith-Cape strata in western Illinois and eastern Missouri. Dunleith strata (Zone 4) have the greatest southward extent and Dubuque beds (Zone 2) the least. The Cape Formation (Zone 1) overlaps Dubuque and Wise Lake strata southward and locally rests on Dunleith equivalents.

KENTUCKY CLASSIFICATION [1] Grp	Formation	Member	Composite Section [2]	CORRELATION WITH ILLINOIS Member	Formation	Grp	CORRELATION WITH NEW YORK AND ONTARIO Member	Fm.	Stg	OTHER COR. Kay, 1948 Fm.	Stg	Twenhofel et al., 1954 Fm.	Stg
	Cynthiana	Nicholas	58'		Cape ?	MAQUOKETA →	(hatched)	(hatched)	Edenian	Glou-cester; Colling-wood		Upper Utica	?
	Cynthiana	Bromley	53'6"		Dubuque	GALENA	Hillier	Cobourg	Trentonian	Cobourg	Trentonian	Upper Utica	?
LEXINGTON	Upper Lexington	Devils Hollow	31'8" (10', 11')	Stewart-ville	Wise Lake	GALENA	Steuben	Cobourg	Trentonian	Denmark	Trentonian	Upper Utica / Cobourg	? / Trentonian
LEXINGTON	Middle Lexington	Woodburn	10'8"; 28'4" (? ? ?)	Sinsinawa	Wise Lake	GALENA	Steuben	Cobourg	Trentonian	Denmark	Trentonian	Cobourg	Trentonian
LEXINGTON	Middle Lexington	Brannon	15'6"	Wyota	Dunleith	GALENA	Rust	Cobourg	Trentonian	Denmark	Trentonian	Cobourg	Trentonian
LEXINGTON	Lower Lexington	Benson	20'0"	Wall	Dunleith	GALENA	Rust	Cobourg	Trentonian	Denmark	Trentonian	Cobourg	Trentonian
LEXINGTON	Lower Lexington	Benson	37'4"	Sherwood	Dunleith	GALENA	Russia	Denmark	Trentonian	Denmark	Trentonian	Denmark	Trentonian
LEXINGTON	Lower Lexington	Jessa-mine	30'7"	Rivoli	Dunleith	GALENA	Poland	Denmark	Trentonian	Denmark	Trentonian	Denmark	Trentonian
LEXINGTON	Lower Lexington	Jessa-mine	12'5"	Mortimer	Dunleith	GALENA	Rathbun	Denmark	Trentonian	Denmark	Trentonian	Shore-ham	Trentonian
LEXINGTON	Lower Lexington	Jessa-mine	15'0"	Fairplay	Dunleith	GALENA		Shore-ham	Trentonian	Denmark	Trentonian	Shore-ham	Trentonian
LEXINGTON	Lower Lexington	Jessa-mine	11'0"	Eagle Point	Dunleith	GALENA		Shore-ham	Trentonian	Denmark	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Jessa-mine	4'3"	Beecher	Dunleith	GALENA		Hull	Trentonian	Denmark	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Jessa-mine	12'4"	St. James	Dunleith	GALENA		Hull	Trentonian	Denmark	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Jessa-mine	11'8"	Buckhorn	Dunleith	GALENA		Hull	Trentonian	Denmark	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Logana	10'8"	Glenhaven	Gutten-berg	GALENA	Napanee	Rockland	Trentonian	Shoreham	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Logana	3'2"	Garnavillo	Gutten-berg	GALENA	Napanee	Rockland	Trentonian	Shoreham	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Logana	17'2"		Kings Lake	GALENA		Rockland	Trentonian	Shoreham	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Curds-ville	9'8"	Glencoe	Spechts Ferry	GALENA	Selby	Rockland	Trentonian	Shoreham	Trentonian	Kirkfield (Hull)	Trentonian
LEXINGTON	Lower Lexington	Curds-ville	13'8"	Castle-wood	Spechts Ferry	GALENA	Selby	Rockland	Trentonian	Hull ↓	Trentonian	Kirkfield (Hull)	Trentonian

(Continued) KENTUCKY CLASSIFICATION			Composite Section	CORRELATION WITH ILLINOIS			CORRELATION WITH NEW YORK AND ONTARIO			OTHER COR. Kay, 1948		Twenhofel et al., 1954	
Grp	Formation	Member		Member	Formation	Grp	Member	Fm	Stg	Fm	Stg	Fm	Stg
HIGH BRIDGE	Tyrone	Upper Tyrone	8'5"	Strawbridge	Quimbys Mill	PLATTEVILLE			Blackriveran		Trentonian	Rockland	Trentonian
			10'0"	Shullsburg									
			9'10"	Hazel Green									
		Lower Tyrone	16'5"	Everett	Nachusa		Watertown	Chaumont		Kirkfield (Hull)			
			3'5"	Elm			Glenburnie						
			10'7"	Eldena			Leray						
			32'7"	Forreston	Grand Detour			Lowville					
	Oregon		4'4"	Victory						Upper Rockland			
			9'0"	Hely									
			2'8"	Clement									
			9'1"	Stillman									
	Camp Nelson		10'1"	Walgreen						Chaumont	Bolarian	Chaumont	Blackriver
			5'0"	Dement									
			18'0"	Briton	Mifflin								
			8'6"	Hazelwood									
			3'0"	Establishment									
			1'9"	Brickeys						Lowville		Lowville	
			5'0"	Blomeyer									
			13'1"	Oglesby	Pecatonica								
			22'3"	Medusa									
			30'	New Glarus						Pamelia		Pamelia	

FIG. 33.—Correlation of the exposed part of the Champlainian Series in central Kentucky with Illinois. Footnotes on next page. (Blackriver should be Black River.)

Cincinnatian Series

The Sylvan (Maquoketa) Shale of Kansas, commonly from 50 to 100 feet thick, is divisible into gray-brown or black, silty, nondolomitic shale overlain by gray, dolomitic, cherty shale (Taylor, 1947). Comparison with the Maquoketa sequence of the Mississippi Valley suggests that the lower shale is of Scales (Edenian-Maysvillian) age and that the upper shale is of Fort Atkinson (Richmondian) age.

KENTUCKY

The lithologic sequence within the Champlainian Series of Kentucky (fig. 33) closely matches the sequence in Illinois. The series is exposed chiefly on the Cincinnati Arch in the central northern portion of the state and has been divided into the Highbridge and Lexington Limestones (McFarlan and White, 1948). The Highbridge Limestone consists, in ascending order, of the Camp Nelson, Oregon, and Tyrone Formations. It is equivalent mainly to the Platteville Group of the Mississippi Valley, although strata of Ancell age probably are included in the lower part of the Camp Nelson Limestone. Highbridge strata were studied in bluffs on the north and south sides of the Kentucky River at Camp Nelson, Garrand County, and in the Builders' Supply Company quarry and nearby exposures at Frankfort, Franklin County (fig. 34).

The Lexington Limestone, essentially corresponding to the Galena Group of the Mississippi Valley, is composed, in ascending order, of the Curdsville, Logana, Jessamine, Benson, Brannon, Woodburn, Devils Hollow, and Cynthiana Limestones of member or formational rank. The Nicholas Limestone constitutes a member near the top of the Cynthiana Formation. Lexington strata were studied in two highway cuts in or near Frankfort, in a ravine between the Old Crow and Old Taylor distilleries, Woodford County, and in highway cuts at Clay's Ferry, Madison County.

Blackriveran Stage

At Camp Nelson the section along U. S. Highway 27 in the south river bluff is complicated by the Kentucky River fault zone, but the section just east of the bridge in the north river bluff seems undisturbed. The lowest exposed beds, found in the south bluff, are about 45 feet above high water level. The highest exposed beds, at the top of the south bluff, are in the middle of the Logana Limestone. The Highbridge Limestone here and at Frankfort is mainly brown and lithographic. The lithologic sequence shows striking similarities to the Platteville sequence in adjacent states, particularly in southeastern Missouri.

Pecatonica Equivalents

Although about 300 feet of Camp Nelson Limestone is exposed along the Kentucky River (McFarland and White, 1948, p. 1628), only the upper 116 feet is exposed in the sections at Camp Nelson. The underlying part of the formation probably includes beds ranging from Dutchtown (Murfreesboro) to

Footnotes for figure 33.

[1]/McFarlan and White, 1948

[2]/Section from base of Eden to top of Stewartville equivalents taken from cut on south side of road beneath south end of Clays Ferry Memorial Bridge, where U. S. Highway 25 crosses the Kentucky River, Madison County, Kentucky. Section from top of Stewartville to base of Sherwood equivalents taken from cut on north side of U. S. Highway 421, beginning 0.35 mile west of Frankfort city limit and continuing west to top of north valley wall of Benson Creek, Franklin County. The upper division of the Devils Hollow is projected from the type section 2.5 miles westward. Section from base of the Sherwood to the base of the Spechts Ferry equivalents taken from cuts on west and south sides of U. S. Highways 60 and 460, 0.2 mile due west of the state Capitol in Frankfort. The section from top of Quimbys Mill to base of Victory and from base of Oglesby to base of New Glarus equivalents taken from bluff and cut along south and west sides of U. S. Highway 27, in south valley wall of Kentucky River, just south of Camp Nelson, Garrard County. Section from base of Victory to base of Oglesby taken from bluff on north side of Kentucky River, just east of bridge on U. S. Highway 27 at Camp Nelson, and just west of Texas Company oil storage tanks.

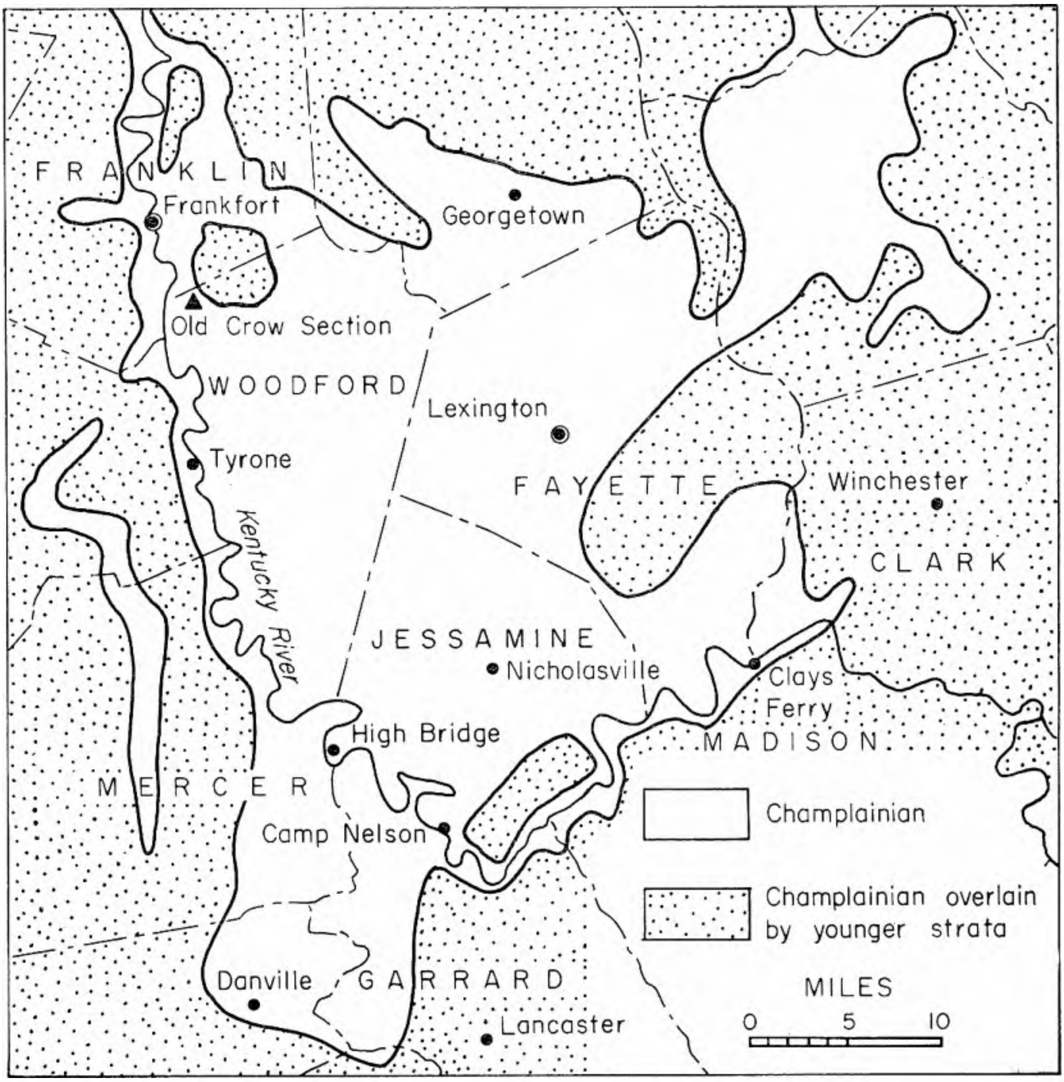


FIG. 34.—Central Kentucky, showing principal outcrop area of Champlainian strata and localities mentioned. Geologic boundaries generalized from *Geologic Map of Kentucky*, Kentucky Geological Survey.

Pecatonica (Ridley) in age. We correlated the lower 65 feet of the section exposed at Camp Nelson with the upper part of the Pecatonica Formation. The basal 30 feet, probably equivalent to the New Glarus Member, consists of dolomite-mottled, fucoidal, massive, pure limestone alternating with 4- to 13-foot units of gray, partly white, thick-bedded, pure limestone. The overlying 22 feet of slightly argillaceous, dolomite-mottled, very fucoidal, massive limestone represents the Medusa Member. At the top of the strata equivalent to the Pecatonica is 13 feet of gray to white, very fine-grained, strongly laminated calcarenite comparable to the Oglesby Member, which has a thin shaly unit in the middle, as in Indiana, Illinois, and Missouri.

Mifflin Equivalents

In the lower part of the strata equivalent to the Mifflin Formation, two thin-bedded shaly units, believed to correspond to the Blomeyer and Establishment Members, are separated by a 21-inch bed of brown, lithographic, massive limestone that appears to be a greatly thinned representative of the Brickeys Member. The fucoidal massive limestone equivalent to the Hazelwood is a conspicuous unit, and, as in northern Illinois, has a smooth, pitted, corrosion surface at the top. The Briton Member is represented by lithographic, thin-bedded, shaly, fossiliferous limestone 18 feet thick. A 68-inch, relatively thick-bedded and nonshaly unit in the middle matches a thin massive unit in the middle of the member in the Mississippi Valley.

Grand Detour Equivalents

Basal Grand Detour units in the Camp Nelson Formation consist of brown, massive, pure limestone like the Dement Member, overlain by lithographic shaly strata very similar to the Walgreen Member. The succeeding fucoidal, thick-bedded, pure limestone seems typical of the Stillman Member and has a 15-inch ledge of gray calcarenite at the base, which also occurs at this point in the stratigraphic sequence in Missouri, Tennessee, and southwestern Virginia. The base of the Stillman seems to correspond to the Camp Nelson-Oregon contact. A gray, calcarenitic, medium-bedded, pure unit above the Stillman is correlated with the Clement Member, which is largely calcarenite, and is overlain by brown to white, lithographic, shaly limestone strongly resembling the Hely Member. Above the Hely equivalent is a white, lithographic, medium-bedded to massive, pure limestone that appears identical in lithology and stratigraphic position to the Victory Member.

The remaining Grand Detour beds consist of brown lithographic limestone showing a cyclic alternation of shaly and massive units, which in character and number match the cycles of the Forreston Member. They also exhibit the argillaceous, carbonaceous, dolomitic banding and the calcarenite streaks characteristic of the Forreston. Huffman (1945, p. 167) drew the Oregon-Tyrone contact at or near a bentonite (T-1 of Tennessee) 9 feet 4 inches above the Victory-Forreston contact, although McFarlan and White (1948, p. 1632) place the Tyrone base at a horizon corresponding to the Victory-Forreston contact. Elsewhere in central Kentucky, Oregon (Stillman-Victory) strata are dominantly dolomitic, gray to buff, and granular (Huffman, 1945, p. 167); McFarlan and White, 1948, p. 1629; Freeman, 1949, p. 1669).

Nachusa Equivalents

The upper 30 feet of the lower division of the Tyrone consists chiefly of brown, dolomite-mottled, lithographic, thick-bedded limestone that is relatively pure, fucoidal, and cherty, and that in lithology, sequence of members, fauna, and stratigraphic position perfectly matches the Nachusa Formation of Illinois (fig. 28). As in Missouri and Illinois, the Eldena Member is somewhat more argillaceous, thinner bedded, and less fucoidal than the Everett, and is separated from it by the thin, dark gray, shaly Elm Member. A bentonite (T-2 of Tennessee) lying 4 feet above the base of the Everett at Camp Nelson occurs in Missouri, Tennessee, and southwestern Virginia (fig. 38).

Quimbys Mill Equivalents

The upper division of the Tyrone is the Quimbys Mill Formation of the Mississippi Valley. The basal Hazel Green Member is represented by white, lithographic, mainly pure, thick-bedded limestone with a 3-foot 7-inch bentonite (T-3 of Tennessee) at the base. The overlying argillaceous greenish buff limestone, equivalent to the Shullsburg, shows the transition from the shaly limestone of the Mississippi Valley to the calcareous mudrock of the Eggleston of Virginia. Beds corresponding to the Strawbridge Member resemble the Hazel Green, but are partly dolomitic, cherty, and fucoidal, and locally are brown instead of white.

Platteville Faunas and Correlations

Although the Highbridge and Platteville Groups have many faunal elements in common, most of the species ranges are too long or too imperfectly known to be of value in correlation. *Foerstephyllum halli* (Nicholson), virtually an index fossil of the Nachusa Formation in the Mississippi Valley, is common in the equivalent portion of the Tyrone. *Öpikina transitionalis* (Okulitch) first becomes common to abundant in Nachusa and corresponding Tyrone strata, and *Actinoceras tenuifilum* (Hall) seems to appear first at this horizon in both Illinois and Kentucky.

Lichenaria carterensis (Safford) has not been found above lower Tyrone and Nachusa strata. The common association of the long-ranging *Lambeophyllum profundum* (Conrad), *Hesperorthis tricenaria* (Conrad), *Öpikina transitionalis* (Okulitch), and *Eoleperditia fabulites* (Conrad) also is characteristic of lower Tyrone and Nachusa strata. This association persists into upper Tyrone and Quimbys Mill beds, were *Strophomena auburnensis* Fenton becomes common.

Huffman (1945, p. 170-174) has correlated the upper part of the Camp Nelson Limestone with the Witten Limestone of Virginia because both contain a zone of *Cryptophragmus antiquatus* Raymond. However, lithologic correlations indicate that the *Cryptophragmus*-bearing Witten strata are of early Grand Detour age and that the *Cryptophragmus*-bearing Camp Nelson strata range from upper New Glarus to lower Briton in age. The long range of *Cryptophragmus* has been pointed out (Cooper and Cooper, 1946, p. 58-59). Huffman also considered the Oregon to be equivalent to the Moccasin, whereas our matching of the sequences suggests that the Oregon equals upper Witten and lower Moccasin (Stillman-Victory Members).

Because the Moccasin and Eggleston Formations of southwestern Virginia were believed to grade laterally into the Nealmont Formation of central Pennsylvania (Huffman, 1945, p. 171; Kay, 1948, p. 1412; Prouty, 1948, p. 1615) and because the Nealmont has been correlated with the Rockland and Hull Formations of New York and Ontario (Kay, 1944, p. 107-109, fig. 2), the base of the Trenton in Kentucky has been drawn at the base of the Oregon Formation (Huffman, 1945, fig. 9; Kay, 1948, fig. 2). Probable errors in this correlation are discussed under *Pennsylvania*. Lithologic tracing from Kentucky to New York via Illinois, northern Michigan, and Ontario indicates that the Oregon-Tyrone sequence is of upper Lowville-Chaumont age, a conclusion strongly supported by the faunal evidence.

Disagreement in correlations in this area is a major factor in the divergence of correlations farther south and east in Tennessee and Virginia. Although Raymond (1922), Bassler (1932) and others, largely on the basis of fossils, placed the Blackriveran-Trentonian contact at the top of the Tyrone, the recent trend has been to include both the Tyrone and Oregon in the Trentonian (Kay, 1948, p. 1402; Twenhofel et al., 1954) (fig. 29). B. N. Cooper (*in* Twenhofel et al., 1954, p. 285) stated that a Trenton age for the Tyrone is indicated in spite of the obvious fact that the Tyrone resembles the Lowville Limestone in both facies and fossils. G. A. Cooper (1956) drew the base of the Trentonian (as used by Twenhofel et al., not as redefined by G. A. Cooper) even lower, near the base of the exposed Camp Nelson.

Trentonian Stage

Spechts Ferry Equivalents

At Camp Nelson, Frankfort, and the Old Crow distillery, the basal Trentonian Curdsville Formation consists of argillaceous, greenish gray to brown calcarenite with subordinate layers of lithographic limestone, ranges from thick bedded to shaly, and contains some shale interbeds. It closely resembles the Spechts Ferry Formation of the Mississippi Valley, and the siliceous, pink, orange-buff, or green, laminated, hard bentonite at its base seems identical with the bentonite at or near the base of the Spechts Ferry. At Frankfort the Curdsville shows the following ascending sequence, which is remarkably similar to the type Castlewood sequence: *Castlewood Member—bentonite, 4″; limestone, shaly, 2′; limestone, thin bedded, 1′3″; limestone, massive, cherty, 7′6″. Glencoe Member—bentonite, ½″; shale, gray-blue to* *buff, 1′8″; coquina, thin bedded, 10″; limestone, shaly, 1′6″; limestone and coquina, thin bedded, 4′2″; limestone and shale interbedded, 6′.*

At Highbridge, Mercer County, Kentucky, the basal bentonite of the Curdsville (Bassler, 1932, p. 64-65) has been mistaken for a lower bentonite (T-4) occurring in the Upper Carters Limestone (Quimbys Mill) in Tennessee (Wilson, 1949, p. 63).

In addition to lithologic evidence for Curdsville-Spechts Ferry equivalence, *Atactoporella insueta* Ulrich, *Dekayella praenuntia* Ulrich, *Stictoporella angularis* Ulrich, and other species seem confined to Curdsville and Spechts Ferry strata, and *Aulopora trentonensis* Winchell & Schuchert and *Subretepora reticulata* (Hall) first appear in these formations.

The Curdsville, like the Spechts Ferry, rests unconformably on Black River strata (Miller, 1919, p. 23-24). The local "welded contact" between the Tyrone and the Curdsville, described by Miller (1919, fig. 6), is the contact between the basal lithographic limestone of the Spechts Ferry and overlying Spechts Ferry calcarenites. The contact is well exposed in the Old Crow section, 40 inches above the Tyrone-Curdsville contact. The unconformity at the base of the Curdsville has been questioned by Huffman (1945, p. 168) under the mistaken impression that the bentonite between the Tyrone and the Curdsville is of Tyrone age, whereas it actually represents initial Curdsville sedimentation.

Kings Lake Equivalents

The lower part of the Logana Formation, 14 to 18 feet thick, is composed of about equal proportions of argillaceous silty limestone or calcarenite and very silty brown shale, in thin, regular, interbedded layers. At Camp Nelson a 6-inch bed of shale, probably bentonitic, occurs at the base, and a thin bentonite (T-5 of Tennessee, V-11 of Virginia) is present 6 feet above the base. The lower Logana is equivalent, lithologically and faunally, to the Kings Lake Formation. It is particularly well exposed in both of the Frankfort roadcut sections.

Guttenberg Equivalents

The remainder of the Logana is correlated with the Guttenberg Formation. The basal portion, just above the Kings Lake representatives, consists of about 3 feet of moderately argillaceous, thick-bedded calcarenite containing red-brown shale partings, phosphatic nodules locally at the base, and a profusion of *Dalmanella fertilis* Ulrich. A clay that probably represents a bentonite is present at the top of the unit in the Frankfort capitol section. This calcarenite probably corresponds to the relatively argillaceous and thick-bedded Garnavillo Member of the Mississippi Valley, which has the same stratigraphic position and phosphatic pellets at the base and a bentonite at the top.

The higher Logana strata are made up of brown, whitish-weathering, somewhat purer, lithographic limestone, brown calcarenite, and red-brown shale in thin, regular, interbedded layers. These beds have a striking resemblance to the Glenhaven Member of Illinois and adjacent states. *Trematis ottawaensis* Billings, *Ctenodonta socialis* Ulrich, *Archinacella simulatrix* Ulrich & Scofield, and *Liospira micula* (Hall) seem to appear first in Guttenberg and upper Logana strata. *Rafinesquina trentonensis* (Conrad) emend. Salmon, first becomes common in this interval, and *Sowerbyella curdsvillensis* (Foerste) is abundant in both formations.

Because a number of cystoids and crinoids are common to the Curdsville and Hull (Kirkfield) Formations (Bassler, 1932, p. 72-73; Wilson, 1946, p. 3-5) and because *Cryptolithus tesselatus* Green occurs in the Logana (Raymond, 1922, p. 573) and first becomes abundant in the basal Shoreham (Kay, 1937, p. 264-265), the Curdsville and the Logana Formations have long been correlated with the Hull and Shoreham Limestones, respectively, of New York and Ontario (Kay, 1948, p. 1412, fig. 2). However, several of the echinoderm genera appear first in Spechts Ferry strata, and although *Cryptolithus tesselatus* Green has been said to appear first in the Shoreham, White (1896) reported it from the Hull at Rathbun Brook, Oneida County, New York.

In view of other strong lithologic and faunal evidence for correlating Curdsville and Logana beds with the Spechts Ferry-Guttenberg sequence, it is believed that the Curdsville echinoderm-*Cryptolithus* fauna originated in the middle west in Spechts Ferry time, but because of ecologic conditions did not reach the eastern region until Hull (Buckhorn-Beecher) or later time. A number of other species limited to Platteville or Decorah strata in the west are reported only from much higher Trentonian beds in the east.

Dunleith Equivalents

Correlation of the post-Guttenberg portion of the Trenton sequence in Kentucky with the Galena Group in the Mississippi Valley is rendered difficult by the great increase of shale in the Kentucky beds, and by the fact that the faunas seem to have only a few long-ranging species in common. Preliminary studies strongly suggest that some differences in the faunas result from assignment of different names to the same species. Nevertheless, certain striking similarities in lithologic sequence and fossils are apparent.

Strata ranging from the Jessamine to the Devils Hollow (McFarlan and White, 1948, p. 1634-1640) are well exposed in roadcuts in and near Frankfort (fig. 2) and in a small shallow ravine cutting the north valley wall of Glenns Creek between the Old Crow and the Old Taylor distilleries, Woodford County, about 3½ miles southeast of Frankfort. The latter section, located 0.15 mile west of the westernmost Old Taylor warehouse and identified only by a small waterfall and by a drain-pipe passing beneath the road, is a substitute for the original Old Crow section half a mile westward (Miller, 1913, p. 321), which has been practically destroyed by weathering and slumping. A second section covering the same stratigraphic interval is well exposed along the road leading northeastward, half a mile east-southeast of Taylorton, Woodford County.

The lower 24 to 26 feet of the Jessamine consists of blue-gray calcarenite and subordinate amounts of argillaceous lithographic limestone in thin to thick irregular beds separated by greenish gray shale partings. *Dalmanella* is abundant in the lower half and common in the upper half, and *Prasopora simulatrix* Ulrich is abundant in the upper 2 feet. In both lithology and fauna this unit closely parallels Buckhorn-St. James (Ion) strata. The faunal zonation and the fact that the upper half is thicker bedded and less shaly suggests that the upper beds represent the St. James Member of Illinois. As in the St. James type area, the *Prasopora* Zone at the top occurs in a relatively thin unit that is more shaly than the beds below.

The overlying middle unit of the Jessamine, 30 to 32 feet thick, is composed dominantly of medium- to thick-bedded nonshaly calcarenite with some limestone, which probably corresponds to the Beecher-Fairplay sequence of Illinois. An 8- to 11-foot, partly shaly zone beginning from 4 to 9 feet above the base of the middle unit of the Jessamine may be Eagle Point.

The remainder of the Jessamine, 25 to 29 feet thick in the exposures examined, and the lower 11 to 13 feet of the Benson consist of shaly lithographic limestone and shale with subordinate interbedded ledges of massive calcarenite. A local contorted and brecciated zone is at the top. The lower 12½ feet of this Jessamine-Benson shaly unit constitutes a well defined cycle, possibly representing the Mortimer Member. The remaining and most shaly portion of the unit is tentatively correlated with the Rivoli Member. Like that member it marks the peak of argillaceousness in post-St. James-Dunleith strata and shows a similar alternation of thin argillaceous and pure beds. The highest occurrence of abundant *Prasopora* and *Dalmanella* is in these strata in Kentucky and in the Rivoli in Iowa and Minnesota. The Jessamine-Benson contact is not a lithologic break, but is drawn at the highest occurrence of abundant *Prasopora* and *Dalmanella,* and hence has a highly variable stratigraphic position (McFarlan and White, 1948).

The strata constituting the remainder of the Benson Member and the overlying Brannon Member are similar to upper Dunleith beds in Illinois. In the Frankfort exposures these strata are correlated as follows, from the base upward:

Brannon Member (Wyota)

Calcarenite and limestone, very argillaceous and shaly, cherty; bedding contorted (compare New York) 3′

Calcarenite, thin to medium bedded, contains a few chert nodules and shale partings, 12′6″

Benson Member (Wall)

Calcarenite, thin bedded and shaly, 6″–4′

Calcarenite, pure, coarse grained, cherty, massive, 18′

Benson Member (Sherwood)

Limestone and calcarenite, thin bedded and shaly; local cherty disturbed zone in upper 5 feet, 17′–18′

Calcarenite, mainly pure, medium to coarse grained and thick bedded with local bentonite (lower bentonite of Sherwood, 6½ feet from top), 17½′–20½′

The top of the Brannon Member marks the highest occurrence of chert nodules in the Kentucky section, as well as the contact between a thick relatively argillaceous sequence below and a thick relatively pure sequence above, in which features it matches the top of the Dunleith Formation of Illinois.

Wise Lake Equivalents

The succeeding Woodburn Formation, from 10 to 50 feet thick, consists mainly of pure, phosphatic, fine- to coarse-grained, thin- to thick-bedded calcarenite, but contains occasional thin layers of argillaceous calcarenite or shaly limestone. *Constellaria teres* Ulrich & Bassler and *Favistella alveolata* (Goldfuss) are the most abundant and conspicuous fossils, although their distribution is irregular. Above the Woodburn is the Devils Hollow Formation (McFarlan and White, 1948, p. 1640), which consists of as much as 15 feet of pure, medium- to very coarse-grained, thick-bedded calcarenite (lower division), in places overlain by partly argillaceous, lithographic limestone and fine-grained calcarenite up to 20 feet thick (upper division). In stratigraphic position and relative purity, the Woodburn and the Devils Hollow appear equivalent to the Sinsinawa and Stewartville Members, respectively, of the Wise Lake Formation in the Mississippi Valley.

The Woodburn, like the Sinsinawa, is somewhat more argillaceous than the overlying beds, and has four local partings of bentonitic (?) shale 3, 9, 12, and 21½ feet above the base, the upper two of which may correspond to bentonites in the Sinsinawa. The partly argillaceous upper division of the Devils Hollow may be approximately equivalent to the thin argillaceous unit in the lower part of the Stewartville Member. If so, strata of upper Stewartville age are missing. The comparative thinness of the Devils Hollow, its sharp upper contact with the Cynthiana Formation, and the local absence of the upper division all suggest the presence of a diastem between the Devils Hollow and the Cynthiana.

Dubuque Equivalents

The lower part of the Cynthiana Formation, 38 to 54 feet thick in the outcrops studied, is composed of thinly interbedded calcarenite, argillaceous chalky limestone, and shale, the approximate proportion of shale ranging from 25 to 75 percent. Fossils generally are abundant and *Cyclonema varicosum* Hall is especially common. On the basis of close similarities in lithology and stratigraphic position, these beds are correlated with the Dubuque Formation of the Mississippi Valley, although the faunas have almost no species in common.

Cincinnatian Series

In central and northern Kentucky, the Nicholas Member constitutes, from a lithologic viewpoint, the upper portion of the Cynthiana Formation. The Nicholas consists of irregularly distributed, medium- to coarse-grained, medium- to thick-bedded calcarenite as much as 35 feet thick, which is said to grade laterally into shaly limestone (McFarlan, 1938, p. 992-995; McFarlan and White, 1948, p. 1641-1643). The fauna of the lower part of the Nicholas Member appears to be sparse and has not been described.

The Rodgers Gap Member, considered the top member of the Cynthiana Formation and classed as youngest Trentonian in Kentucky

(McFarlan and Freeman, 1935), is a faunal zone up to 30 feet thick, rather than a lithologic unit. The lower portion includes the upper part of the Nicholas Member and the upper portion consists of beds that the writers would place in the Fulton Formation, at the base of the lower Cincinnatian Eden Group. At Clays Ferry, Madison County, the fauna of the Rodgers Gap seemingly is confined to the upper 20 feet of the Nicholas Limestone (compare McFarlan, 1943, p. 21, fig. 4, and McFarlan and White, 1948, fig. 2, with the section given below). At this locality, the contrasting lithology and fauna of the Trentonian and of the overlying Cincinnatian are particularly well shown. A section measured on the south side of the Kentucky River, beginning in cuts along the road to the old Clays Ferry bridge, below the new Memorial bridge, and 100 feet west of the Kentucky River fault, and continuing in cuts along U.S. Highway 25, just south of the Memorial bridge, is as follows:

Paint Lick Formation
- Siltstone, very calcareous, buff, massive to bouldery, 25′ (estimated)

Fulton–Million Formations
- Limestone, argillaceous, and shale, dark gray, thinly interbedded, 150′ (estimated)

Cynthiana Formation
- Nicholas Member (Cape?)
  - Calcarenite, coarse grained, thick bedded, somewhat crinoidal; Rodgers Gap fauna reported from upper 20 feet, 58′
- Bromley Member (Dubuque) (McFarlan, 1943, p. 22-23
  - Earthy limestone and shale thinly interbedded, very shaly in upper part, 53′6″

Lexington Limestone
- Devils Hollow Member, lower division (Stewartville)
  - Calcarenite, coarser grained than below, medium to thick bedded, 7′
- Woodburn Member (Sinsinawa)
  - Calcarenite, thin to thick bedded, with some shale partings, 13′6″
- Brannon Member (Dunleith)
  - Calcarenite and limestone, mainly thin bedded and shaly, cherty near top, 15′6″

As the top of the Nicholas is undulating, pitted, ferruginous, and phosphatic, a diastem or unconformity appears to be present. The overlying 13 inches of basal Fulton contains some minute phosphatized gastropods and pelecypods like those in the depauperate zone at the base of the Maquoketa Group in the Mississippi Valley.

The Nicholas Member at Clays Ferry has a lithology and stratigraphic position similar to the basal Cincinnatian Cape ("Fernvale") Limestone of Illinois, Missouri, Kansas, and Oklahoma. The stratigraphic relations at the top are the same, and those at the bottom may be the same if the irregular distribution and thickness of the Nicholas Limestone is caused by an unrecognized unconformity at the base, instead of by lateral gradation into the Cynthiana. The presence of Rodgers Gap fossils both in upper Nicholas and lower Fulton strata suggests that no great interval of time separated Nicholas and Fulton deposition, in spite of the physical break between the two units. Although the faunas of the Cape ("Fernvale") (Branson, 1944, p. 92-93) and the Rodgers Gap (McFarlan and Freeman, 1935) seem to have little in common, this does not prove that the units are of different age. By generally accepted correlations, the Nicholas is a late Trentonian unit apparently missing in the Mississippi Valley and New York, and the Cape is an early Cincinnatian deposit not laid down east of the Illinois Basin. However, should later subsurface tracing demonstrate that the Cape and Nicholas-Rodgers Gap Limestones are the same, the base of the type Cincinnatian Series should be lowered to include these units, because the major faunal and physical break is at the base of the Cape Limestone rather than at the top.

MANITOBA

In Southeastern and central Manitoba, the following Ordovician sequence rests unconformably on the Precambrian basement (Dowling, 1900, p. 34-93; Wallace, 1925; Foerste, 1929b, p. 129-130; Okulitch, 1943; Goudge, 1945, p. 9-12, 19-36; Kerr, 1949, p. 4-9, 75-130; Baillie, 1952; Genik, 1954; Sinclair and Leith, 1958).

Cincinnatian Series
- Stony Mountain Formation
  - Birse Member—dolomite, thin bedded, 15′
  - Gunton Member—dolomite, massive, 15′–19′

Cincinnatian Series *(continued)*
Stony Mountain Formation *(continued)*
Penitentiary Member—dolomite, argillaceous, 15′
Gunn Member—shale, red, with limestone interbeds, 60′
Champlainian Series
Red River Formation
Selkirk Member
Limestone, mainly pure, dolomite mottled, and thick bedded, but partly cherty near base; thin bedded and shaly towards top on west shore of Lake Winnipeg, about 260′
Limestone, slightly argillaceous, dolomite mottled, partly cherty, thick bedded, with a probable bentonite 18½ feet above the base, 33′
Limestone, argillaceous, dolomite mottled, cherty, thin to medium bedded, 62′
Cat Head Member
Dolomite, pure, vuggy, cherty at top, thick bedded, 31′
Limestone, argillaceous, dolomitic, very cherty, medium bedded, 37′
Dog Head Member
Limestone, argillaceous and slightly cherty, like 30-foot unit below, 30′
Limestone, relatively pure, medium bedded, 10′
Limestone, argillaceous, dolomite mottled, slightly cherty, thin bedded, 30′
Winnipeg Formation
Deer Island Member
Shale, partly calcareous, green, splintery, grading into sandstone and shale along west shore of Lake Winnipeg, 0–100′
Black Island Member
Sandstone, composed of medium to coarse, rounded, frosted grains, 6′–120′

Andrichuk (1959) greatly extends the knowledge of these formations and in part modifies the nomenclature.

The thickening of the sequence in comparison with that of the Mississippi Valley indicates approach to the Williston Basin of southwestern Manitoba, North and South Dakota, and Montana, where the Winnipeg and Red River Formations are each more than 600 feet thick. Our discussion is related primarily to the outcrop areas bordering the basin (see also *South Dakota*), but the subsurface sequence in the basin has been widely studied because of the recent deep drilling (Carlson, 1960, and Ross, 1957, give additional data and references). Correlation of the Manitoba sequence with that in Illinois and other states is shown in figure 27.

Blackriveran Stage

The basal sandstone member of the Winnipeg Formation probably represents the St. Peter Sandstone (fig. 27), although comparison with the Minneapolis section suggests that Glenwood beds are included at the top. The upper shale member of the Winnipeg Formation resembles the Harmony Hill-Platteville-Decorah sequence in parts of Minnesota, where most of the formations have graded laterally to calcareous gray-green shale. Along the west shore of Lake Winnipeg the fauna of the upper portion of this member includes the significant species (shown below) which support this correlation.

Because of faunal similarities between the Winnipeg Formation and the overlying Red River and Stony Mountain Formations, both of which have been classed as Upper Ordovician by Foerste and others, it has been suggested that the Winnipeg Formation also is of Upper Ordovician age (Macauley and Leith, 1951). The faunal evidence cited above and the lithologic similarities between Red River and Galena strata, described below, oppose this view.

Trentonian Stage

The Red River Formation has the stratigraphic position and the typical lithology and fauna of the post-Decorah part of the Galena Group, although it is more than

Genus and Species	*Champlainian Range*
Licrophycus ottawaensis Billings	Ion to Stewartville
Glyptocrinus	Ion to Dubuque
Escharopora ramosa (Ulrich)	Platteville
Dalmanella rogata (Sardeson)	Spechts Ferry to Dubuque
Strophomena trilobata (Owen)	Ion to Dubuque
Cyrtodonta canadensis Billings	Guttenberg
Ectomaria occidentalis (Whiteaves)	Nachusa to Ion

twice as thick. The Dog Head Member, the Cat Head Member, and the lower 95 feet plus of the Selkirk Member are cherty and consist of argillaceous, thin-bedded units alternating with relatively pure, thicker bedded units. In these features they are similar to the Dunleith Formation, although the published sections are not sufficiently detailed to permit full recognition of the sequence of members in the Dunleith. *Rafinesquina deltoidea* (Conrad) first appears in the lower part of the Dunleith Formation and in Cat Head strata. Middle Selkirk strata exposed in quarries at East Selkirk, Garson, and Tyndall, 20 miles northeast of Winnipeg, resemble the Wall Member in that they lie near the top of the cherty part of the Galena, are less argillaceous and thicker bedded than the strata beneath, and contain a clay bed that probably represents a bentonite. The cherty but relatively pure lower part of the upper Selkirk, four feet of which is exposed at St. Andrew's Locks, 12 miles northeast of Winnipeg, appears to contain the highest chert in the Red River Formation. It probably corresponds to the uppermost Dunleith Wyota Member, but its total thickness is not known.

The great majority of Selkirk fossils seems to have been obtained from Wall-Wyota (?) beds in the East Selkirk-St. Andrews area. The suggested correlations are supported by the absence of *Fusispira intermedia* Ulrich & Scofield, *Hormotoma major* (Hall), *Lophospira minnesotensis* Ulrich & Scofield, *Maclurites crassus* (Ulrich & Scofield) and *Orthodesma subnasutum* (Meek & Worthen), which first appear in Sinsinawa strata, and of *Lophospira augustina* Billings, *Maclurites cuneata* (Whitfield), and *Maclurites subrotunda* (Whitfield), which first appear in the Stewartville.

The succeeding pure, noncherty, thick-bedded portion of the Selkirk Limestone has the lithology and stratigraphic position of the Wise Lake Formation. The strata are poorly exposed and the distinctive fauna of the Wise Lake has not been reported.

About 15 feet of argillaceous, thin-bedded, shaly limestone representing uppermost Selkirk strata crops out at Carscallen and Clark Points, Lake Winnipeg (Dowling, 1900, p. 84-85). The limestone resembles upper Dubuque beds in lithology and stratigraphic position. It contains a late Trentonian fauna, including *Lepidocyclus capax* (Conrad), *Megamyonia unicostata* (Meek & Worthen), and *Strophomena trilobata* (Owen), which are present to common in Dubuque strata, though not confined to that formation.

The formational correlations proposed above are in general similar to those suggested by Dowling (1900, p. 35), by Wallace (1925), and by Baillie (1952). Although Foerste (1929a, p. 37-39; 1929b, p. 129-146) recognized that the fauna was predominantly Trentonian, he classed the formation as Richmondian because of the appearance of a few fossils of supposedly Richmondian age. Miller and Carrier (1942, p. 532-534), Macauley and Leith (1951), Miller et al., (1954, p. 45), and Ross (1957, p. 459) have concurred in regarding the Red River Formation as Upper Ordovician.

The evidence for the Richmondian age of the Red River has been summarized by Dunbar (*in* Twenhofel et al., p. 281), who interpreted this to be the prevailing view. Kay (*in* Twenhofel et al., 1954, p. 282) summarized the faunal and paleogeographic evidence that the Red River is principally or wholly Trentonian, supporting his previous position (Kay, 1935b).

Because many of the supposed Cincinnatian fossils appear to have arisen in Trentonian time (see *South Dakota*) and because the Red River lithologic sequence closely matches the Galena sequence, there appears to be ample reason to classify the Red River Formation as Champlainian rather than Cincinnatian.

MICHIGAN

In the lower peninsula of Michigan, Champlainian rocks are confined to the subsurface (Cohee, 1945a, 1945b, 1948), but in the upper peninsula they crop out at several localities and were studied by the writers in the Escanaba area at Bony Falls, Cornell, Chandler Falls, and Groos, in Delta County, at Trenary in Alger County (fig. 35), and at Limestone Mountain in Houghton County (fig. 26). Preliminary correlations with the Champlainian succession in the Mississippi Valley suggest some modifications from previous correlations (Hussey 1936, 1950, 1952; Kay 1935a, p. 291; 1935c, p. 238; 1937, p. 294, fig. 13). As in other regions, the correlation of units of Blackriveran age seems reasonably definite, but because many of the units of Trentonian age are less distinctive and show more variation, their correlation is less certain.

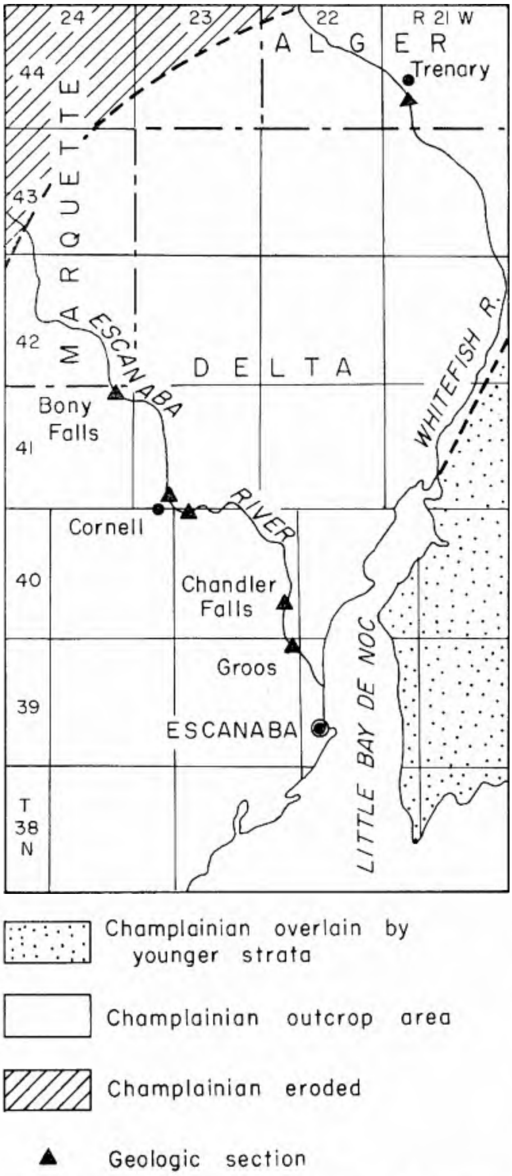


FIG. 35.—Upper Michigan, showing outcrop area of Champlainian strata and localities mentioned. Geologic boundaries from *Geologic Map of Michigan*, Michigan Geological Survey.

The general Ordovician sequence in the Escanaba area is as follows:

Richmond Formation (Maquoketa)
Limestone and shale, 153′
Trenton Limestone (Galena), 205′
Black River Limestone (Platteville), 70′
Oneota Dolomite, 23′

The above sequence overlies the Upper Cambrian Jordan Sandstone and underlies the Lower Silurian Manitoulin Formation (dolomite and shale). In the Escanaba area much of the Black River-Trenton sequence consists of argillaceous, greenish gray, thin-bedded, ripple-marked, shaly limestone that was deposited in relatively shallow water and closely resembles a large part of the Platteville-Galena succession in Minnesota. In subsurface east of Escanaba the sequence becomes purer (Cohee, 1948, p. 1432).

The general Ordovician sequence at Limestone Mountain, using Illinois nomenclature, is as follows:

Maquoketa, thickness unknown
Galena, dolomite, 200′+ (250′ estimated)
Platteville, dolomite, 62′+ (85′ estimated)
Glenwood, sandstone, 9′

The sequence unconformably overlies the Upper Cambrian Jacobsville Sandstone, probably of Mt. Simon age, and apparently underlies dolomite of Silurian age, at least part of which is of Niagaran age.

The Platteville-Galena section at Limestone Mountain, between the Escanaba and Minnesota areas, consists mainly of comparatively pure thick-bedded dolomite. Hence it seems likely that the shale in the Minnesota succession was derived from the west and the shale in the Escanaba sequence from the north.

ESCANABA AREA

Blackriveran Stage

Platteville Group Equivalents

The best exposure of strata equivalent to the Platteville Group in northern Michigan is on the Escanaba River at Bony Falls dam, 20 miles northwest of the town of Escanaba (E. line SW NE 2, 41N-24W, Delta Co.). It correlates with the Illinois sequence as follows:

Platteville Group
- Quimbys Mill Formation
  - Shullsburg Member
    - Dolomite, argillaceous, buff, chalky, thin bedded, shaly, 2′
- Nachusa Formation
  - Eldena Member
    - Limestone, very fucoidal, medium bedded; blue-gray shale partings; scour surface at top, 5′3″
- Grand Detour Formation
  - Forreston Member
    - Limestone, very thin bedded and shaly, 6″
    - Limestone, thin bedded, slightly shaly, fossiliferous; corrosion surface at top, 2′2″
    - Limestone, very thin bedded and shaly; bentonite at base, 3′6″
  - Stillman Member
    - Limestone, fine to medium grained, fucoidal, thin bedded; some thin blue-gray to brown-red shale partings; 1-foot calcarenite layer at base; corrosion surface at top, 8′3″
- Mifflin Formation
  - Briton Member
    - Limestone, thin bedded, shaly; 7-inch massive bed 2 feet above base, 6′8″
  - Hazelwood Member
    - Limestone, medium bedded, slightly shaly in lower part, fucoidal in upper part, 1′2″
  - Establishment Member
    - Limestone, thin bedded, shaly, 3′2″
  - Brickeys Member
    - Limestone, medium bedded, slightly shaly, 1′
- Pecatonica Formation
  - Oglesby Member
    - Calcarenite, medium grained, massive; corrosion surface at top, 1′3″
  - New Glarus Member
    - Dolomite, slightly argillaceous, medium bedded, nonshaly and nonfucoidal; corrosion surface at top, 2′6″

The Pecatonica contains a few specimens of *Actinoceras* and *Cycloceras* (Hussey, 1936, p. 237). The Stillman contains *Solenopora compacta* (Billings), *Stromatocerium rugosum* Hall, *Foerstephyllum magnificum* (Okulitch), *Favistella alveolata* (Goldfuss), *Tetradium cellulosum* (Hall), *Strophomena winchelli* Hall & Clarke, *Maclurites bigsbyi* (Hall), *Endoceras* and other orthoceroid cephalopods, and many crinoid columnals and bryozoans. The slightly shaly Forreston unit contains numerous *Lambeophyllum profundum* (Conrad) and crinoidal debris. The Eldena fauna includes large colonies of *Foerstephyllum halli* (Nicholson) and toward the base has many *Eoleperditia fabulites* (Conrad). Hussey (1950, p. 3; 1952, p. 20) listed several other typical Platteville species from the section as a whole.

The Platteville section at Bony Falls is unusual in that many units are missing and in that some units that are comparatively pure to the south have become moderately shaly. Nevertheless, the sequence shows several features characteristic of Platteville strata far to the south. The Oglesby Member, largely calcarenite, is known elsewhere only south of the type locality near LaSalle, Illinois. The corrosion surface at the top of the member is also present from Minneapolis to Cape Girardeau and eastward to LaSalle County, Illinois. The calcarenite at the base of the Stillman has been recognized elsewhere only in a region extending from Missouri to Virginia. The bentonite at the base of the abbreviated Forreston section is correlated with a bentonite known only from lower Forreston equivalents in Kentucky and Virginia. The relatively pure *Lambeophyllum*-bearing bed near the top of the Forreston at Bony Falls is a conspicuous unit of the Forreston in central northern Illinois. The Shullsburg Member of the Quimbys Mill is more shaly than the overlying Strawbridge Member. The latter is best exposed at Trenary, as described below, where it reaches the abnormal thickness of at least 16 feet.

Hussey and Ulrich also correlated the Bony Falls section with the Platteville Limestone of the Mississippi Valley (Hussey, 1936, p. 233-238). Hussey (1952, p. 17) named the strata at Bony Falls the Bony

Falls Member of the Black River Formation, but he thought that the corrosion surface beneath the bentonite at the base of the Forreston Member equivalent might be the top of the Black River. Kay (1937, p. 294, fig. 13) regarded the entire sequence as Rockland (Guttenberg), presumably because of the occurrence of *Foerstephyllum halli* (Nicholson), a common Rockland species which, however, first appears abundantly in Chaumont and equivalent strata.

Trentonian Stage

Galena Group Equivalents

Lower Galena strata are exposed on the east bank of the Whitefish River and in a quarry on the west side of the river, between the Minneapolis, St. Paul, and Sault Ste. Marie Railroad and U.S. Highway 41, 0.8 mile south of the railroad station in Trenary (SW 29, 44N-21W), and 28 miles north of Escanaba, and correlate with the Illinois sequence as follows:

Galena Group
- Dunleith Formation
  - Eagle Point Member
    - Limestone, dolomitic, phosphatic, conglomeratic, gray; in hillslope above quarry, 6′
  - Beecher Member
    - Limestone, moderately argillaceous and shaly, blue-gray, thin bedded; abundant *Zygospira recurvirostris* (Hall) in lower part, 6′4″
  - Buckhorn and St. James Members
    - Limestone, argillaceous, greenish gray, thin bedded, shaly, 15′

Platteville Group
- Quimbys Mill Formation
  - Strawbridge Member
    - Dolomite, partly argillaceous, buff, chalky to medium crystalline, in 4- to 13-inch regular beds, 16′

As in eastern Wisconsin, Spechts Ferry and Guttenberg beds seem to be missing. As in Minnesota, the Beecher Member is intermediate in shaliness to St. James and lower Eagle Point strata and has the *Zygospira* Zone at its base. Hussey (1936, p. 239-240) recognized the age of the Trenary exposures as Platteville, upper Decorah, and Trenton, but in 1952 (p. 27) he appeared to include them in his Chandler Falls Member at the base of the Trenton Formation.

We did not see upper Eagle Point and Fairplay equivalents, but they probably are exposed along the Escanaba River between Bony Falls and Cornell. Judging from the total thickness of the Trentonian strata in northern Michigan and from the thickness of these members in Minnesota, each may be about 15 feet thick.

Middle Dunleith beds are poorly exposed in the banks of the Escanaba River north and south of the concrete bridge half a mile northeast of Cornell and 13 miles northwest of Escanaba (cen. N½ 32, 41N-23W, Delta Co.), as follows:

Dunleith Formation
- Wall Member
  - Limestone, very argillaceous, shaly, gray-green, thin bedded; containing calcarenite layers, chert band, *Plectorthis plicatella* (Hall) and *Isotelus gigas* Dekay, 5′
  - Limestone, thin to medium bedded, slightly shaly, with *Sowerbyella punctostriata* (Mather), 3′
- Sherwood Member
  - Limestone, shaly; containing large *Prasopora selwyni* (Nicholson) in upper portion, and *Hemiarges paulianus* (Clarke); 6-inch conglomerate 1′5″ below top; three bentonite layers above the conglomerate, 7′4″
  - Limestone and calcarenite, pure, phosphatic, conglomeratic in lower part, in regular medium beds, 5′7″
- Rivoli Member
  - Limestone, shaly, 8′4″
  - Limestone, thin bedded, slightly shaly, with massive ledge at top, 3′
- Mortimer Member
  - Limestone, argillaceous, greenish gray, thin bedded, shaly, with numerous *Zygospira recurvirostris* (Hall) in upper 30 inches, 8′4″
  - Limestone, somewhat argillaceous, gray to buff, thin bedded, nonshaly, with scour surface at top, 5′5″

Parastrophina hemiplicata (Hall) is present from upper Mortimer through lower Sherwood strata.

The uppermost Wall unit at Cornell forms the basal portion of the section in the cliff along the west side of the Escanaba River below the dam at Chandler Falls, 6 miles north of Escanaba (NE SW 25, 40N-23W, Delta Co.) where the sequence is as follows:

Wise Lake Formation
  Stewartville Member
    Limestone, slightly argillaceous, buff, in 12- to 30-inch beds weathering to thin, irregular layers; abundant *Maclurites cuneata* (Whitfield) and other typical Stewartville fossils, 5′
  Sinsinawa Member
    Limestone, moderately argillaceous, buff, chiefly in 6- to 15-inch beds but thin bedded and somewhat shaly toward base; *Sowerbyella* common; bentonites present 5′6″ and 9′ above the base, 17′
Dunleith Formation
  Wyota Member
    Limestone, more argillaceous and shaly than above, gray-green to buff, nonconglomeratic; corrosion surface at top, 6′2″
    Limestone, dolomitic, calcarenitic, conglomeratic, moderately argillaceous and shaly, 5′6″
  Wall Member
    Shale, calcareous, blue-green, in very thin, irregular beds; abundant *Prasopora oculata* Foord, *P. selwyni* (Nicholson), *P. simulatrix* Ulrich, and other bryozoans (Hussey, 1950, p. 6-9), 3′9″
    Limestone, very argillaceous and shaly, gray-green, thin bedded, chert band at base, 8′

The Dunleith Formation in the Cornell-Chandler Falls section contains a large proportion of shale, even in comparison with Minnesota exposures. In most of the Mississippi Valley the upper Rivoli unit is the most argillaceous portion of the Dunleith above the St. James Member, but in the Cornell-Chandler Falls section the upper Wall unit is the most argillaceous part, as it also is at Trenton Falls, New York.

The Dunleith-Wise Lake sequence at Cornell and Chandler Falls is similar to that in the Mississippi Valley in the following features: (1) the typical Dunleith cycles of relatively pure units alternating with argillaceous units are excellently developed; (2) the only bentonite discovered in the Dunleith Formation of Michigan seems to match an unusually thick and widespread bentonite in the Sherwood Member of Illinois and neighboring states; (3) the Wise Lake Formation is comparatively pure, and reaches maximum purity in the Stewartville Member; (4) two bentonites are present in the Sinsinawa Member, as at Galena, Illinois; and (5) *Maclurites cuneata* (Whitfield) is abundant in the lower half of the Stewartville Member. *Maclurites crassus* (Ulrich & Scofield) and *Maclurites manitobensis* (Whiteaves) are locally common in both Sinsinawa and lower Stewartville beds in the Mississippi Valley, but *Maclurites cuneata* (Whitfield) and *Maclurites subrotunda* (Whitfield) are known only from the lower half of the Stewartville. The genus itself is not an index of the Wise Lake Formation, because *Maclurites bigsbyi* (Hall) is a common Platteville species. *Maclurites macer* (Ulrich & Scofield) ranges from Mortimer through Wyota strata, and *Maclurites manitobensis* (Whiteaves) arises in the lower part of the Dunleith Formation, above the St. James Member.

At Cornell, Ulrich and Hussey drew the Black River-Trenton boundary 2 feet 7 inches below the top of the Mortimer Member of the Dunleith Formation because the *Zygospira recurvirostris* Zone in the uppermost Mortimer was thought to be the same as the *Zygospira recurvirostris* Zone at the base of the Prosser Member in Minnesota and at Trenary, and because at that time Decorah strata were included in the Black River Group (Hussey, 1936, p. 233, 240-245). Kay (1935c, p. 238, fig. 8) placed the contact between Hull and "Black River (?)" Limestones 7 feet 8 inches below the top of the Mortimer because the beds above this point contain *Parastrophina hemiplicata* (Hall) and *Hemiarges paulianus* (Clarke), then believed to be most common in or confined to the Hull. It is now known that both species range from pre-Hull (pre-Dunleith) beds into or through the Cobourg Formation of Wall to Dubuque age. Later the Cornell section apparently was classified as Hull and lower Shoreham (Kay, 1937, p. 294, fig. 13). At Chandler Falls Kay (1935a, p. 291; 1935c, p. 238; 1937, p. 294, fig. 13) recognized the Stewartville Member, but considered the underlying beds to be of Sherman Fall (Shoreham) age because of the presence of *Prasopora oculata* Foord and *Prasopora selwyni* (Nicholson), both common in the Shoreham of New York and Ontario. Strata of Denmark and Lower Cobourg age were thought to be missing from northern Michigan. *Prasopora selwyni* is now known to range from the base of the Shoreham to the top of the lower Cobourg (Steuben). In Minnesota, Ontario, and New York, *Prasopora oculata* has been found only in beds of Shoreham (Eagle Point-Fairplay) age, but in northern Michigan it apparently survived into much younger beds.

Hussey (1952, p. 23) included all the Trentonian strata to the top of the *Maclurites* Zone in his Chandler Falls Member. He put the base of the Trenton at the base of the conglomeratic zone at Chandler Falls, which gives the member a thickness of 37 feet. As we put the *Maclurites* Zone at least 125 feet above the base of the Trentonian sequence, it is apparent that we do not agree on the compilation of exposures along the Escanaba River.

Practically the full thickness of the Stewartville Member crops out in the south bank of the Escanaba River, 1½ miles east-southeast of Cornell and 12 miles northwest of Escanaba (center W. line NW NE 6, 40N-23W, Delta Co.). In this exposure about 30 feet of slightly argillaceous to pure, medium-bedded, nonshaly limestone, with abundant *Maclurites cuneata* (Whitfield) in the lower 15 feet, dips 10° eastward.

Forty feet of the Dubuque Limestone, probably the full thickness of the formation, is well exposed in the Bichler quarry at Groos (cen. SW 1, 39N-23W, Delta Co.), 4 miles north of Escanaba (Hussey, 1936, p. 248-251; 1950, p. 12-13). The limestone is dolomite mottled, somewhat argillaceous, gray, fine grained, in 2- to 24-inch beds separated by thin, dark brown to black shale partings, and has a 2-foot shaly unit 29 feet from the top. It contains *Conularia trentonensis* Hall, *Cheirocrinus, Megamyonia unicostata* (Meek & Worthen), *Pseudolingula iowensis* (Owen), *Sowerbyella praecosis* (Sardeson), and *Ogygites latimarginatus* (Hall), and has a 2-foot zone of *Whitella eardleyi* Hussey 20 feet below the top.

Although Kay (1935b, p. 579-580) apparently regarded a 4-foot thin-bedded unit at the top of the quarry as Dubuque and the remainder of the sequence as Stewartville, the fauna of the entire section is typically Dubuque and no species characteristic of the Stewartville have been reported. *Sowerbyella praecosis* (Sardeson) is reported only from the Dubuque, and *Ogygites lactimarginatus* (Hall) is not found below the Hillier Member of the Cobourg Limestone in Ontario and New York, which we regard as Dubuque in age. Both species occur below the uppermost thin-bedded unit. It has been suggested that the Dubuque Formation grades eastward into the Collingwood Shale (Kay, 1935b, p. 580-582), which we consider Cincinnatian (see *New York and Ontario*). However, the Dubuque section at Groos, as a whole, is less shaly than the Dubuque of the Mississippi Valley and shows no sign of gradation into Collingwood lithology. Typical Collingwood beds appear to be present 85 miles northeast (Ruedemann and Ehlers, 1924).

Hussey (1952, p. 33-35) divided the sequence in the Bichler quarry at Groos into two members, the Groos Quarry Member below the top of the 2-foot shale unit, and the Haymeadow Creek Member above. The Groos Quarry Member extends down to the *Maclurites* Zone and the Haymeadow Creek Member up to the top of Trentonian strata at the base of the Bill's Creek Shale.

We correlate the basal Cincinnatian Bill's Creek Shale (Bill's Creek beds, Hussey, 1926), exposed on the Stonington peninsula just east of Groos, with Collingwood–lower Gloucester, Eden–Maysville?, and Elgin strata. Because of lithologic and faunal similarities, the overlying Stonington Limestone is correlated with the Fort Atkinson (Waynesville) Limestone, and the uppermost Cincinnatian Big Hill Limestone, which is much more shaly than the Stonington, is correlated with the Brainard (Liberty–Whitewater–Elkhorn) Shale. Clermont (Arnheim) equivalents may be absent along a diastem between the Bill's Creek and Stonington Formations. The presence of a nearly complete Cincinnatian sequence above the strata exposed in the Groos quarry thus supports the Trentonian age of the Dubuque.

LIMESTONE MOUNTAIN AREA

Small synclinal outliers of Champlainian and younger strata are preserved in a Jacobsville Sandstone terrain at Limestone Mountain and Sherman Hill, central Houghton County, upper Michigan (Case and Robinson, 1915; Thwaites, 1943, p. 494-496; Raasch, 1950, p. 141, 146). These outliers are important because of their isolated position in the area between exposures in the Minneapolis, Escanaba, and Winnipeg areas. At Limestone Mountain the beds are complexly faulted. The red, argillaceous, granule-bearing sandstone of the Jacobsville Formation, of Mt. Simon age (Raasch, 1950; Templeton, 1950), is overlain unconformably by 9 feet of argillaceous, silty, nondolomitic, greenish gray sandstone of the Glenwood Formation, which is fully exposed only on the northwest slope of Little Limestone Mountain. The sandstone has a bimodal texture with a mixture of very fine and coarse sand grains.

Above the Glenwood Sandstone is a Platteville–Galena sequence of unknown total thickness, which consists chiefly of pure thick-bedded dolomite. The beds closely resemble the Platteville–Galena strata of southern Wisconsin and northern Illinois and contrast sharply with the shaly thin-bedded strata of this age found in the Escanaba area and Minnesota. The sequence in the bluff on the east side of Little Limestone Mountain is tentatively correlated as follows:

Platteville Group
- Nachusa Formation
  - Eldena Member
    - Dolomite, pure, fucoidal, massive; face pitted, 9′
- Grand Detour Formation
  - Forreston Member
    - Dolomite with argillaceous streaks, thick bedded; weathering in lower 5 feet to thin beds with some thin shale partings, 12′
  - Stillman Member
    - Dolomite, pure, fucoidal, medium to thick bedded; face pitted, 8′
- Mifflin Formation (exposed in small, old quarry)
  - Briton Member
    - Limestone, argillaceous, thin bedded, shaly, fossiliferous, 4′
  - Hazelwood Member
    - Dolomite, relatively pure, fucoidal, medium bedded; face pitted, 1′3″
  - Brickeys (?) and Establishment Members
    - Limestone, dolomitic, argillaceous, thin to medium bedded, shaly, 7′
- Pecatonica Formation
  - Medusa Member
    - Dolomite, fucoidal, medium bedded, nonshaly; face pitted, 6′
  - Dane Member
    - Dolomite, argillaceous, thin to medium bedded; some thin shale partings, 6′
  - Chana Member
    - Dolomite, sandy, buff, mottled dark red, medium bedded, 4′

Glenwood and Jacobsville Sandstones

Case and Robinson (1915, p. 175) report a Decorah (Guttenberg–Ion) faunule from beds that we regard as Pecatonica and Mifflin at this locality and as Chana on Sherman Hill. It seems possible that the fossils came from higher strata.

Seven feet of buff, chalky, thin-bedded dolomite with buff shale partings, thought to represent the Shullsburg Member of the Quimbys Mill Formation, crop out in the southeast slope of Big Limestone Mountain on the road to the ski-jump. Fossils found at the southwest end of Big Limestone Mountain were considered indicative of "Upper Buff" age (Case and Robinson, 1915, p. 175), but to us suggest a Guttenberg age. *Cyrtodonta tenella* (Ulrich) is reported only from the Guttenberg and *Ctenodonta gibberula* Salter apparently ranges from the Grand Detour to the Guttenberg. The two other definitely identified forms, *Ctenodonta nasuta* (Hall) and *Cyrtodonta billingsi* Ulrich, range from Pecatonica and Grand Detour beds, respectively, to Dunleith strata.

Nearly vertical post-St. James Galena Dolomite, 200 feet thick, crops out around the ski-jump at the top of the southeast slope of Big Limestone Mountain, and more than 60 feet of post-St. James Galena strata, dipping gently eastward, is exposed at the top of the west face of the mountain. Chert seems to be absent from these outcrops. Their subdivision was not attempted.

Buff thick-bedded dolomite carrying a fauna typical of the lower Stewartville is present near the tops of Little Limestone Mountain and Sherman Hill (Case and Robinson, 1915, p. 174). At the top of Little Limestone Mountain 10 feet of dolomite called lower Richmond by Case and Robinson (1915, p. 174) has a lithology and fauna typical of the Dubuque Formation in the Mississippi Valley and contains no forms that are exclusively Cincinnatian.

A single ledge of dolomite containing fossils suggestive of Arnheim (Clermont) age crops out at the base of the south slope of Big Limestone Mountain (Case and Robinson, 1915, p. 173-174), but exposures of other Cincinnatian strata have not been found.

NEBRASKA

Condra and Reed (1939, p. 8-9, 18-19; 1943, p. 67-70) have presented detailed subsurface data on the Champlainian Series of southeastern Nebraska and have correlated the sequence with the Mississippi Valley.

Blackriveran Stage

Equivalents of Ancell and Platteville Groups

The St. Peter Sandstone, 30 to 60 feet thick, rests unconformably on rocks ranging from Precambrian to Shakopee (Canadian) in age. As in the Mississippi Valley, the lower part of the St. Peter is conglomeratic and shaly. Glenwood sandstones seem to be absent (Elder, 1936b). However, in a well near Nehawka, Cass County, the St. Peter is overlain by 43 feet of dark gray shale with thin limestone layers, which seems most closely to resemble the Harmony Hill Member of the Glenwood in Illinois. Subsurface tracing from the Glenwood type-area of northeastern Iowa to eastern Nebraska (Elder, 1936b) supports this correlation, but Agnew (1955, p. 1732) believed the Glenwood Shale (our Harmony Hill Member of the Glenwood) is missing in extreme western Iowa. The Glenwood is overlain by 7 feet of brownish, fine-grained limestone assigned to the Platteville (Pecatonica–McGregor). Fossils normally restricted to the Galena are reported from Glenwood and Platteville strata in the Nehawka well (Condra and Reed, 1943, p. 69).

Trentonian Stage

Galena Group Equivalents

In general, the Spechts Ferry, Guttenberg, and Ion Formations of Nebraska, as recognized by Condra and Reed, seem very similar in lithology, fauna, and thickness to the same units near Guttenberg, northeastern Iowa. The Spechts Ferry in the Nehawka well consists of 17 feet of dark gray shale with limestone interbeds. Here and at Lincoln the Guttenberg is composed of partly argillaceous, brownish to dark gray limestone from 15 to 20 feet thick, and the Ion consists of dark gray, partly dolomitic shale from 24 to 34 feet thick. Common Spechts Ferry and Ion fossils were recovered from the Nehawka well. In the Arab No. 1 Ogle well, Richardson County, southeasternmost Nebraska, strata that we tentatively correlate with the Ion consist of sandstone with interbedded green shale (Leatherock, 1945, p. 12-13). Sandstone thought to be partly of Ion age is present to the west from South Dakota to Colorado, and sandy dolomite is found within this stratigraphic interval to the east in Illinois.

Although the post-St. James Galena sequence in Nebraska is considerably thicker than that in the Mississippi Valley, the data given by Condra and Reed seem to justify the provisional correlations in five Nebraska wells shown below.

The lower 70 to 90 feet of the post-St. James Dunleith seems relatively pure, com-

	Falls City	*Shrine Club*	*Capitol Beach*	*Nehawka*	*South Omaha*
Dubuque	30′	eroded	eroded	eroded	130′
Wise Lake	55′	65′	26′+	75′	70′
Post-St. James Dunleith	166′	165′	187′	159′	170′

monly has a buff to brownish hue, generally is finer grained than succeeding strata, and is chert-free. In purity, color, absence of chert, and thickness this unit resembles the lower part of the Dunleith Formation in Missouri and western Illinois and is thus equivalent to the type Kimmswick Limestone which ranges from St. James to basal Sherwood in age. In Nebraska it is dolomite and lacks the coarse grain size of the Kimmswick. The upper part of the Dunleith, normally from 75 to 90 feet thick, is gray, ordinarily very cherty, and partly argillaceous or shaly. These beds appear closely similar to the New London Member of the Dunleith Formation in Missouri and southern Illinois, but are at least twice as thick.

Strata correlated with the Wise Lake Formation seem to be relatively pure, nonshaly, and generally noncherty, as in the Mississippi Valley. Although some chert occurs in cuttings from this interval in one of the five wells (Falls City), the chert is described as being like that in the overlying Dubuque Formation and may be caved.

Above the Wise Lake strata there is as much as 130 feet of light gray, coarse-grained, cherty dolomite. This unit appears to be similar to the Dubuque Formation, which in parts of Illinois is cherty and is given a coarse texture by crinoidal debris. The abnormally great thickness of the unit in the South Omaha well may indicate northward thickening of the Dubuque Formation toward the Williston Basin of North Dakota. Also, undifferentiated Cape ("Fernvale") strata may be included at the top.

Cincinnatian Series

The strata equivalent to the Galena Group are overlain by dolomite and shale of Cincinnatian age or by younger strata. The following correlations are suggested for the Cincinnatian sequence in Otoe County (Condra and Reed, 1943, p. 68):

Nebraska	*Illinois*
Unit 1 (top)	Neda Formation (top)
Unit 2	Brainard Formation
Units 3, 4, and 5	Fort Atkinson Formation
Unit 6	Scales Formation
	Clermont Member
Unit 7 (base)	Elgin Member (base)

In southeasternmost Nebraska all the Cincinnatian formations except the Neda grade into dark gray dolomitic shale, a facies change similar to that occurring in northwestern Illinois and northeastern Iowa (Ladd, 1929, p. 329-331). If the correlations outlined above are correct (compare Lee, 1943, p. 41-42), they support the assignment of the underlying limestones to the Galena Group.

OKLAHOMA

In the Arbuckle Mountains of southern Oklahoma, Champlainian rocks are represented by a thick geosynclinal sequence (not studied by the writers, that has been divided into the Simpson Group at the base and the Viola–Fernvale Limestones at the top. Correlations of the Oklahoma sequence with that in Illinois and other states is shown in figures 27 and 29.

The Simpson Group (Decker and Merritt, 1931; Decker, 1941; Ham, 1945; Harris, 1957) rests unconformably on the Arbuckle Limestone of Canadian age and consists of the following formations in ascending order: *Joins, 0-342′; Oil Creek, 46′-627′; McLish, 334′-533′; Tulip Creek, 22′-486′; Bromide, 86′-675′*. The Joins consists principally of thin-bedded, partly shaly limestone, but each of the higher formations consists of a basal sandstone overlain by limestone and shale with minor sandstones. The formations thicken southwestward and the Tulip Creek grades to shale in that direction. Because of the great thickening, the accompanying facies changes, and the difficulties of northward or eastward subsurface tracing across post-Ordovician structural highs, the correlation of some of the Simpson formations is very uncertain. However, the subsurface stratigraphy of the Simpson has been worked out in great detail in parts of the region. The literature has been summarized by Harris (1957, p. 10-54).

Chazyan Stage

Everton Group Equivalents

The Joins, Oil Creek, and McLish Formations are most commonly assigned (Decker, 1952, p. 135) to the Chazyan. The faunas are peculiar in that each is a mixture of lower, middle, and upper Chazyan species. The Oil Creek and McLish also contain forms equivalent or allied to Blackriveran–Trentonian fossils. A possible interpretation is that the Oil Creek and McLish are Blackriveran and contain a predominant relict Chazyan fauna that survived in the geosynclinal environment. However, the recent faunal studies of Harris (1957) strongly suggest the Chazyan age of both the Joins and the Oil Creek. Their equivalence to the similar but less clastic Everton strata thus seems likely.

Twenhofel et al. (1954) assigned all the Simpson below a position well up in the Bromide to the Chazyan. Cooper (1956, p. 118-120) assigned the Joins and Oil Creek to a new Whiterock Stage, which is Champlainian but older than Chazyan.

Blackriveran Stage

Equivalents of Ancell and Platteville Groups

The McLish is Chazyan according to Decker (1952, p. 135), Twenhofel et al. (1954), and Cooper (1956). Harris (1957) gave evidence for a major faunal break between the Oil Creek and McLish and for assignment of the McLish to the Blackriveran Stage. According to Harris (1957, p. 76), only one of 26 Oil Creek ostracodes survived into the McLish, but several McLish species continue into the Tulip Creek and Bromide. Lithographic limestone with calcite flecks ("birds-eyes") is characteristic of the upper McLish and suggests correlation with the Plattin of Arkansas and Missouri and the Platteville of the Mississippi Valley. The basal sandstone of the McLish, probably the Burgen of eastern Oklahoma, is a friable clean sandstone similar to and at the position of the St. Peter Sandstone. Although this sandstone is one of the most prominent and persistent, the other Simpson sandstones have a similar character, and the interval including most or all of them is commonly correlated with the St. Peter (Twenhofel et al., 1954; Dapples, 1955, p. 447). As our correlations suggest that the Simpson covers the entire range from the base of the Everton to the lower part of the Galena, only one of the sandstones, probably the basal McLish, may be equivalent to the type St. Peter. The other Simpson sandstones may be represented in the thinner, dominantly carbonate sequence of the Mississippi Valley by relatively thin sandstones or sandy and silty limestones, which are common in this interval.

The sparse fauna of the Tulip Creek was assigned to the Blackriveran by Decker (1952, p. 135). However, of the 17 forms reported, 3 are Chazyan, 1 (*Rhinidictya grandis* Ulrich) is Platteville, 3 range from Blackriveran into Trentonian strata, 8 are known only from the Trentonian, and 2 have not been reported outside of Oklahoma. Considering only the forms restricted to the Blackriveran or Trentonian, the fauna is nearly 90 percent Trentonian. As the overlying Bromide Formation is believed to be Kings Lake to Beecher in age, it appears probable that at least the upper part of the Tulip Creek is basal Trentonian (Spechts Ferry).

Harris (1957, p. 82-83) assigned the Tulip Creek to the Blackriveran, but correlated it with the Decorah of the Mississippi Valley, which we consider Trentonian. His correlation perhaps is with the basal Decorah Spechts Ferry Formation, which for many years was classified as Blackriveran although it was not called Decorah at that time.

Cooper (1956, p. 120) assigned the Tulip Creek to the Ashby Stage (fig. 29), the lower of two new stages between the type Chazyan and the type Blackriveran. However, he correlated the Tulip Creek with the Dutchtown Limestone, which we consider directly traceable to the Murfreesboro Limestone of Tennessee and nearly as directly to the lower Pamelia in the type Black River of New York. Cooper puts the Murfreesboro in his Porterfield Stage, above the Ashby, and the Pamelia in his new Wilderness Stage, which includes the type Black River. If our correlation is correct, it returns to the Blackriveran many of the units placed by Cooper in the two stages that he erected between the Chazyan and Blackriveran.

Trentonian Stage

Galena Group Equivalents

As noted by Decker (1952, p. 136-137), the Bromide Formation contains a Trentonian (Galena) fauna. Out of the 127 forms reported, 8 (6 percent) are known only from the Platteville, 27 (21 percent) range from Blackriveran into Trentonian beds, 70 (55 percent) appear restricted to the Trentonian, and 22 (17 percent) have not been found outside Oklahoma. If we eliminate the second and fourth categories, the part of the fauna pertinent to correlation is 10 percent Blackriveran and 90 percent Trentonian.

The Bromide Formation is believed to be of lower Trentonian age for the following reasons: (1) It underlies the Viola Limestone, which is correlated with strata from middle Dunleith to Dubuque. (2) A sandstone at the base of the Bromide probably is equivalent to the siltstone and silty dolomite of the Kings Lake Formation farther east. (3) The remainder of the formation consists chiefly of thin-bedded limestone and shale that in gross lithology resembles the Guttenberg-St. James sequence. (4) The upward change of the shaly limestone of the Bromide into an uppermost, pure, thick-bedded unit from 10 to 15 feet or more thick (Decker and Merritt, 1931, p. 42, 54-86) is similar to the change from the St. James Member to the Beecher Member in the Dunleith Formation of Illinois. (5) Faunal analyses support the early Trentonian age of the Bromide. Of 97 Bromide species known from Trentonian strata elsewhere (the second and third groups above), 51 (53 percent) range from Blackriveran or Spechts Ferry strata into post-St. James beds, 33 (34 percent) are not known above the St. James, and 13 (13 percent) seem restricted to post-St. James strata elsewhere. Eliminating the first group, 72 percent of the pertinent fauna appears to be confined to St. James and earlier Trentonian beds (the Decorah of Iowa and Minnesota). Raasch (1951, personal communication) found faunal assemblages in the Bromide that are characteristic of Guttenberg and Ion (Buckhorn–St. James) beds, and Loeblich (1942, p. 416-417) found that the bryozoan fauna of the Bromide is closely allied to the bryozoan fauna of the Decorah in Minnesota. Finally, such species as *Ischadites iowensis* (Owen) and *Cheirocrinus logani* (Billings), which appear in lower Bromide strata above the basal sandstone, have not been reported from strata older than Guttenberg.

Harris (1957, p. 94-101) restricted the Bromide by separating from it an uppermost unit, the Corbin Ranch, commonly called the "Simpson Dense," that consists of lithographic limestone with thin beds of shale. It is commonly 20 to 30 feet thick but is absent in some areas and has a maximum thickness of 110 feet. He classified the lower part of the Bromide (Bromide restricted) as Blackriveran on the basis of a large ostracode fauna and on other fossils, but mainly, as he did the Tulip Creek, on comparison with the Decorah fauna that is Trentonian rather than Blackriveran. He correlated the Corbin Ranch with the Trentonian Prosser strata in the Mississippi Valley. However, the Viola-Kimmswick-Prosser correlation is well established, and it seems probable that the Corbin Ranch is equivalent to pre-Prosser Trentonian strata. The lithologic descriptions of part of the unit, probably the basal part, strongly suggest the Guttenberg Formation of the Mississippi Valley sequence.

Twenhofel et al. (1954) assigned the Bromide to the uppermost Chazyan and to the Blackriveran below the Chaumont. Although Loeblich (1942) dated the Bromide as Trentonian on the basis of its bryozoans, Cooper (*in* Twenhofel et al., 1954, p. 265; 1956, p. 120-123) stated that the brachiopods of the upper Bromide are Blackriveran. Cooper (1956, p. 120-123) divided the Bromide into the Mountain Lake Member (the dominantly clastic lower Bromide) and the Pooleville Member (the more calcareous upper member) which would include the Corbin Ranch Formation of Harris at the top. He extended the Bromide from the Ashby Stage through the Porterfield Stage to the middle of the Wilderness Stage, near the top of the Blackriveran.

The Viola Limestone, overlying the Bromide Formation, ranges from about 80 to

885 feet thick. It exhibits considerable lateral change in facies, and to the southwest it shows a marked increase in thickness and in clay and chert content. The fauna has been described by Decker and Merritt (1931), and the regional lithology has been studied by Wengerd (1948), who divided the formation into the following four members, numbered in descending order.

Member 1 (top)	Limestone, cherty, partly shaly, thin bedded to massive, 15′–135′
Member 2	Limestone, in general distinctly less cherty and shaly than adjoining members, 50′–125′
Member 3	Limestone, argillaceous, cherty, and shaly; upper part ordinarily less shaly and thicker bedded than lower part, 65′–235′
Member 4	Limestone, argillaceous, cherty and shaly; differs from Member 3 in having higher silica and shale content and planar bedding, 10′–235′

Members 3 and 4 contain a fauna similar to post-Beecher Dunleith strata and equivalent beds farther east. The upper part of member 3 probably represents the comparatively pure Wall and Wyota Members. Member 2, the least impure portion of the Viola sequence, appears to correspond approximately to Taylor's member 3 in Kansas and to the Wise Lake Formation of Illinois, although in places its boundaries probably are not identical with those of the Wise Lake. Strata that belong at least in part to member 2 contain *Rafinesquina deltoidea* (Conrad), *Deistoceras* cf. *D. Whiteavesi* Foerste, *Westonoceras manitobensis* (Whiteaves), and *Whiteavesites*. Elsewhere these fossils occur in beds of late Dunleith or Wise Lake age. Member 1 is tentatively correlated with the shaly, partly cherty limestone and dolomite of the Dubuque Formation of the Mississippi Valley.

Twenhofel et al. (1954) correlated basal Viola strata with the upper Blackriveran but extended the Viola upwards to the top of the Trentonian. The essential continuity of Galena, Kimmswick, and Viola strata from Illinois to Kansas makes it unlikely that it differs significantly in the Oklahoma area.

Cincinnatian Series

The Fernvale Limestone of Oklahoma, absent to 100 or more feet thick, rests unconformably on the Viola Limestone. It is equivalent to the Cape ("Fernvale") Limestone of Illinois and Missouri and has the same lithology, fauna, stratigraphic position, and stratigraphic relations. Because it is older than the type Fernvale Limestone of Tennessee, the name Ada was proposed for this limestone in Oklahoma (Shideler, 1937), but the name was preempted and did not come into use. In Oklahoma the Fernvale is overlain with probable unconformity by the Sylvan (Maquoketa) Shale. In at least one locality the upper surface of the Fernvale is rough and ferruginous (Decker and Merritt, 1931, p. 1412) and seems to resemble the solution-etched surface so widely present beneath the Maquoketa Shale in the Mississippi Valley. A depauperate zone in basal Sylvan strata seems equivalent to a similar zone at the base of the Elgin Shale in the Mississippi Valley.

Largely on the basis of the correlation of the Fernvale (Cape) Limestone of Oklahoma with the Fernvale of Tennessee and thence to the Waynesville of the Richmond Group, the Fernvale Limestone and Sylvan Shale of Oklahoma both have been assigned to the Richmondian Stage (Twenhofel et al., 1954). However, because of its similarity to the Maquoketa, we believe that the Sylvan contains Edenian and Maysvillian strata as well as Richmondian.

PENNSYLVANIA

Although we did not have an opportunity to study the Champlainian succession of Pennsylvania (Kay, 1944, 1956; Craig, 1949; Neuman, 1951), the area is of particular interest because of discrepancies between correlations based on following the Blackriveran-Trentonian boundary southward from New York to Virginia via Pennsylvania and correlations based on following the same boundary from New York to Virginia via Illinois (figs. 27, 29). Kay (1944, 1946, 1948, fig. 2) traced the contact through central

Pennsylvania and concluded that the Moccasin and Eggleston Formations of southwestern Virginia are of early Trentonian age and equivalent to the Rockland-Hull sequence of New York. We place the contact somewhat higher. By tracing the contact the long way around, through Ontario, northern Michigan, Illinois, and Kentucky, it appears to us that the Moccasin and the lower part of the Eggleston are Blackriveran, corresponding to upper Lowville and Chaumont strata in New York. Correlations through Pennsylvania and West Virginia (Woodward, 1951) are difficult because of geosynclinal thickening, marked facies changes, and structural complications.

Twenhofel et al. (1954) followed the correlations of Kay. However, Cooper (1956) presented another interpretation, placing the Blackriveran-Trentonian boundary even lower in Pennsylvania and somewhat lower in Virginia than had Kay. In 1956 Kay lowered the Blackriveran-Trentonian contact in southwestern Virginia to include uppermost Witten beds. Above the contact he raised the top of the Eggleston to within the Denmark and thus further enlarged the differences between our correlations.

The controversial portion of the sequence in central Pennsylvania is as follows (Kay, 1944):

Salona Formation
Nealmont Formation
  Rodman Member
    Limestone, argillaceous, dark gray, brownish weathering, mainly coarse grained and thick bedded, fossiliferous; lower 8 feet is thin bedded, cherty, partly shaly, and contains thin layers of dense, white-weathering limestone; 26′–30′
  Centre Hall Member
    Limestone, gray, medium grained, mostly thin bedded and shaly, but contains thick ledges; bentonite at the base; overlaps Oak Hall Member; contains *Arthroclema, Chasmatopora reticulata* (Hall), *Eridotrypa, Escharopora subrecta* (Ulrich), *Pachydictya occidentalis* Ulrich, *Stictoporella, Doleroides pervetus* (Conrad), *Glyptorthis* cf. *G. bellarugosa* (Conrad), *Sowerbyella punctostriata* (Mather), and others; 45′–60′
  Oak Hall Member
    Limestone and calcarenite, mainly pure, gray, medium grained, thick bedded, partly cherty; bentonite from 12 to 18 feet below the top; major widespread unconformity at the base; contains *Foerstephyllum halli* (Nicholson), *Eoleperditia fabulites* (Conrad) and other long-ranging Blackriveran-Trentonian fossils; 0–60′
Curtin Formation

The Nealmont Formation is said to grade southward into Moccasin-Eggleston strata and has been correlated with the Rockland and Hull ("Kirkfield") Formations of New York and Ontario (Kay, 1944, p. 107-109, fig. 2; 1946; 1948, p. 1411-1412, fig. 2). The relatively pure, thick-bedded basal Oak Hall Member of the Nealmont seems strikingly similar in lithology, thickness, and fauna to the Nachusa (Chaumont) and Quimbys Mill Formations elsewhere in the eastern United States. *Foerstephyllum halli* (Nicholson) first becomes abundant in lower Oak Hall beds and in Nachusa and Chaumont strata, and in both units is associated with numerous *Eoleperditia fabulites* (Conrad). The bentonite from 12 to 18 feet below the top of the Oak Hall is believed to be the very widespread bentonite (V-3 of Virginia) at the base of the Quimbys Mill Formation. Traced from the west the Nachusa and Quimbys Mill Formations appear to be equivalent to upper Moccasin strata and nearly all of the Eggleston Formation in Virginia.

The bentonite at the top of the Oak Hall Member or the base of the Centre Hall Member is equivalent to the bentonite at the base of the Spechts Ferry Formation (V-4 of Virginia). This bentonite and bentonite V-3 are the two thickest and most persistent Champlainian bentonites. In lithology the Centre Hall Member seems to resemble very closely the southwest Virginia equivalents of the basal Trenton Spechts Ferry Formation and the units are comparable in thickness. The fauna of the Centre Hall is typical of the Spechts Ferry, and most of the forms mentioned above are unknown in older beds. Strata equivalent to the Spechts Ferry have been classed as uppermost Eggleston and lower Martinsburg near Tazewell, Virginia, and as uppermost Eggleston, Curdsville, and lower Hermitage at Hagan Siding, Virginia (see *Virginia*). Kings Lake strata appear to be absent in central Pennsylvania.

The lower 8 feet of the Rodman Member seems much like the Guttenberg Formation. *Lichenaria coboconkensis* Okulitch, described from the Rockland (Guttenberg) of Ontario, reported in the Rodman Member may have come from these lower beds. The lithology and stratigraphic position of the remainder of the Rodman strata appear to match the Buckhorn-Beecher (Hull) sequence both in Kentucky and New York, although part of the typical fauna of these units has not been reported from the Rodman.

The unconformity at the base of the Nealmont Formation is widespread in central Pennsylvania and may be present in Tennessee (see *Tennessee*). However, it has not been recognized in other areas that we have studied.

SOUTH DAKOTA

Near Deadwood, Lawrence County, South Dakota, in the northern Black Hills, the following sequence rests on Deadwood strata of Upper Cambrian age and is overlain unconformably by the Mississippian Englewood Limestone (Darton and Paige, 1925, p. 5-7; Furnish et al., 1936; McCoy, 1952; Carlson, 1960):

Whitewood Formation
- "Dolomite Member"
  - Dolomite, buff, mottled with red, fine grained, thick bedded; contains argillaceous zones; chert in upper part; 60′–70′

Winnipeg Formation
- Roughlock Member
  - "Transitional Member"
    - Dolomite, silty, sandy, interbedded with and grading into partly dolomitic sandstones; 10′–20′
  - "Siltstone Member"
    - Siltstone, sandy, partly dolomitic; contains fucoids and fish plates; 20′
- Icebox Member
  - "Shale Member"
    - Shale, sandy, phosphatic, gray, platy, weak; 25′–70′

Deadwood Formation
- Aladdin Member
  - "*Scolithus* Sandstone Member"
    - Sandstone, light brown to red, coarse grained, cross bedded, partly quartzitic; contains many specimens of the worm-boring *Scolithus*; 15′–50′
- "Upper Member"
  - Sandstone, red, interbedded with green shale and brecciated dolomite, very glauconitic and fucoidal, but otherwise unfossiliferous; 50′–110′

Darton and Paige placed the Deadwood-Whitewood contact at the base of the "Dolomite Member," whereas Furnish et al. lowered it to the top of the "*Scolithus* Sandstone Member," tentatively leaving the latter in the Deadwood Formation. McCoy restored Whitewood to its original boundaries and introduced the Roughlock, Icebox, and Aladdin Formations. Carlson correlated the Icebox and Roughlock with the Winnipeg and made them members of that formation. In subsurface in the Williston Basin he included the Black Island Sandstone from the Manitoba sequence as the basal member of the Winnipeg.

The "Upper Member" of the Deadwood, which overlies fossiliferous limestone and shale, may be either Upper Cambrian or Lower Ordovician. Its lithology suggests that it is Upper Cambrian, but fossils found in this interval (Lochman and Duncan, 1950) suggest an early Ordovician age.

In lithologic and faunal features, the Aladdin, Icebox, and Roughlock Members resemble, respectively, the lower, middle, and upper members of the Harding Sandstone of Colorado (See *Colorado*). The transitional zone at the top of the Roughlock Member probably is equivalent also to the Lander Sandstone of Wyoming. In relation to the Mississippi Valley sequence (fig. 27), it seems likely that the Aladdin Sandstone is of St. Peter-Glenwood age. The basal portion of the overlying Icebox Member probably is of late Glenwood age.

Although the part of the Harding correlated with the Icebox Shale Member contains a macrofauna of Platteville age in Colorado, the fact that it carries a basal Trentonian scolecodont fauna in South Dakota suggests that Spechts Ferry beds also are included (Furnish et al., 1936, p. 1333). The siltstone of the Roughlock Member contains a macrofauna (Furnish et al., 1936, p. 1335, 1338-1340) that is clearly Trentonian and probably represents strata of Kings Lake to St. James age. The upper transitional unit of the Roughlock contains forms allied to *Cyrtodonta gibbera* Ulrich and *Bellerophon similis* Ulrich & Scofield, both of which are confined to Buckhorn-Sinsinawa (Ion-Prosser) beds, and a species allied to *Tripteroceras hastatum* (Billings) which is limited to Guttenberg, Buckhorn, and St. James strata. It thus seems likely that the transitional unit is equivalent to Buckhorn-St. James beds, which are sandy toward the base as far eastward as Illinois.

Carlson (1960, p. 73) reported that the lower part of the Icebox Member contains a conodont fauna similar to that of the Glenwood of Minnesota, and the middle and upper parts contain a fauna similar to that of the Decorah Formation. As the Roughlock Member contains a conodont fauna more closely related to the Decorah than to higher Galena strata, Carlson's correlation closely supports the above interpretations. Cooper (1956, p. 213) also assigns the "Siltstone Member" (Roughlock) to an early Trentonian (Rockland) age on the basis of its brachiopods.

The Whitewood Formation has striking similarities in lithology, fauna, and stratigraphic position to the post-St. James portion of the Dunleith Formation in Illinois and with the equivalent part of the Fremont Dolomite in Colorado.

According to Cooper (1956), the Whitewood Dolomite contains fossils of probable Upper Devonian age.

Although the Whitewood Dolomite has been classed as Upper Ordovician on the basis of its cephalopod fauna (Miller and Furnish, 1937, p. 539), many of the cephalopod genera from the Whitewood and related dolomites of western and arctic North America actually arise in the Champlainian (Kay, 1935b, p. 586-590; Miller and Furnish, 1937, p. 536-540; Flower, 1942, p. 8-12; 1946, p. 105-107). For this reason Miller and Carrier (1942, p. 534) and Bassler (1950, p. 19) have suggested assignment of the Stewartville Dolomite of the Mississippi Valley to the upper Ordovician (Cincinnatian). However, the regional lithology, other elements of the fauna, and stratigraphic relations of the Galena-Trenton strata, as well as relation to the defined lower boundary of the Cincinnatian in its type area, strongly oppose this suggestion.

TENNESSEE

The Champlainian sequence in central Tennessee (fig. 36) closely matches the sequence in Illinois and elsewhere in the Mississippi Valley. Many units are almost identical in fauna and lithology in both regions. The Tennessee sequence consists of limestone with subordinate amounts of dolomite and shale and is classified as follows (Wilson, 1949, fig. 1):

Nashville Group
- Catheys Formation
- Bigby-Cannon Limestone
- Hermitage Formation

Stones River Group
- Carters Limestone
- Lebanon Limestone
- Ridley Limestone
- Pierce Limestone
- Murfreesboro Limestone
- Wells Creek Dolomite

The Nashville Group is equivalent to the Galena Group of the Mississippi Valley and the Trenton Group of New York (excluding Collingwood beds). The Stones River Group is equivalent to the Everton, Ancell, and Platteville Groups of the Mississippi Valley and to the Black River and Chazy Groups of New York (fig. 27).

Twenhofel et al. (1954) assigned the Nashville Group and the Carters Formation of the Stones River Group to the Trentonian Stage and the remainder of the Stones River to the Blackriveran. They did not mention the Wells Creek Dolomite, which is not exposed in the Central Basin of Tennessee. Cooper (1956) put the base of the Trentonian even lower, at the base of the Lebanon Limestone, and he included the Murfreesboro Limestone in his Porterfield Stage, below the Blackriveran. He assigned the Wells Creek Dolomite to the Canadian Series. The base of his redefined Trenton Stage is the base of the Hermitage (fig. 29).

The section at Aspen Hill in southern Tennessee, which Ulrich (1911) correlated with

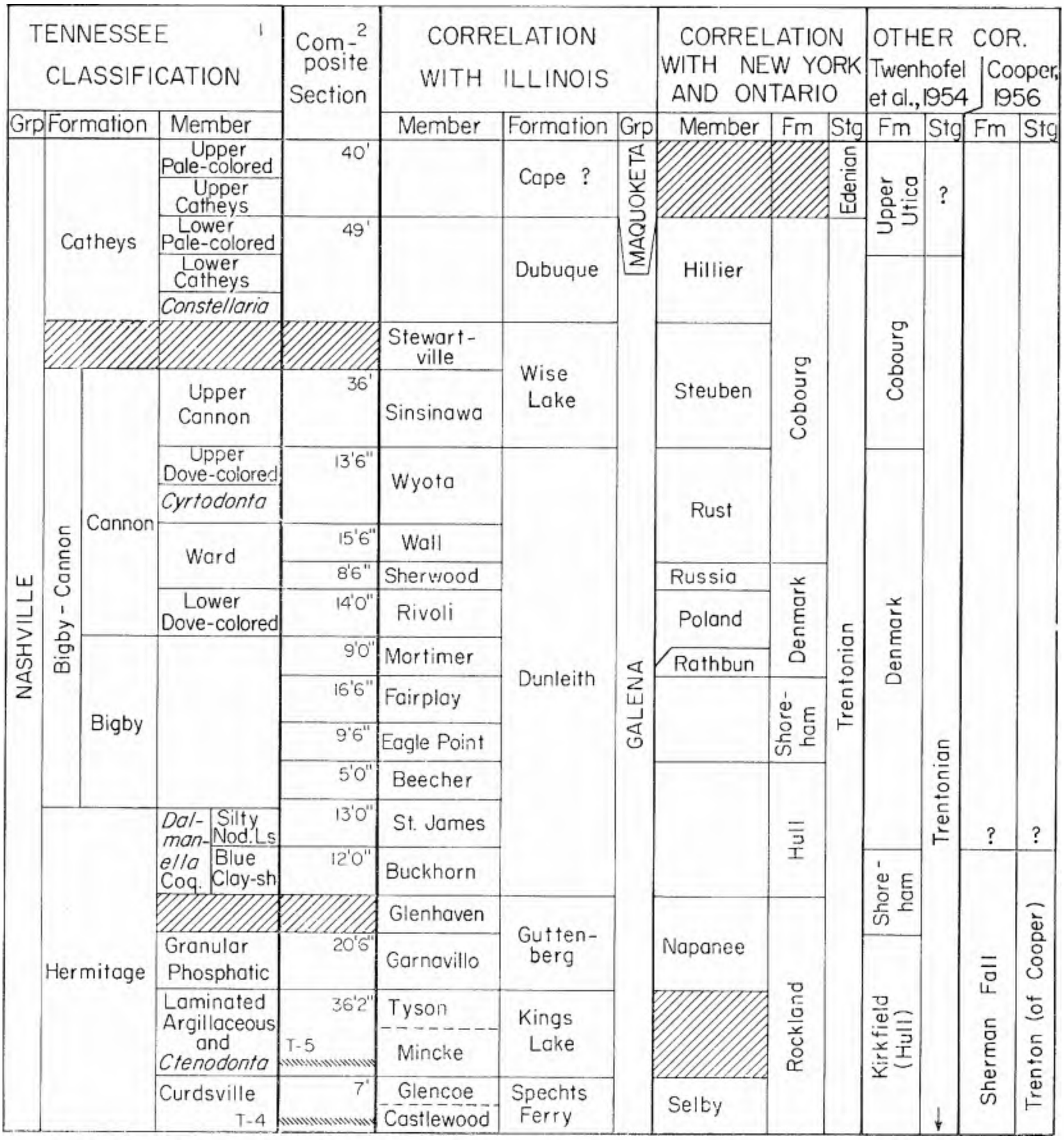


FIG. 36.—Correlation of the Champlainian Series in central Tennessee with Illinois.

[1]/Bentall and Collins, 1945, sheet 1; Wilson, 1948, p. 8-45; Wilson, 1949, p. 23-201. Catheys and Cannon Member names are applied only in the Nashville area.

[2]/Upper Pale-colored Member taken from quarry at Charlotte Pike and 38th Avenue N., Nashville (Wilson, 1948, locality 84). Upper Catheys Member and Lower Pale-colored Member taken from quarry at Dickerson Pike and Carver Street, Nashville (locality 27). Lower Catheys Member is from locality 27 and northwest end of cut on Tennessee Central Railroad, just east of freight station, Nashville. Section from top of *Constellaria* Member to base of strata correlated with the St. James Member taken mainly along Tennessee Central Railroad and in Blind School quarry at southeast end of cut, Nashville (locality 18). Mortimer Member equivalents projected from bluff on south side of Cumberland River and of U. S. Highway 70N at South Carthage, Smith County. The Mortimer is absent at Nashville, where upper foot of Bigby Formation represents basal part of Rivoli Member. Buckhorn Member equivalents taken from bluff on east side of Stones River and north side of U. S. Highway 70N, 7 miles east of Nashville. Granular Phosphatic Member from ravine exposure on north side of road, 2 miles southeast of Greenvale, Wilson County, and one-eighth of a mile north of locality 6,

(Continued on p. 198)

(Continued) TENNESSEE CLASSIFICATION[1]			Composite[2] Section	CORRELATION WITH ILLINOIS			CORRELATION WITH NEW YORK AND ONTARIO			OTHER COR. Twenhofel et al., 1954		OTHER COR. Cooper, 1956	
Grp	Formation	Member		Member	Formation	Grp	Member	Fm.	Stg	Fm.	Stg	Fm.	Stg
STONES RIVER	Carters	Upper Carters T-4	4'1"	Strawbridge	Quimbys Mill	PLATTEVILLE	(hatched)	(hatched)		Rockland	Trentonian	Hull	Wilderness
			6'0"	Shullsburg									
		T-3	0.5'	Hazel Green									
		Lower Carters T-2	3'8"	Everett	Nachusa		Watertown	Chaumont				Rockland	
				Elm			Glenburnie						
		T-1		Eldena			Leray						
			30'	Forreston	Grand Detour		Upper Division	Lowville					
	Lebanon	Upper Thin-bedded	6'	Victory						Chaumont	Black River		
			9'	Hely									
			1'	Clement									
			9'6"	Stillman			Lower Division						
			8'6"	Walgreen									
		Massive-bedded	14'4"	Dement									
		Lower Thin-bedded	8'6"	Briton	Mifflin								
			12'	Hazelwood									
			13'	Establishm'nt									
				Brickeys									
				Blomeyer									
	Ridley		6'	Oglesby	Pecatonica				Blackriveran	Lowville		Chaumont	
			23'2"	Medusa									
			14'3"	New Glarus									
		Thin-bedded	32'6"	Dane								Lowville	
			22'4"	Chana									
	Pierce	(hatched)	(hatched)			ANCELL	Upper Division	Pamelia				Pamelia	
			27'		Joachim								
		(hatched)	(hatched)							Pamelia			
	Murfreesboro	Upper: Dark Cherty	50'		Dutchtown		Lower Division					(hatched)	Porterfield
		Upper: Dark	72'										
		Lower: Dark Argill.	48'										
		Lower: Dark	140'							?	?		
		Lower: Light	75'		St. Peter								
	Wells Creek		35'			EVERTON		Valcour	Chazyan				Canadian
								Crown Pt.					
								Day Point					

the Kimmswick of Missouri, is equivalent to upper Platteville strata. This accounts in part for the erroneous assignment of a Trentonian age to Carters strata.

Twenty of the more important exposures of the Stones River and Nashville Groups in the Central Basin of Tennessee and in the Sequatchie Valley were examined during this study (fig. 37). The continuation of central Tennessee stratigraphic units into the Chattanooga area of southeastern Tennessee has been summarized by Fox and Grant (1944).

Chazyan Stage

Everton Group Equivalents

The Wells Creek Dolomite unconformably overlies Beekmantown (Canadian) Dolomite in the subsurface of Tennessee (Bentall and Collins, 1945, Sheet 1). Most of the formation is argillaceous, silty, sandy, and shaly. It is similar in lithology and stratigraphic position to the Everton Group of Illinois and Missouri and can be traced into Everton strata via wells in western Kentucky (Freeman, 1945, p. 39; 1953). Eastward, the Wells Creek Dolomite appears to grade laterally into the basal clastics and ash-gray shale of the Blackford Formation of southwestern Virginia (Prouty, 1946, p. 1145), which is thought to be Chazyan (see *Virginia*). This evidence, coupled with the occurrence of Chazyan fossils in the Everton of Arkansas, suggests that the Wells Creek and Everton Formations are of Chazyan age.

Blackriveran Stage

Ancell Group Equivalents

St. Peter Equivalents.—The light colored limestone and dolomite in the lower part of the Murfreesboro (Bentall and Collins, 1945, Sheet 1) appears to be an off-shore carbonate facies of the St. Peter Sandstone of the Mississippi Valley. It is traced into the St. Peter through the subsurface of western Kentucky and southern Illinois. In Tennessee it rests with apparent conformity on the Wells Creek Dolomite.

Dutchtown Equivalents.—The black to dark gray, partly cherty or argillaceous middle and upper parts of the Murfreesboro Limestone also can be traced in wells into the very similar Dutchtown Formation of Missouri, a correlation supported by the abundance of *Lophospira* in both formations. Nearly identical lithology is found in the Lincolnshire–lower Peery Limestones of southwestern Virginia, and, as noted by Cooper and Prouty (1943, p. 867-868), *Poly-*

Footnotes for figure 36 *(continued)*

cross section F-F′ (Wilson, 1949, p. 163, fig. 36). Laminated Argillaceous Member is from South Carthage section. Curdsville and Upper Carters Members taken from cut and quarry on northeast side of State Highway 11, just southeast of Tennessee Central Railroad tracks and opposite the State Fair Grounds, Nashville (Wilson, 1948, locality 22). Bentonite in Curdsville projected from cut on east side of U. S. Highway 41, just north of the Coffee-Rutherford County line and 2 miles north of Beech Grove. Bentonite in Strawbridge projected from cut on west side of State Highway 130, a quarter of a mile north of Singleton, Bedford County. Nachusa Formation equivalents taken from quarry on north side of U. S. Highway 70N, opposite east end of Mt. Olivet Cemetery, Nashville (locality 10), and from bluff on east side of East Fork of Stones River and north side of U. S. Highway 70S at Readyville on Cannon-Rutherford County line. Forreston Member equivalents taken from Readyville section. Victory and Hely equivalents taken from bluff on south side of Cumberland River and east side of State Highway 10 at Hunters Point, Wilson County. Clement and Stillman equivalents are from combined Readyville and Hunters Point sections. Walgreen and Dement equivalents are from Readyville section. Lower Thin-bedded Member of Lebanon Formation (Mifflin equivalents) taken from Hunters Point section, on both sides of highway. Oglesby, Medusa, and New Glarus equivalents are from Readyville section. Dane equivalents are from bluff on west bank of West Fork of Stones River, 1 mile west of Jefferson, Rutherford County. Chana equivalents taken from bluff on south bank of East Fork of Stones River and north side of Jefferson-Lascassas Turnpike, 0.6 miles east of Jefferson, Rutherford County. Pierce Limestone is from type section in bluff on north side of East Fork of Stones River and east side of State Highway 10, half a mile south of Walterhill. Upper 70 feet of Murfreesboro Limestone taken from valley exposure west of ice plant at south edge of Murfreesboro, on west side of U. S. Highway 41, just south of junction with Bradyville Turnpike. Remainder of Murfreesboro Limestone and Wells Creek Dolomite is from Vultee Aircraft, Inc., Fee No. 1, sec. 12, 5S-34E, Davidson County, 3 miles southeast of Nashville (Bentall and Collins, 1945, sheet 1, well 266).

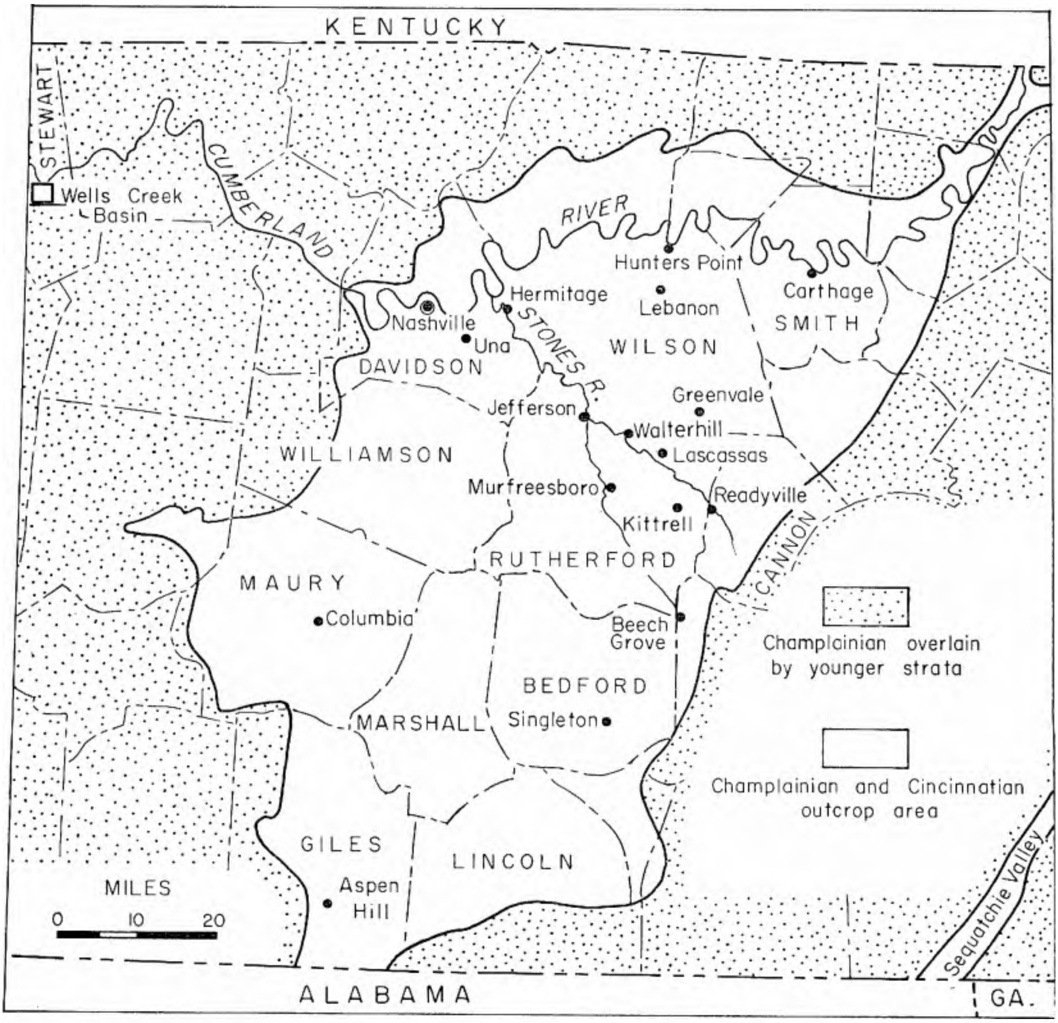


FIG. 37.—Central Tennessee, showing outcrop area of Champlainian and Cincinnatian strata and localities mentioned. Boundary of Ordovician rocks generalized from *Geologic Map of Tennessee*, Tennessee Division of Geology.

lopia billingsi (Safford) and several species of *Lophospira* are common both to upper Murfreesboro and to lower Peery strata (Zone 8—*Lophospira* beds of Virginia).

Joachim Equivalents.—The Pierce Limestone is a more or less argillaceous and silty formation averaging about 27 feet thick. It corresponds to the Joachim Formation of Missouri and Illinois in being relatively impure (Wilson, 1949, p. 33) and in stratigraphic position. The lower 9 feet are less argillaceous and silty than the overlying beds, are fine grained, slightly cherty, and chiefly massive. The upper 18 feet are chalky, thin bedded, shaly, and contain some thin layers of coarse-grained, very fossiliferous calcarenite .

Because a diastem is present in places at the top of the Ancell Group, and because no break in sedimentation is known between the Dutchtown and Joachim Formations, it seems likely that the comparative thinness of the Pierce Limestone is caused by a hiatus at the top. If upper Joachim equivalents are missing over the Nashville Dome, the lower massive Pierce unit may represent the Augusta Member and the upper thin-bedded unit the Boles Member, although any correlations must remain speculative until subsurface tracing has been carried out. The abundant bryozoan fauna of the Pierce suggests deposition in a normal marine environment, in contrast to the highly saline environment of Joachim sedimentation.

Platteville Group Equivalents

Pecatonica Equivalents.—In gross lithology and subdivisions the Ridley Limestone closely matches the Pecatonica Limestone of eastern Missouri. Both contain abundant *Stromatocerium* cf. *S. rugosum* Hall and *Tetradium syringoporoides* Ulrich in certain beds and have other fossils in common. The lower 20 to 35 feet of the Ridley, well exposed at Pierce's Mill and at the Ridley type section (Wilson, 1949, p. 32, 34), is pure, massive, and locally vuggy, and corresponds to the Chana Member of the Pecatonica Formation. The overlying Dane equivalent is from 30 to 35 feet thick, is thin bedded and moderately shaly at bottom and top, and carries numerous *Öpikina minnesotensis* (N. H. Winchell). It differs from the Dane of northern states in having a pure massive unit from 13 to 15 feet thick in the middle, beginning from 3 to 10 feet above the base of the member. The basal shaly unit of the Dane equivalent is the Thin-bedded Member of Wilson (1949, p. 35). Dane equivalents are completely exposed in the bluffs on the west side of the West Fork of Stones River, 1 mile west of Jefferson, Rutherford County, beginning 8 feet above the base of the exposure (Galloway, 1919, p. 41).

The next 11½ to 14½ feet of the Ridley Formation is pure and mainly thick bedded. This unit, carrying numerous black silicified *Stromatocerium* and *Tetradium* at Hunters Point, Wilson County, is correlated with the New Glarus Member in Missouri which has similar lithology and contains numerous *Tetradium*. With adjacent members the New Glarus equivalent is well exposed at Readyville, Rutherford County (Wilson, 1949, p. 40), and at Hunters Point along the south bank of the Cumberland River west of State Highway 10. At the latter locality the sequence is complicated by small faults.

The succeeding 21 to 23 feet of the Ridley Formation, is equivalent to the Medusa Member. It generally is very fucoidal and is in thick beds separated by weak shale partings. At Hunters Point, however, only the upper 7 feet is strongly fucoidal and at Readyville the upper 6 feet is thin bedded and shaly. A 3-foot bed with black chert nodules 4½ feet above the base of the unit at Hunters Point probably is equivalent to part of a basal 10-foot layer that contains black to white chert nodules at Cape Girardeau, Missouri. The upper part of the Medusa equivalent is exceptionally well exposed in a quarry on the north side of U. S. Highway 70N on the west edge of Lebanon, Wilson County, where 19 feet of Medusa is overlain by 2 feet 6 inches of the Oglesby Member.

The most distinctive unit in the sequence equivalent to the Pecatonica is calcarenitic limestone and coarse-grained calcarenite that corresponds to the Oglesby Member of the Mississippi Valley. It ranges from 2½ feet thick in the Lebanon quarry and 3½ feet thick at Hunters Point to 6 feet thick at Readyville and 7 feet thick at Kittrell, Rutherford County (Galloway, 1919, p. 44-45). At Kittrell this unit was considered basal Lebanon, and at Readyville, the Oglesby and upper Medusa equivalents were placed in the Lebanon (Wilson, 1949, fig. 11). At some other localities, however, the Oglesby appears to have been included in Ridley Limestone, and it is so treated in this paper. The Oglesby equivalents are thinner and much coarser grained in Tennessee than in Kentucky. In Tennessee its comparative thinness, its irregularity in thickness, and the apparent absence of the middle shaly unit and of higher beds suggest that there is a diastem at the top of the member, as in the region to the north.

Mifflin Equivalents.—At Hunters Point the basal 25 feet of the Lebanon Formation, resting on the calcarenite of the Oglesby Member, consists of blue-gray, lithographic, fucoidal, platy limestone with a few weak shale partings in the lower thirteen feet. This sequence is tentatively correlated with the Blomeyer through Hazelwood Members of the Mifflin Formation in Missouri and Illinois. The upper 12 feet has thicker primary beds and more fucoids and probably is of Hazelwood age, but deep weathering makes this unit indistinguishable from lower strata along most of the exposure. The succeeding 8½ feet, equivalent to the Briton Member, is composed of argillaceous, shaly, thin-bedded limestone and calcarenite with profuse *Eoleperditia fabulites* (Conrad) and other common upper Mifflin fossils. Mifflin representatives are 8 feet thicker at Readyville but are poorly exposed.

In a quarry on the north side of U. S. Highway 70N and at the west edge of Lebanon 14½ feet of Mifflin (lower Lebanon) strata rests on 21½ feet of Pecatonica (Ridley) beds. The 13 feet of thin-bedded, slightly shaly limestone, tentatively correlated with the Blomeyer-Establishment representatives at Hunters Point, seems to have wedged out southward toward the crest of the Nashville Dome within a distance of 6 miles. Consequently, the overlying somewhat purer and thicker bedded fucoidal Hazelwood Limestone, here reduced to 7½ feet thick, rests directly on the Pecatonica Limestone. Wilson (1949, p. 42) has shown thinning of the entire Lebanon (Mifflin-Grand Detour) Formation over the Nashville Dome. The top 7 feet of the quarry consists of argillaceous, calcarenitic, very thin-bedded, shaly limestone which in places contains a profusion of *Eoleperditia* and which seems typical of the Briton Member.

Grand Detour Equivalents.—The most complete exposures of Grand Detour equivalents that were studied in Tennessee are in the bluff on the south side of the Cumberland River east of the bridge carrying State Highway 10. The lower part of the formation is best exposed in a low cliff rising from the water's edge immediately east of the bridge. The upper part crops out in a small, shallow ravine cutting the lower part of the bluff, beneath cliffs of Lower Carters (Nachusa) strata, about three-fourths of a mile east of the bridge and just west of the point where the river turns northward. Other outcrops occur in the Lebanon type section near Readyville and at various other localities.

At Readyville a 14½-foot unit beginning 41½ feet above the Ridley-Lebanon contact consists of calcarenitic, medium- to thick-bedded limestone that is distinctly less argillaceous and thicker bedded than the strata below, and which matches the Dement Member of the Grand Detour Formation. The 8½ feet of thin- to medium-bedded, slightly shaly limestone overlying this unit seems to correspond to the Walgreen Member. At Hunters Point the combined Dement and Walgreen equivalents appear to be represented by 17½ feet of slightly argillaceous, slightly shaly, medium-bedded limestone. Above this is a 1-foot bed of coarse-grained massive calcarenite overlain by 6½ feet of pure, medium-bedded, partly fucoidal limestone that in turn is capped by 2 feet 8 inches of coarse-grained massive calcarenite having a 5-inch limestone layer in the middle. Only the lower calcarenite and lower part of the fucoidal limestone are exposed at Readyville, at the base of a 22-foot covered interval. This striking succession matches the Stillman-Clement sequence in Missouri, Kentucky, and Virginia, where the upper calcarenite equals the Clement Member.

Overlying the Clement at Hunters Point is 10½ feet of very thin- to medium-bedded, partly shaly limestone with a few thin calcarenite layers, which is believed to represent the Hely Member. Above this unit is a massive 7-foot ledge of pure, lithographic, whitish-weathering limestone that matches the Victory Member except for being brown instead of gray or white.

The Victory Member is succeeded by 30 feet of thin- to medium-bedded, partly shaly limestone that is equivalent to the Forreston Member. At Readyville also the Forreston is about 30 feet thick and shows a sequence of three argillaceous shaly units separated by two relatively pure thicker bedded units, which is characteristic of the member in northern Illinois. Like the Forreston in the Mississippi Valley, the unit has a few thin calcarenite layers, is partly fucoidal, and at Readyville is partly cherty. The 30-foot thickness at Hunters Point and Readyville compares with the 32½ feet present at Camp Nelson, Kentucky. In a quarry in Rutherford County, on the west side of U. S. Highway 41, 11½ miles south of the Murfreesboro city limits, the Forreston equivalent contains dark brown-red shale partings much like those occurring in Forreston strata in the type area in Illinois. Southeast of Nashville the upper 18 feet of the Forreston is well exposed in the Hermitage Portland Cement Company quarry on the west side of Mill Creek, 2¼ miles by road west of the hamlet of Una on the Murfreesboro Pike (U. S. Highway 41).

At Hunters Point the Victory Member has been designated the Massive-bedded Member of the Lebanon Formation, but at Readyville the lower part of the Dement equivalent was thought to represent the Massive-bedded Member (Wilson, 1949, p. 40-41, fig. 11). The Lebanon-Carters contact, like the equivalent Oregon-Tyrone contact in Kentucky, also has not been consistently recognized. At Readyville it was drawn at a position equivalent to the top of the lower Forreston pure bed, 21½ feet below the top of the Forreston Member, but at Hunters Point it was placed at the top of the Forreston Member (Wilson, 1949, fig. 11).

Nachusa Equivalents.—The Lower Carters, exclusive of upper Forreston beds included in places at the base, is remarkably similar in lithology, fauna, and stratigraphic position to the Nachusa Formation of the Mississippi Valley and to the middle and upper parts of the Lower Tyrone of Kentucky. The Lower Carters consists mainly of light gray to brown, dolomite-mottled, lithographic limestone that is cherty, fucoidal, and thick bedded. In the vicinity of Nashville and near Aspen Hill, Giles County, it contains thin to thick layers of partly cross-bedded calcarenite as well as some conglomeratic or pisolitic streaks. It is only 38 feet thick at Readyville and 44 feet thick at Aspen Hill. Southeast of Nashville, however, the Lower Carters attains a thickness of 64 feet in the east bluff of Mill Creek and the adjacent Franklin Limestone Company quarry, 1.65 miles by road west of Una, Davidson County. The greatest thickness measured was 70 feet in the north bluff of Mill Creek, 1.3 miles by airline northeast of Wrencoe, Davidson County, and an equal thickness occurs in the south bluff of the Cumberland River three-fourths of a mile east of Hunters Point.

The lower part of the Lower Carters is slightly argillaceous and is less fucoidal and less massively bedded than the upper part. This lower unit corresponds to the Eldena Member of the Nachusa Formation. A bentonite from 1 to 2 inches thick (T-1 of Wilson, 1948, p. 17; 1949, p. 62-65) is present at the top of the Eldena representative in the quarry at the east edge of Nashville on the north side of U. S. Highway 70N opposite Mt. Olivet Cemetery, and at the southeast edge of Nashville in the west bluff of Mill Creek just north of U. S. Highway 41 (Murfreesboro Pike). The bentonite is absent, however, in the Franklin Limestone Company quarry and 0.6 mile farther west in the Hermitage Portland Cement Company quarry. Eldena equivalents are 32 to 33 feet thick in the Franklin and Hermitage quarries but are only 16½ feet thick at Readyville.

The extent of Elm equivalents in Tennessee is uncertain. At Readyville 9 feet of slightly fucoidal, thin-bedded limestone which makes a slope between projecting ledges of fucoidal, medium-bedded to massive limestone is tentatively assigned to the Elm Member. In the vicinity of Nashville, however, where the Nachusa equivalents are 26 to 32 feet thicker than at Readyville, the only trace of Elm lithology is a layer of thin-bedded, moderately shaly limestone from 3 to 7 inches thick that directly overlies bentonite T-1, is found only where the bentonite is present, and might result from a slight reworking of the bentonite. In the Nashville area Elm strata may have graded into pure, thick-bedded calcarenite and limestone which are indistinguishable from the overlying representatives of the Everett Member. However, in southeastern Missouri, where the Everett has comparable thickness and the Elm is distinct, the interval between the bentonite in the middle of the Everett and the base of the member is the same as, or greater than that interval at Nashville. This suggests that Elm beds are thin or absent in the Nashville area. Local preservation of bentonite T-1 indicates that the hiatus occurs at the top rather than the base of the 3- to 7-inch thin-bedded unit correlated with the Elm.

The upper part of the Lower Carters is composed of pure, fucoidal, thick-bedded to massive limestone that is equivalent to the Everett Member. This unit ranges from 13 feet thick at Readyville to 31 feet thick at Nashville. At Nashville a 2-inch bentonite (T-2) lies 12 feet 4 inches above the base of the member. Like the bentonite at the top of the underlying Eldena equivalent, the bentonite in the Everett can be traced from Missouri to Virginia. At Nashville a 1- to 3-inch layer of white limestone at the top of the Everett seems identical with the persistent "white bed" that occurs at that position throughout the Mississippi Valley. This layer is well exhibited in the cut on State Highway 11 (Nolensville Pike) opposite the State Fairgrounds (Wilson, 1948, p. 18, locality 22), in the quarry opposite Mt. Olivet Cemetery, and in a cut on the north side of U. S. Highway 41 (Murfreesboro Pike) where it descends the west valley slope of Mill Creek.

Wilson (1949, p. 54-56) reported a minor unconformity between the Lebanon and the Carters. Although part of the evidence of unconformity may stem from inconsistent drawing of the Lebanon-Carters contact, some of the data suggest that uplift of the Nashville Dome produced a local break in sedimentation in the Forreston or at the Grand Detour-Nachusa contact. An unconformity at the latter horizon is believed to occur in Pennsylvania but has not been observed in other areas that we have studied.

The abundance of *Foerstephyllum halli* (Nicholson), *Lambeophyllum profundum* (Conrad), *Lichenaria carterensis* (Safford), *Tetradium fibratum* Safford, and fucoids makes the faunal correlation of the Lower Carters with Nachusa striking. *Stromatocerium rugosum* Hall, abundant in the Nachusa parts of both the Carters Limestone and the Tyrone Limestone of Kentucky, also is abundant in the Chaumont Limestone of New York (Young, 1943, p. 233). It may be confined to that stratigraphic unit, although an allied but different species is locally profuse in the Ridley and Pecatonica Limestones. *Tetradium fibratum* Safford likewise is common in the Chaumont. *Actinoceras tenuifilum* (Hall), an abundant Chaumont species, also is present to common in the Nachusa and in equivalent Carters-Tyrone strata, although in Tennessee it ranges into Upper Carters strata of Quimbys Mill age.

In the Louisville and Nashville Railroad cut three-fourths of a mile south of Aspen Hill, the Lower Carters interfingers with coarse-grained calcarenite resembling the Kimmswick Formation of Missouri and is said to contain *Echinosphaerites* and *Receptaculites oweni* Hall (Wilson, 1949, p. 65-67). Examination of this locality revealed a reef in the Lower Carters (Nachusa) Limestone. The structureless reef core consists of intermingled dove-colored limestone and calcarenite which is replete with large specimens of *Foerstephyllum, Lichenaria, Stromatocerium, Tetradium,* and *Isotelus,* and which also contains some lenses packed with gastropods and many pisolitic streaks. The top of the reef core exhibits low but distinct elongate domes, and is overlain by the thin layer of white limestone, here 3 inches thick, that typically marks the top of the Nachusa Formation in states bordering the Mississippi Valley. The reef core is about 27 feet thick. It grades downward into fine- to coarse-grained calcarenite and grades laterally into coarse-grained calcarenite representing reef-flank beds. Beds of similar calcarenite are common in the Lower Carters of the Nashville area. Careful search of the calcarenite and limestone at Aspen Hill failed to reveal any trace of *Echinosphaerites* or *Receptaculites,* and it appears probable that reported occurrences of these fossils are based upon erroneous locations or identifications. The stratigraphic sequence, beginning at the hill crest west of the railroad cut and terminating along a farm lane just northeast of the cut, correlates with the Mississippi Valley sequence as follows from the top downward: *Galena Group, Dunleith*

MISSISSIPPI VALLEY				CENTRAL KY.[1]	CENTRAL TENN.[2]	SE. TENN.[3]	SW. VA.[4]
Grp.	Formation	Member	Position in member				
MAQUOKETA	Brainard		17' below top	—	—	B-14	—
GALENA	Dunleith	St. James Buckhorn	9 bentonites	—	—	—	V-14
	Guttenberg	Glenhaven	At base	Probably present	—	B-13	—
	Kings Lake	Tyson	Middle	—	—	B-12	—
		Mincke	18" below top	Present	T-5	B-11	Present
	Spechts Ferry	Glencoe	—	—	—	—	V-13
			—	—	—	—	V-12
			At or just above base	Present	Present	B-10	V-11
			—	—	—	—	V-10
		Castlewood	—	—	—	—	V-9
			—	—	—	—	V-8
			—	—	—	—	V-7
			—	—	—	—	V-6
			—	—	—	—	V-5
			At base	"Mud Cave"	T-4	B-9	V-4
PLATTEVILLE	Quimbys Mill	Strawbridge	—	—	—	B-8	—
			—	—	—	B-7	Present
		Shullsburg	—	At top	T-4	B-6	Present
			—	—	—	B-5	—
			—	—	—	B-4	—
		Hazel Green	At base	"Pencil Cave"	T-3	B-3	V-3
	Nachusa	Everett	12' above base	Present	T-2	B-2	Present
			—	—	—	—	V-2
		Eldena	At or just below top	—	T-1	—	Present
			—	—	—	—	V-1
	Grand Detour	Forreston	—	23' below top	—	—	Present
EVERTON	(= Wells Creek)		—	—	—	B-1	—

FIG. 38.—Correlation of numbered or named Ordovician bentonites in Kentucky, Tennessee, and Virginia with bentonites in the Mississippi Valley. Many bentonites undesignated by name or number in Kentucky, Tennessee, and Virginia are not shown. A dash indicates that the bentonite has not been reported.

[1]/McFarlan, 1943, p. 12-13; McFarlan and White, 1948, p. 1629, 1632.
[2]/Wilson, 1949, p. 62-65, 90-91. [3]/Fox and Grant, 1944. [4]/Rosenkrans, 1936.

(Buckhorn) silicified float on hilltop, Kings Lake 49′, Spechts Ferry 6″; Platteville Group, Quimbys Mill (Shullsburg) 1′7″, Nachusa 44′, Grand Detour (Forreston) 8′. The usual member sequence in the Nachusa is not evident here, and the argillaceous Elm Member may not have been deposited in the agitated waters of the reef.

Although the above sequence combined with regional tracing shows that the Aspen Hill exposure cannot represent an interfingering of the Carters and Kimmswick Formations, the locality is of historical interest because it doubtless was an important factor in leading Ulrich to classify the Kimmswick Limestone as Blackriveran (Ulrich, 1911, pl. 27). In addition, the acceptance of the Carters–Kimmswick correlation is perhaps the most important factor in the continuing and, we believe, erroneous assignment of the Carters to the Trentonian (Twenhofel et al., 1954; Cooper, 1956, p. 103).

Coralline reef limestone also constitutes the upper 2 feet of the Eldena and the basal 3 feet of the Everett equivalents in the Hermitage Portland Cement Company quarry southeast of Nashville.

Quimbys Mill Equivalents.—The Upper Carters Member is equivalent to the Quimbys Mill Formation of the Mississippi Valley and to the Upper Tyrone of Kentucky. Because of the marked unconformity at its top, the Upper Carters is missing at some places in central Tennessee. Near Singleton, Bedford County, however, it reaches a thickness of 28 feet (Wilson, 1949, p. 59-61). At Readyville the member is 13 feet thick, and in the vicinity of Nashville it ranges from 9 to 11 feet thick. One of the best exposures in the Nashville area is in the cut on the north side of U. S. Highway 41 (Murfreesboro Pike) and the adjacent bluff to the north on the west side of Mill Creek, at the southeast edge of Nashville, where the sequence correlates with the Mississippi Valley as follows, from the top downward: *Galena Group, Kings Lake 7′, Spechts Ferry 2′6″; Platteville Group, Quimbys Mill 9′ (Strawbridge 2′, Shullsburg 3′7″, Hazel Green 3′5″), Nachusa 41′9″ (Everett 31′, Elm 7″, Eldena 10′2″).* The lower 9 feet of the Upper Carters also is well exposed in the cut on State Highway 11 (Nolensville Pike), opposite the State Fairgrounds in Nashville (Wilson, 1948, p. 18, locality 22).

The Hazel Green equivalent consists of pure, white to blue-gray or brown-gray, lithographic limestone that contains calcarenitic streaks and is massive in the upper 1½ feet, but is mostly thin bedded and shaly in the lower part. A bentonite at the base (T-3 of Wilson, 1948, p. 17; 1949, p. 64) is traceable to Missouri, Kentucky, and Virginia, and the lower, thin-bedded, shaly unit is conspicuous in Missouri. The beds equivalent to the Shullsburg Member are argillaceous, brown-gray, fucoidal limestone that is partly shaly and thin to medium bedded, except for a 14-inch massive layer at the base. The overlying Strawbridge equivalents consist of pure, medium- to thick-bedded limstone with calcarenite layers at top and bottom.

In parts of Tennessee a bentonite at the top of the Shullsburg, also found in Kentucky and Virginia, has been confused with the bentonite at the base of the Curdsville (Spechts Ferry) Limestone, and both bentonites have been designated T-4 (Wilson, 1949, p. 63) (fig. 38). In the vicinity of Chattanooga, southeastern Tennessee, Fox and Grant (1944, p. 326-327) designated the bentonite of the Shullsburg as B-6 and the basal bentonite of the Curdsville as B-9. Two intervening bentonites in the Strawbridge have not been recognized outside of the Chattanooga area except at Hagan Siding, Lee County, southwestern Virginia, where a bentonite occurs that appears to be B-7, the lower of the two. The bentonite of the Shullsburg and the basal bentonite of the Curdsville are easily confused because of the unconformity at the base of the Curdsville and the similarity of lowermost Curdsville (Castlewood) beds to Upper Carters and Upper Tyrone strata (see *Kentucky*).

The Upper Carters also resembles the Quimbys Mill in the common occurrence of *Lambeophyllum profundum* (Conrad), *Eoleperditia fabulites* (Conrad), and other ostracodes, although the abundant *Tetradium*–bryozoan–gastropod fauna of the Upper Carters does not extend to northern outcrops.

Trentonian Stage

Galena (Nashville) Group Equivalents

The Hermitage Formation of Tennessee overlies the Carters Limestone and has been divided into the following members: (1) Curdsville Member, at the base, (2) Laminated Argillaceous Member, (3) *Ctenodonta* Member, (4) Granular Phosphatic Member, (5) *Dalmanella* Coquina Member, (6) Blue Clay-shale Member, and (7) Silty Nodular Limestone Member (Wilson, 1949, p. 81-107).

Spechts Ferry Equivalents.—The Curdsville Member of Tennessee is virtually identical with the Curdsville Member of the Lexington Limestone in Kentucky, which correlates with the Spechts Ferry Formation, the basal formation of Trentonian age in the Mississippi Valley. As elsewhere in the interior platform region, the Curdsville is separated from the underlying limestone of Blackriveran age by an unconformity. At Nashville and in a cut on the east side of U. S. Highway 41, just north of Beech Grove, Coffee County, the lowermost Curdsville beds contain fragments of the upper beds of the Carters Limestone. At other localities the Upper Carters has been removed by pre-Curdsville erosion, so that the Curdsville rests on the Lower Carters (Wilson, 1949, p. 87). The break in sedimentation persisted into or through Curdsville (Spechts Ferry) time, as it did in the region to the north. Over the Nashville Dome the Curdsville Member is absent but elsewhere in central Tennessee it reaches a maximum thickness of 15 feet (Wilson, 1949, p. 85-87). In most localities around the flanks of the Nashville Dome, as at South Carthage, Smith County, at Nashville, and at Aspen Hill, only upper Glencoe equivalents are present, and both of the Spechts Ferry bentonites are missing. In the highway cut near Beech Grove, however, the sequence correlates with the Mississippi Valley section as follows from the top: *Galena Group, Spechts Ferry 7′4″ (Glencoe with bentonite at base 5′2″, Castlewood with conglomerate at base 2′2″); Platteville Group, Quimbys Mill with bentonite at base 9′3″, Nachusa 3′6″.*

Relations of post-Curdsville Hermitage Strata.—Bassler (1932, p. 79) described eight faunal zones, which he regarded as successively younger, in the Hermitage Formation of central Tennessee. Wilson (1949, p. 82-105, fig. 19) interpreted the post-Curdsville members of the Hermitage Formation as nearly contemporaneous facies because of their irregular distribution and compensating thickness variations. We have studied several Hermitage sequences in Tennessee, including a well exposed section in a westward-trending ravine on the north side of the road, midway between Greenvale and Ewingsville, Wilson County, just north of Wilson's Locality 6 on cross section F-F′ (Wilson, 1949, p. 159, 163). We suggest that (1) the Laminated Argillaceous Limestone Member and the *Ctenodonta* Member correlate with the Kings Lake of Illinois, (2) the Granular Phosphatic Member is equivalent to the lower part of the Guttenberg (Garnavillo), (3) the *Dalmanella* Coquina Member is Buckhorn–St. James (Ion), (4) the Blue Clay-shale Member probably is a facies of the lower portion of the *Dalmanella* Coquina Member and is of Buckhorn age, and (5) the Silty Nodular Limestone Member may be a facies of the upper part of the *Dalmanella* Coquina Member and of St. James age. However, because the Silty Nodular Limestone Member thickens greatly in the Sequatchie Valley of eastern Tennessee and there occupies the entire interval between the Curdsville and Bigby–Cannon Limestones, this member in eastern Tennessee may be a facies of the other Hermitage members, as maintained by Wilson (1949, p. 101, fig. 15).

We regard some of the post-Curdsville Hermitage members as successive units instead of contemporaneous facies for the following reasons: (1) The units are not merely local but closely resemble formations or members in Kentucky and in the Mississippi Valley. (2) Irregularities in distribution and thickness might be expected over the unstable Nashville Dome during the encroachment and deepening of the Trentonian sea. Similar irregularities are characteristic of the early Trentonian strata around the flanks of the Ozark, Wisconsin, and Adirondack Uplifts. (3) Wilson's cross-sections (1949) (figs. 36-39) show no actual intertonguing or gradation between the members, and we found none during our brief field examinations.

Kings Lake Equivalents.—The Laminated Argillaceous Limestone Member consists principally of silty, blue-gray to yellow-brown, chalky limestone thinly interbedded with silty, calcareous, laminated shale. The upper portion is less shaly, more calcareous, and contains layers of calcarenite and coquina. At Aspen Hill, the upper part carries some thin beds of glauconitic, purple, fine-grained quartzitic sandstone, and at South Carthage, Smith County, the topmost unit is a 6-foot bed of calcareous siltstone. A bentonite, T-5, usually is present near the base. *Dalmanella fertilis* (Ulrich) is the only common fossil. Although apparently absent in the Sequatchie Valley of eastern Tennessee, the member thickens irregularly westward to 36 feet at South Carthage and to 49 feet at Aspen Hill, reaching a reported maximum of 180 feet in Decatur County, western Tennessee (Wilson, 1949, p. 90).

In general lithology, internal sequence, fauna, stratigraphic position, conformable stratigraphic relations, and possession of a basal bentonite this member seems nearly identical with the Kings Lake Formation in Missouri, Kentucky, and southwestern Virginia. The more shaly lower portion, which at South Carthage is 20 feet thick, averages about 80 percent shale, and has a 3-foot bentonite 2 feet above the base, is correlated with the Mincke Member. The more calcareous upper part, which at South Carthage is 16 feet thick and averages about 50 percent shale, is correlated with the Tyson Member. The chief divergence from typical Kings Lake lithology is found in the distribution of calcarenite, which in Missouri is more abundant in the Mincke equivalent but in Tennessee is more abundant in the Tyson equivalent. The *Ctenodonta* Member is lithologically identical with the Laminated Argillaceous Limestone Member, is distinguished only by a profusion of *Ctenodonta hermitagensis* Bassler, and is considered a local faunal facies of the Kings Lake Formation.

Guttenberg Equivalents.—The Granular Phosphatic Member is exceedingly similar in nearly all respects to the middle Logana strata in the vicinity of Frankfort, Kentucky, which we correlate with the Garnavillo Member of the Guttenberg Formation. It consists of phosphatic, fine- to coarse-grained, thin- to thick-bedded calcarenite with dark red-brown shale partings, is absent to 20 feet thick, and is restricted to a roughly elliptical region in east-central Tennessee (Wilson, 1949, fig. 19). Higher Guttenberg (Glenhaven) beds have not been recognized in Tennessee. Glenhaven strata contain abundant *Dalmanella,* and they may be locally present in Tennessee, but included in the *Dalmanella* Coquina Member.

Dunleith Equivalents.—At Nashville (Wilson, 1948, p. 18-20) the *Dalmanella* Coquina Member is composed of 20 feet of argillaceous, fine-grained, thin to thick-bedded calcarenite containing strong shale partings and a profusion of *Dalmanella fertilis* (Ulrich). A 3-foot unit of interbedded argillaceous limestone and shale is present 9 feet above the base of the member, below which shale partings are more numerous than above. The basal 5 feet of the calcarenite in the overlying Bigby is distinguished by strong argillaceous streaks and thin shale partings, contains abundant *Prasopora simulatrix* Ulrich, and has layers crowded with *Dalmanella* in the lower 3½ feet. It appears to be more like the *Dalmanella* Coquina Member than like the Bigby. If it is included with the older unit, the *Dalmanella* Coquina Member closely matches the lower Jessamine (lower Dunleith) sequence at Frankfort, Kentucky. Thus expanded the *Dalmanella* Coquina Member is very similar in lithology and fauna to Buckhorn and St. James strata in Illinois. The lower 12 feet resembles the Buckhorn in having a higher proportion of shale partings and a shaly unit at the top. In the Mississippi Valley *Prasopora simulatrix* Ulrich first becomes abundant near the top of the St. James, which suggests correlation of the upper 13 feet of the expanded *Dalmanella* Coquina Member with the St. James Member.

Locally, as near Aspen Hill, the basal bed of the *Dalmanella* Coquina Member is silicified and white. The *Dalmanella* Coquina Member probably is unconformable on the Laminated Argillaceous Member and lies conformably beneath the Bigby–Cannon Limestone.

At South Carthage, Smith County (Wilson, 1949, p. 163, cross section F-F′, locality 9), the interval between the Granular Phosphatic Member (Guttenberg) and the Bigby–Cannon Limestone is occupied in ascending order by the Blue Clay-shale Member, 10½ feet thick, and the Silty Nodular Limestone Member, 10 feet thick. The Blue Clay-shale Member consists chiefly of thin-bedded calcarenite and limestone with greenish gray argillaceous mottlings and green to brown shale partings. A 1-foot bed of interlayered siltstone and limestone occurs 15 inches below the top. Some beds are very fossiliferous and contain *Dalmanella fertilis* (Ulrich). The Silty Nodular Limestone Member is composed of argillaceous, calcarenitic, very fine-grained limestone in thin nodular beds separated by wavy shale partings. It is much less shaly than the underlying member. The basal 4 feet contains abundant *Tetradium*. Wilson (1949, fig. 36) included an additional 5 feet of irregularly bedded limestone in the top of the member, but the relative purity of this limestone and comparison with the Frankfort, Kentucky, sequence suggest that it belongs to the Bigby–Cannon Limestone.

The Blue Clay-shale and Silty Nodular Limestone Members do not resemble the *Dalmanella* Coquina Member, except for the presence of calcarenite layers and *Dalmanella* in the Blue Clay-shale Member, and no proof of lateral gradation into the *Dalmanella* Coquina Member was found. Nevertheless it seems likely that the Blue Clay-shale and Silty Nodular Limestone Members are equivalent, respectively, to the lower (Buckhorn) and upper (St. James) divisions of the *Dalmanella* Coquina Member. Not only do they occupy the same stratigraphic position beneath the Bigby–Cannon Limestone and show a comparable difference in argillaceousness, but the sequence of shaly calcarenite (Blue Clay-shale Member) overlain by less shaly limestone (Silty Nodular Limestone Member) matches the Buckhorn–St. James sequence at Nashville and at Frankfort, Kentucky.

The Bigby–Cannon–"Catheys" succession at South Carthage shows close resemblance to the middle Jessamine to lower Woodburn succession at Frankfort, Kentucky, in (1) the sequence of pure and argillaceous units, (2) the thickness of these units, and (3) the distribution of chert. The South Carthage sequence is much less shaly and lacks the *Prasopora–Dalmanella* fauna of the Kentucky strata. The suggested correlation of the South Carthage exposure with the Mississippi Valley sequence is as follows:

Galena Group
- Wise Lake Formation
  - Sinsinawa Member (Woodburn) (15′ est.)
    - (30) Calcarenite and limestone, medium to thick bedded, at top of exposure
- Dunleith Formation (136′)
  - Wyota Member (25′)
    - (29) Calcarenite, argillaceous, thin to medium bedded, cherty at top, 8′
    - (28) Calcarenite, thick bedded, cherty at top, 9′6″
    - (27) Limestone, pure, very fine grained, in 9- to 15-inch beds, 7′6″
  - Wall Member (15′)
    - (26) Limestone, thin bedded, moderately shaly, 4′
    - (25) Limestone, calcarenitic, in fairly regular 6- to 12-inch beds, 4′8″
    - (24) Limestone, white weathering, thick bedded, 3′4″
    - (23) Calcarenite, cherty, massive, 3′
  - Sherwood Member (19′6″)
    - (22) Limestone, thin to medium bedded, partly shaly, 3′9″
    - (21) Calcarenite, coarse grained, massive, 3′4″
    - (20) Limestone, white weathering; in two beds, 2′7″
    - (19) Limestone, pure, thick bedded, with 17-inch argillaceous or shaly layers at top and 4′4″ below top, 9′10″
  - Rivoli Member (12′8″)
    - (18) Limestone, in 6- to 12-inch regular beds separated by thin shale partings, 6′8″
    - (17) Limestone, partly argillaceous or calcarenitic, thick bedded, 6′
  - Mortimer Member (12′)
    - (16) Limestone, thin bedded to medium bedded, with prominent shale partings, 3′
    - (15) Limestone, with argillaceous mottlings, in medium to thick beds; 10-inch shaly layer at base, 9′
  - Fairplay Member (16′7″)
    - (14) Calcarenite, pure, coarse grained, streaked with lithographic limestone, very thick bedded, 10′3″
    - (13) Limestone, very calcarenitic, in irregular thin to medium beds, 6′4″

Eagle Point Member (9′7″)

(12) Limestone, in very regular 5- to 11-inch beds separated by thin shale partings

Beecher Member (included by Wilson in the Silty Nodular Limestone Member) (5′2″)

(11) Limestone, pure, in very irregular medium to thick beds; abundant *Tetradium* in lower part

St. James Member (lower part of the Silty Nodular Limestone Member) (10′2″)

(10) Limestone, argillaceous, thin to medium bedded, shaly, 6′4″

(9) Limestone, argillaceous, massive, weathering nodular; abundant *Tetradium,* 3′10″

Buckhorn Member (Blue Clay-shale Member) (10′4″)

(8) Calcarenite, very argillaceous and shaly; 1-foot layer of limestone and siltstone 15″ below the top

Guttenberg Formation (Granular Phosphatic Member) (8′8″)

Garnavillo Member

(7) Calcarenite, phosphatic, fossiliferous, partly shaly

Kings Lake Formation (Laminated Argillaceous Limestone Member) (36′)

Tyson Member (16′)

(6) Siltstone, calcareous, contorted in upper 2′6″ by submarine slumping, 6′2″

(5) Shale, calcareous, thinly interbedded with coquina and calcarenite, 9′10″

Mincke Member (20′)

(4) Shale, moderately calcareous, with a few limestone layers; 3-foot bentonite bed (T-5) 2 feet above base

Spechts Ferry Formation (3′)

Glencoe Member

(3) Calcarenite, with argillaceous streaks and lenses of lithographic limestone, 1′8″

(2) Limestone, gray, lithographic, with greenish gray argillaceous streaks, 1′4″

Platteville Group

Quimbys Mill Formation (15′ est.)

(1) Limestone, dark gray, lithographic, thin to medium bedded, in railroad cut northeast of highway cut

In both the South Carthage and Frankfort sections there is a marked increase in purity beginning with the Sherwood equivalent, and in both sections chert first appears adjacent to the Sherwood–Wall contact and last occurs at the top of the Wyota equivalents. Units 29 and 30 of the South Carthage section have been called Catheys (Wilson, 1949, fig. 41), but comparison with the Nashville section suggests that they belong to the upper, or Cannon, part of the Bigby–Cannon Formation.

At Nashville the Bigby–Cannon Formation seems to correspond to the middle Jessamine to Woodburn sequence of Kentucky, and the Catheys Formation to the Cynthiana Formation of Kentucky. As in Kentucky, calcarenite predominates, but at Nashville the sequence generally is less shaly, is thinner, and is interrupted by several local diastems. The pure calcarenite of the Bigby also contrasts with its argillaceous Kentucky counterpart. A major change in facies takes place between South Carthage and Nashville (Wilson, 1949, fig. 41), the lithographic limestones at South Carthage grading westward into thinner calcarenites. The degree of shaliness is about the same, except for the greater purity of the Bigby at Nashville.

At Nashville the Bigby–Cannon–lower Catheys succession is well exposed in the Blind School quarry and the railroad cut leading northwestward (Wilson, 1948, p. 12-13). Above the 5 feet of argillaceous *Prasopora*-bearing calcarenite, which is considered equivalent to the top of the St. James Member, the white, pure, coarse-grained, thick-bedded, cross-bedded calcarenite of the Bigby is well exposed. These beds are believed to be equivalent to the strata at South Carthage and Frankfort that we correlate with the Beecher to Fairplay interval. The rock is identical to lower Kimmswick (Moredock) strata in Missouri and Illinois.

Above these beds is a foot of conglomeratic calcarenite with abundant *Cyrtodonta grandis* (Ulrich), which is included in the Bigby and is succeeded by 13 feet of shaly to thick-bedded lithographic limestone constituting the Lower Dove-colored Member of the Cannon Limestone. The lower 3 feet of this member is calcarenitic, conglomeratic, and contains *Tetradium*. Comparison with sections at South Carthage and in Kentucky suggests (1) that the *Cyrtodonta* Zone corresponds to the basal Rivoli *Cyrtodonta* Zone at the Old Crow section in Woodford County, Kentucky, (2) that the Lower Dove-colored Member represents the rest of the

Rivoli Member, and (3) that beds of Mortimer age are missing. The presence of a diastem at the top of the main body of the calcarenite in the Bigby is suggested also by the conglomeratic character of the *Cyrtodonta* Zone and of the basal part of the Lower Dove-colored Member.

The Ward Member of the Cannon Limestone, overlying the Lower Dove-colored beds, shows the following sequence from the base: (1) calcarenite, very coarse grained, thick bedded, with numerous *Tetradium*, 7½′; (2) limestone, white weathering, platy and shaly, 1′ (3) calcarenite, coarse grained, irregularly bedded, cherty in upper part, 12½′; (4) calcarenite, cherty, thin bedded, moderately shaly, 3′. Units 1 and 2 are regarded as Sherwood and units 3 and 4 as Wall. The pure to impure cycles are similar to Dunleith members in the Mississippi Valley.

Stromatocerium pustulosum (Safford) first appears in the Ward and in upper Benson strata in Kentucky, which we consider equivalent to Sherwood strata in Illinois. The distribution of chert in the Wall cycle at Nashville matches that in uppermost Benson strata along U. S. Highway 421 just northwest of Frankfort, Kentucky. Above the Ward Member in ascending order are (1) the *Cyrtodonta* Member, 1½ to 8½ feet thick, composed of coarse-grained calcarenite that is cherty and massive at the base and thin bedded toward the top, and (2) the Upper Dove-colored Member, absent to 5 feet thick, composed of argillaceous, white-weathering, cherty limestone with abundant *Tetradium* in the upper part. These members are correlated with Wyota equivalents at Carthage and Frankfort. Here, as at many places in the eastern central United States, the Wyota Member marks the highest occurrence of chert in the Trentonian strata, except for the local occurrence of chert in the Dubuque Formation. *Peronopora milleri* Nickles appears first in the Upper Dove-colored Member and in the essentially equivalent Brannon Member of Kentucky.

Wise Lake Equivalents.—The Upper Cannon Member, resting unconformably on the Upper Dove-colored Member, is 36 feet thick and consists of more or less argillaceous and shaly, fine- to medium-grained calcarenite in thin to medium beds. It is similar in general lithology, in certain faunal features, in thickness, and in stratigraphic position to the Woodburn Member of the Lexington Limestone in Kentucky, but is more shaly. The Woodburn is considered equivalent to the Sinsinawa Member of the Wise Lake Formation in the Mississippi Valley. The *Favistella alveolata–Constellaria teres–Rhynchotrema increbescens* fauna so characteristic of the Woodburn first appears in the Upper Cannon Member. *Constellaria* is abundant in a 10-foot shaly zone 16 feet above the base in the Blind School exposure. *Hallopora multitabulata* (Ulrich) does not occur above the Woodburn in Kentucky and extends only a few feet farther into the *Constellaria* Member at the base of the Catheys in Tennessee.

Although the Bigby–Cannon Limestone and the middle Jessamine–Woodburn succession have many other fossils in common, the ranges of most species within the two sequences cannot be matched. To give only two examples, *Prasopora* and *Dalmanella fertilis* (Ulrich) are abundant in Kentucky outcrops as high as Rivoli strata, whereas at Nashville *Prasopora* is abundant as high as the upper member of the Cannon (Sinsinawa) and *Dalmanella* is not reported above the Bigby (Beecher–Fairplay). This variation in range shows the effect of minor changes in lithology on the composition of the faunas (Wilson, 1948, p. 49-57; 1949, p. 133-134).

Devils Hollow (Stewartville) strata appear to be absent in the Nashville area.

Dubuque Equivalents.—The Catheys Formation appears to be equivalent to the Cynthiana Formation of Kentucky and to the Dubuque Formation of the Mississippi Valley. The *Constellaria* Member at the base of the Catheys Formation consists of 2 to 4 feet of fine-grained, thin-bedded, shaly limestone which seems to be the same as the 3½-foot *Constellaria* Zone at the base of the Cynthiana Formation along U. S. Highway 421 just northwest of Frankfort, Kentucky (fig. 33). The Lower Catheys Member and the overlying Lower Pale-colored Member, respectively 38 and 7 feet thick in the sections studied, are similar to the pre-Nicholas portion of the Cynthiana Formation, although less shaly. The lower 20 feet of the sequence is composed chiefly of partly argillaceous and shaly, fine- to very coarse-grained, thin- to thick-bedded calcarenite containing abundant *Stromatocerium pustulosum* (Safford) and *Favistella alveolata* (Goldfuss) in the basal 10 feet. The next 15½ feet is made up dominantly of pure, medium- to thick-bedded calcarenite and calcarenitic limestone. The uppermost 2½ feet of the Lower Catheys Member consists of shaly calcarenite. The overlying Lower Pale-colored Member consists of thin-bedded shaly limestone.

The three-fold division of the Lower Catheys–Lower Pale-colored succession into a lower shaly unit, a middle pure unit, and an upper shaly unit matches in relative argillaceousness the conspicuous three-fold division of the Cynthiana Formation at Clays Ferry, Madison County, Kentucky, and is only 8½ feet thinner. The *Stromatocerium-Favistella* zone of the lower shaly unit may correspond to a similar zone in the pre-Nicholas Cynthiana strata in central Kentucky (McFarlan and White, 1948, p. 1641-1642, fig. 2).

The Upper Catheys Member, 19 feet thick, resting on the Lower Pale-colored Member consists of medium- to coarse-grained calcarenite that is thin bedded and shaly in the lower 10 feet but is mainly pure and medium to thick bedded above. *Favistella alveolata* (Goldfuss) is locally abundant. Except for the shale partings in the lower half, this member is lithologically like the Nicholas Limestone of Kentucky and has the same stratigraphic position. The succeeding Upper Pale-colored Member, the topmost unit of the Catheys Formation, consists of about 21 feet of argillaceous, fine-grained limestone in beds averaging 8 inches thick, with prominent shale partings and particularly numerous calcarenite layers in the upper 3 feet. This unit may be a local shaly facies of the upper part of the Nicholas.

Although beds of Dubuque age normally are conformable on strata of Wise Lake age, Wilson (1949, p. 135-136) cited evidence for a diastem or minor unconformity between the Bigby–Cannon and Catheys Formations on the Nashville Dome. Similar relations appear to prevail between the Devils Hollow and Cynthiana Formations in Kentucky over the Jessamine Dome. An unconformity is present at the top of the Catheys at Nashville, along which Edenian (lower Cincinnatian) strata are absent, so that the Catheys is overlain by the Leipers Formation of Maysvillian age.

Considerable faunal data, in addition to that mentioned above, supports equivalency of the Catheys and Cynthiana Formations. *Escharopora maculata* (Ulrich) and *Hebertella sinuata* (Hall) seem to occur first in the *Constellaria* or lower Catheys Members and in lower Cynthiana strata. *Platystrophia precursor* Foerste and *Cyclonema varicosum* Hall appear to be index fossils of the Catheys and Cynthiana, ranging throughout or nearly throughout both formations. In the Catheys of central Tennessee, as in the Cynthiana of central Kentucky and in the Catheys of southwestern Virginia, *Cyclonema varicosum* is associated with *Zygospira recurvirostris* (Hall). *Orthorhynchula linneyi* (James) also is very common in both formations. *Eridotrypa briareus* (Nicholson) and *Peronopora milleri* Nickles have not been reported above Catheys and Cynthiana strata.

VIRGINIA

In Lee and Tazewell Counties, southwestern Virginia, the Champlainian formational sequence, given below, rests unconformably on Canadian (Beekmantown) dolomites and underlies Cincinnatian strata (Huffman, 1945; Cooper and Prouty, 1943; Cooper, 1944, p. 33-111, 281-285; Prouty, 1948) (fig. 39). Although New York names for groups have long been applied to the Champlainian of Virginia, there is disagreement as to the position of the boundaries, and those given below show our correlations.

Lee County (Huffman)	*Tazewell County* (Cooper and Prouty)
Trentonian Stage	Trentonian Stage
Catheys	
Cannon	Lower Martinsburg
Hermitage	
Curdsville	Eggleston (upper third)
Blackriveran Stage	Blackriveran Stage
Eggleston	Eggleston (lower two-thirds)
Moccasin	Moccasin
Formations similar to those of Tazewell County, but described under older nomenclature	Witten
	Bowen
	Wardell
	Gratton
	Benbolt
	Peery
	Ward Cove
	Thompson Valley
	Lincolnshire
	Five Oaks
	Elway
	Chazyan Stage
	Blackford

After we had studied the Hagan Section, in Lee County, Miller and Brosgé (1954) renamed the formations below the Eggleston and considered the units above it as one formation, the Trenton Limestone.

Twenhofel et al. (1954) correlated the base of the Trentonian with the top of the Witten, Kay (1956) correlated it with the base of the upper part of the Witten, and Cooper (1956) put it at the base of the Witten. Although Twenhofel et al. and Kay correlated the base of the Blackriveran with the top of the Lincolnshire, Cooper correlated it with the top of the Benbolt (figs. 29, 39).

Except for the Martinsburg Shale, the sandstone and claystone of the Bowen, and the largely clastic Blackford Formation, the Champlainian sequence in southwestern Virginia consists largely of limestone. It was deposited in a geosynclinal environment and is at least 2,000 feet thick. The succession was studied at Scales, Tazewell County, and at Hagan Siding, Lee County (fig. 40). Several other important exposures in southwestern Virginia were examined briefly. Many lithologic and faunal similarities between these sections and those in Illinois and elsewhere in the Mississippi Valley suggest the regional correlations shown in figure 27.

TAZEWELL COUNTY

Chazyan Stage

Everton Group Equivalents

The basal clastics of the Blackford Formation (Zone 1) consist of interbedded conglomerate, shale, and dolomite from 25 to 107 feet thick. In Russell County, Virginia, southwest of the Tazewell County exposures, these beds contain *Rostricellula pristina* (Raymond), a common middle and upper Chazyan brachiopod (Cooper and Prouty, 1943, p. 284; Cooper and Cooper, 1946, p. 73). (In 1956 Cooper renamed the southern Appalachian species *Rostricellula basalaris*). The basal clastics are overlain by ash-gray shale (Blackford Zone 2) from 30 to 75 feet thick. We tentatively classify Blackford Zones 1 and 2 as Chazyan. They are similar in thickness and stratigraphic position and partly in lithology to the Wells Creek Dolomite of Tennessee, which has been traced in subsurface to Laurel County, southeastern Kentucky (Bentall and Collins, 1945, sheet 1, cross-section C-C′, well 296), within 50 miles of Blackford exposures west of Arthur, Claiborne County, Tennessee. The Wells Creek can be traced directly into the Everton Group of the Mississippi Valley (see *Tennessee*).

Blackriveran Stage

Ancell Group Equivalents

The Elway Formation (Zone 3 of the Blackford Formation in some reports) consists of 30 feet of blocky chert containing the brachiopod *Dinorthis,* which ranges from Blackriveran into Richmondian strata but is unknown in the type Chazyan of New York (Cooper and Cooper, 1946, p. 77). The chert is overlain by the Five Oaks Formation (Zone 4), dove-gray lithographic limestone 25 to 125 feet thick. Subsurface tracing (Bentall and Collins, 1945) suggests that these two units correspond to the basal light colored limestone of the Murfreesboro of Tennessee and thin off-shore carbonate equivalents of St. Peter Sandstone in the Mississippi Valley. The Five Oaks is similar to the basal light colored limestone of the Pamelia of New York in most lithologic features, in stratigraphic position, and in containing *Tetradium syringoporoides* Ulrich and *Eoleperditia fabulites* (Conrad).

The Five Oaks Formation is overlain, in ascending order, by the Lincolnshire, Thompson Valley, Ward Cove, and lower Peery Limestones (Zones 5 through 8), which together average about 255 feet thick (Cooper and Prouty, 1943). The Thompson Valley Formation, considered part of the Ward Cove in some reports, is composed of light gray coarse-grained calcarenite, but the remaining formations are made up of nearly black, partly cherty or shaly, fine-grained limestones. These limestones appear almost identical to all but the basal part of the Murfreesboro Limestone of Tennessee, to the Dutchtown Limestone of Missouri, and to the upper part of the lower division of the Pamelia of New York. The faunas of the lower Peery (Zone 8, *Lophospira* beds), of the upper exposed part of the Murfreesboro, of the Dutchtown, and of this portion of the Pamelia are similar. The correspondence between the faunas of the lower Peery (Cooper and Prouty, 1943, p. 831) and the upper Murfreesboro (Ulrich, 1939, p. 109; Wilson, 1949, p. 31-32) is especially striking. The great thickness of the Lincolnshire–lower Peery succession compared with the corresponding part of the Pamelia and the faunal similarities between these Pamelia beds and the lower Peery suggest that Lincolnshire-Ward Cove strata may be absent in the New York section.

Kay (1948, p. 1404-1407, fig. 2) and Prouty (1948, p. 1612-1613, 1619, fig. 1) placed Blackford-Lincolnshire strata in the Chazyan, and Cooper (1956, chart 1) considered Blackford-Benbolt strata as pre-Blackriveran; but the presence of Blackriveran fossils in the Elway and subsequent strata and the occurrence of limestones resembling the Five Oaks and lower Peery in the lower Pamelia of the Blackriveran type area strongly suggest that Elway-Lincolnshire beds (Zones 3 through 5) are of earliest Blackriveran age.

The upper part of the Peery Limestone (Zone 9), 37 to 170 feet thick, consists of gray lithographic limestone and calcarenite that in several respects resembles the pure unit at the top of the Pamelia Formation in New York, the pure members of the Joachim Formation in Missouri and Illinois, and the Pierce Limestone in Tennessee. It lacks, however, the thin bedding, shale partings, and bryozoan fauna of the Pierce. For these reasons, and because of its stratigraphic position between Dutchtown and Pecatonica equivalents, the upper Peery is correlated with upper Pamelia, Pierce, and Joachim strata, although the only fossil common to upper Peery and upper Pamelia beds seems to be the long-ranging *Tetradium syringoporoides* Ulrich.

Platteville Group Equivalents

Pecatonica Equivalents.—The succeeding Benbolt Formation, absent to over 200 feet thick, appears to be similar in many respects to the Ridley Limestone of Tennessee, the Pecatonica Dolomite of the Mississippi Valley, and basal Lowville strata in New York. The calcarenite (Zone 10) at the base of the Benbolt is locally absent to 30 feet thick and resembles the Chana Member in relative purity, coarse grain-size, and medium to thick bedding. It has in common with Chana and basal Ridley strata *Nicholsonella pulchra* Ulrich, *Camerella varians* Billings, *Glyptorthis bellarugosa* (Conrad), *Öpikina minnesotensis* (N. H. Winchell), *Strophomena tennesseensis* Willard and *Maclurites magnus* Lesueur.

The overlying *Öpikina* beds (Zone 11), 5 to 100 feet thick, seem unmistakably linked by their argillaceous shaly character, by their flood of *Öpikina minnesotensis* (N. H. Winchell), and by other fossils to the Dane Member of the Pecatonica Formation and equivalent Ridley strata. A medium- to coarse-grained calcarenitic limestone about 15 to 30 feet thick in the lower part of Benbolt Zone 12 matches the New Glarus Member in relative purity and thick bedding. The overlying main body of Zone 12, about 12 to 60 feet thick, has the stratigraphic posi-

VIRGINIA CLASSIFICATION[1] Formation	Member	Composite[2] Section	CORRELATION WITH ILLINOIS Member	Formation	Grp	CORRELATION WITH NEW YORK AND ONTARIO Member	Fm	Stg	OTHER COR. Twenhofel et al., 1954 Fm	Stg	Cooper, 1956 Fm	Stg
Martinsburg ↑		12'		Cape ?	MAQ.	//////	//////	Eden				
Catheys		207'		Dubuque		Hillier			Upper Utica	?		
		126'	Stewartville	Wise Lake		Steuben	Cobourg		Cobourg			
			Sinsinawa									
Cannon		26'4"	Wyota			Rust						
		41'	Wall									
		83'8"	Sherwood			Russia	Den-mark	Trentonian				
			Rivoli		GALENA	Poland						
			Mortimer	Dunleith		Rathbun				Trentonian		
			Fairplay				Shore-ham		Sherman Fall			
			Eagle Point									
			Beecher				Hull					
			St. James									
			Buckhorn									
		21'6"	Glenhaven	Gutten-berg		Napanee						
		9'6"	Garnavillo									Trenton (of Cooper)
Hermi-tage	Zone 20	42'	Tyson	Kings Lake		//////	Rockland				?	
	T-5		Mincke									
	Zone 19	37'6"	Glencoe	Spechts Ferry		Selby			Kirkfield (Hull)	↓	Sherman Fall	
	Zone 18 V-11											
Curds-ville	Zone 17	43'6"	Castlewood									
	Zone 16	V-4										

FIG. 39.—Correlation of the Champlainian Series in southwestern Virginia with Illinois.

[1]/Butts, 1940, p. 213-214; Cooper and Prouty, 1943; Cooper, 1944, p. 34-111; Huffman, 1945; Prouty, 1948.

[2]/Section from top of Catheys to base of Zone 14 taken mainly from railroad cut at Hagan, Lee County; Shullsburg-Hazel Green equivalents and bentonites V-1 and V-2 projected from highway cut at Scales, Tazewell County. Section from base of Zone 14 to base of Wardell taken mainly from highway cut at Scales, Tazewell County; Zone 20 and basal 10 feet of Zone 21 inserted from Bowen type section (Cooper and Prouty, 1943, p. 876). Gratton, Burkes Garden, Shannondale, and Cliffield (Peery to Blackford) strata taken from respective type sections (Cooper and Prouty, 1943), except Peery which is from exposure three-fourths of a mile northeast of Cliffield, Tazewell County.

tion of the Medusa Member but is more calcarenitic and shaly. It also lacks the typical Medusa fucoidal mottlings. It contains numerous *Subretepora [Chasmatopora]* cf. *S. sublaxa* (Ulrich), a species that occurs in Medusa equivalents in the Ridley Limestone of Tennessee, but which has a long range.

Zone 13 in the top of the Benbolt averages 50 feet thick and consists of coarse-grained, cross-bedded calcarenite indistinguishable in hand specimens from coarse

(Continued) VIRGINIA CLASSIFICATION [1]		Composite Section [2]	CORRELATION WITH ILLINOIS			CORRELATION WITH NEW YORK AND ONTARIO			OTHER COR. Twenhofel et al., 1954		Cooper 1956	
Formation	Member		Member	Formation	Grp	Member	Fm	Stg	Fm	Stg	Fm	Stg
Eggleston	Zone 15 (V-3, V-2)	26'	Strawbridge	Quimbys Mill		//////	//////	Blackriveran	Rockland	Trentonian ↑	Hull	Wilderness
		8'8"	Shullsburg									
		8'7"	Hazel Green									
		62'7"	Everett	Nachusa		Watertown	Chaumont					
		39'	Elm			Glenburnie						
Moccasin	Zone 14 V-1	105'	Eldena			Leray						
	Zone 13 of Huffman - Lower 178'6" of Zone 27 of Cooper & Prouty	52'	Forreston	Grand Detour		Upper Division	Lowville					
		16'6"	Victory									
		110'	Hely								Rockland	
	Zone 26	16'1"	?									
		7'8"	Clement		PLATTEVILLE							
Witten	Zone 25	78'3"	Stillman						Chaumont	Black River		
	Zone 24											
	Zone 23	6'	Walgreen			Lower Division						
	Zone 22	10'10"	Dement									
Bowen	Zone 21	108'6"	?	Mifflin							Chaumont	
	Zone 20		Briton									
Wardell	Zone 19								Lowville			
	Zone 18	19'6"	Hazelwood									
	Zone 17	29'	Establishment								Low-ville	
	Zone 16											
Gratton	Zone 15	39'2"	Brickeys								Pam-elia	
	Zone 14	9'6"	Blomeyer									
Benbolt (Shannondale, Burkes Garden)	Zone 13	47'	Oglesby	Pecatonica							//////	Porterfield
	Zone 12	56'	Medusa									
		15'	New Glarus									
	Zone 11	60'	Dane						Pamelia			
	Zone 10	19'	Chana									
Peery	Zone 9	165'		Joachim	ANCELL		Pamelia					
	Zone 8	255'		Dutchtown								
Ward Cove	Zone 7											
Thompson V.	Zone 6											
Lincolnshire	Zone 5								Val-cour	Chazyan		
Five Oaks	Zone 4	55'		St. Peter								Ashby
Elway	Zone 3											
Blackford	Zone 2	136'6"			EVERTON			Chazyan	Crown Point		Val-cour	Marmor
	Zone 1								Day Point		Crown Point	

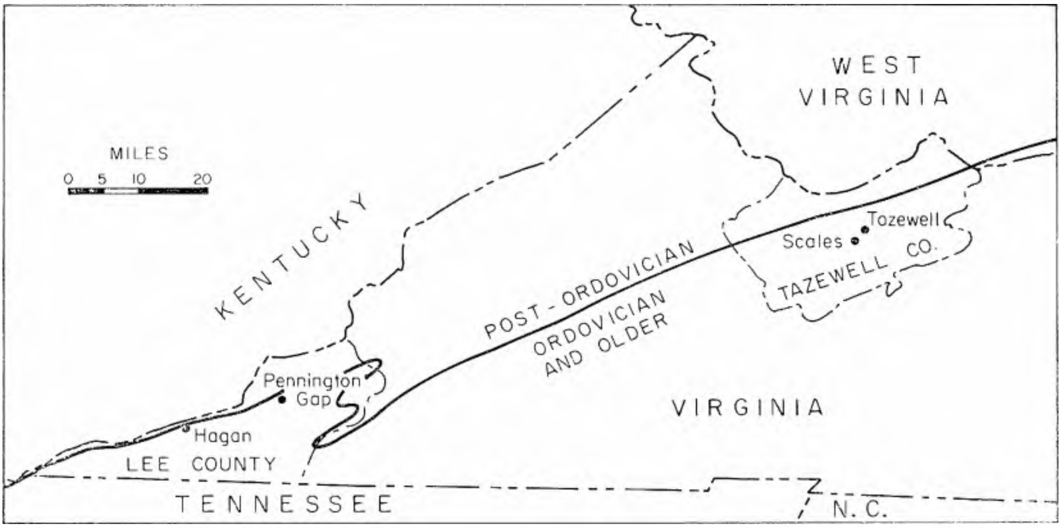


FIG. 40.—Southwestern Virginia, showing outcrop area of Ordovician and older strata and localities mentioned. Boundary of Ordovician rocks generalized from *Geologic Map of Virginia*, Virginia Geological Survey.

phases of the Oglesby Member at the top of the Ridley and Pecatonica Formations.

Mifflin Equivalents.—The Gratton and Wardell Formations combined appear to correspond to the Mifflin Formation of Illinois and to part of the lower division of the Lowville of New York. Cooper and Prouty (1943, p. 838) considered the Gratton-Wardell contact to be unconformable in Tazewell County, but later Cooper (1953, fig. 1) showed the formations as partially equivalent. Our comparison is based on the Tazewell County sequence and may not apply to these formations as differentiated elsewhere.

The argillaceous, laminated, slightly shaly limestone of Zone 14 at the base of the Gratton, 10 to 35 feet thick, is lithologically similar to the Blomeyer Member at the base of the Mifflin Formation. *Tetradium cellulosum* (Hall) seems to appear first in these strata in southwestern Virginia, Tennessee, Kentucky, Missouri, and New York. The remainder of the Gratton Formation, Zone 15, consists of dove-gray lithographic limestone about 50 feet thick, most of which is relatively pure and thick bedded. This unit resembles the Brickeys Member. *Primitiella constricta* Ulrich appears first in Gratton and Brickeys strata.

The lower part of the Wardell Formation is composed of 15 to 50 feet of argillaceous calcarenite with abundant *Stromatocerium rugosum* Hall (Zone 16), overlain by 15 to 75 feet of argillaceous limestone with numerous *Receptaculites biconstrictus* Ulrich (Zone 17). These zones we correlate tentatively with the argillaceous Establishment Member of the Mississippi Valley. The overlying coarse-grained, pinkish, pure calcarenite up to 25 feet thick (Zone 18) seems equivalent to the pure Hazelwood Member.

The upper part of the Wardell Formation, about 40 feet of calcareous, platy shale (Zone 19), is the most strongly developed shale unit in the Blackriveran sequence of southwestern Virginia and is correlated with the Briton Member of the Mifflin, which regionally is the most shaly unit in the Platteville Group. A 30-inch calcarenite in the middle of the shale matches a thin but very persistent bed of more or less calcarenitic, massive limestone in the middle of the Briton. Zone 19 and the Briton both contain abundant bryozoans, including *Subretepora, Eridotrypa, Escharopora, Graptodictya, Monotrypa,* and *Scenellopora radiata* Ulrich.

The overlying Bowen Formation, absent to 74 feet thick, consists of brown sandstone

(Zone 20) beneath red mudrock (Zone 21). No similar beds are known in states west of Virginia or in New York. The Bowen seems to represent a rapidly deposited near-shore clastic wedge marking the peak of the orogeny that produced the Wardell Shale. It appears most closely related to the Mifflin Formation and may be equivalent to uppermost Briton strata.

Grand Detour Equivalents.—The Witten-lower Moccasin lithologic succession of southwestern Virginia matches the Grand Detour (upper Lowville) sequence of Tennessee, Kentucky, and the Mississippi Valley in a remarkable manner, although the Virginia succession is much thicker. Zone 22, averaging 20 feet thick, consists of moderately argillaceous, laminated to thin-bedded, lithographic limestone. The overlying unit, Zone 23, averages 25 feet thick and also consists of lithographic limestone. The lower half is moderately argillaceous to pure and thin to thick bedded, but the upper half is argillaceous, thin bedded, and shaly. Zone 22 and the lower half of Zone 23 are correlated with the basal Dement Member of the Grand Detour and the upper half of Zone 23 with the succeeding Walgreen Member. As in exposures west of Virginia, both members are much purer than the underlying Mifflin strata, and the Dement Member is distinctly purer than the Walgreen. Interfingering of the lowermost part of Zone 22 with uppermost Bowen strata (Cooper and Prouty, 1943, p. 841) is in harmony with the conformable Mifflin-Grand Detour contact in areas to the west and northwest.

Zone 24 of the Witten is composed of 10 to 25 feet of calcarenite with abundant *Cryptophragmus antiquatus* Raymond, and appears equivalent to a 1- to 2-foot calcarenite layer at the base of the Stillman Member in Kentucky and Tennessee. The overlying fine-grained thick-bedded limestone of the upper Witten (Zone 25) is 60 feet in average thickness. It contains large numbers of the sponge *Camarocladia gracilis* Bassler and the fucoid *Buthotrephis inosculata* Bassler, and weathers to a pitted face. Thus it has the distinctive lithologic features and the fucoid content of the main body of the Stillman Member.

The basal Moccasin unit (Zone 26), about 40 feet thick, is made up of mottled, gray and red, lithographic limestone which has strong streaks of purple calcarenite in the lower 7 to 8 feet. The calcarenitic part seems to correspond to the Clement Member of the Mississippi Valley, but the remainder constitutes a comparatively pure unit not recognized west of Virginia. At Scales the overlying 110 feet of the Moccasin Formation consists of red, argillaceous, shaly limestone[1] that resembles the Hely Member of Missouri and Illinois in relative impurity, thickness, and stratigraphic position. The succeeding 16½ feet is composed of light gray, lithographic, calcite-flecked limestone strikingly like the Victory Member. Both units contain *Tetradium*. The next 52 feet of Moccasin again consists of red argillaceous limestone that has a cyclic alternation of shaly and relatively pure units matching that of the Forreston Member. A 2-foot bed containing thin bentonite layers 24 feet above the base of the Forreston equivalent at Scales has the same position in this cyclic sequence as a bentonite at Camp Nelson, Kentucky.

Nachusa Equivalents.—The succeeding 93 feet of the Moccasin Formation at Scales is composed of red, argillaceous, thick-bedded limestone that is distinctly less argillaceous and shaly than the adjoining units. It contains a 3-inch bentonite 8 feet below the top and a 14-inch bentonite (V-1) 36 feet below the top. This 93-foot unit is correlated with the Eldena Member of the Nachusa Formation through the section at Hagan, Lee County, described below. We did not observe bentonite V-1 west of Tazewell County and it seems to have a limited distribution (Rosenkrans, 1936, p. 93), but the bentonite 8 feet from the top is traceable to Missouri (fig. 38).

The following 26½ feet of Moccasin strata at Scales consists of red, strongly argillaceous, medium-bedded limestone with ma-

[1]Limestone containing from 10 to 40 percent insoluble residue in the Moccasin and Eggleston Formations of Virginia commonly has been called "mudrock."

roon shale partings and a 2-inch bentonite at the base. Channels as much as 3 feet deep have been cut in the top of this unit along a prominent scour surface. The impurity of the unit suggests equivalency with the Elm Member of the Nachusa Formation. The basal bentonite has not been found west of Tazewell County.

Above the Elm representatives at Scales is 67½ feet of argillaceous thick-bedded to massive limestone which in the lower 56½ feet is red, is partly silty, and locally has a horizontally fluted weathered face; in the upper 11 feet it is gray and lithographic. A 1- to 6-inch bentonite (V-2) is present at the base, a 3-inch bentonite occurs 19 feet above the base, and 1-inch bentonites occur 28 and 33 feet above the base. This 67½-foot sequence is correlated with the Everett Member of the Nachusa Formation. It is comparatively pure and thick bedded, even in the very argillaceous Moccasin. The 3-inch bentonite matches one found at a similar stratigraphic position in the Everett from Virginia to Missouri, but the other two bentonites have not been seen west of Virginia.

Beds from the base of the Hely Member of the Grand Detour Formation to a point 25 feet below the top of the Everett Member of the Nachusa Formation have been included in Zone 27 of the Moccasin Formation at Scales (Cooper and Prouty, 1943, p. 843, 879). The next 18½ feet of the Everett equivalent, mainly silty limestone, were placed in Zone 28 at the top of the Moccasin Formation and called "red siltstone." The top 7 feet of the beds equivalent to the Everett were assigned to the Eggleston Formation (Zone 29) at Scales.

Quimbys Mill Equivalents.—Overlying the Nachusa equivalents at Scales are 36 feet of limestone and mudrock that represent the Quimbys Mill Formation of the Mississippi Valley and, with the uppermost Nachusa strata, constitute the lower two-thirds of the Eggleston Formation as recognized at this exposure (Cooper and Prouty, 1943, p. 846). The basal bentonite (V-3) of the Hazel Green equivalent is 3½ feet thick, contains shale and limestone interbeds, and grades laterally to very argillaceous and shaly limestone. The remainder of the Hazel Green representative consists of 5 feet of gray, siliceous, thin-bedded limestone with gray-green shale partings. It is overlain by 8 feet of gray, calcareous, thin- to medium-bedded mudrock, also containing shale partings, which corresponds to the impure Shullsburg Member in western states. The mudrock is capped by 6 inches of bentonite that marks the top of the Shullsburg Member and is traceable to eastern Missouri. The strata corresponding to the Strawbridge at the top of the Quimbys Mill consist of gray, argillaceous, very fine-grained, thin-bedded limestone 19 feet thick, and are purer than the underlying members.

Trentonian Stage

Galena Group Equivalents

Spechts Ferry Equivalents.—At Scales the basal Trentonian Spechts Ferry Formation (Curdsville) is 78½ feet thick and shows the following sequence as correlated with the Mississippi Valley section from the top:

Glencoe Member

- Limestone, gray to black, thin bedded, shaly, barren; 7-inch bentonite (V-13, Rosenkrans, 1936, p. 104) at base, 12′7″
- Calcarenite, light gray, in 4- to 8-inch base with shale partings; 7-inch bentonite (V-12) 2 feet above base; contains profusion of *Dalmanella fertilis* (Ulrich), 13′4″
- Shale, calcareous, brown, 12′
- Shale, calcareous, buff to green; 3-inch bentonite (V-10) at base and 6-inch bentonite (V-11) 4 inches below top, 2′7″

Castlewood Member

- Limestone, argillaceous, dark blue-gray to brown, thick bedded; 4 inches of bentonite and shale (V-8, V-9) 3 feet above base, 8′
- Shale, olive green, hackly, 1′2″
- Bentonite (V-7), 1′6″
- Limestone, argillaceous, gray, locally cherty, thin to thick bedded; four 3- to 6-inch bentonites, including V-5 and V-6, 22′4″
- Shale and limestone, greenish gray, interbedded, 3′6″
- Bentonite (V-4), 3′6″

The major units in this sequence parallel the major units in the Spechts Ferry sequence of the Mississippi Valley, although most of them are much thicker. *Dalmanella* *fertilis* (Ulrich), *Rafinesquina trentonensis* (Conrad) emend. Salmon, and *Sowerbyella curdsvillensis* Foerste, all thought to be Trentonian index fossils, first appear in the Scales section in chert bands 10½ feet above the base of the Spechts Ferry.

Cooper and Prouty (1943, p. 846) placed the lower 20 feet of the strata correlated with the Spechts Ferry in the Eggleston Formation (Zone 29), and put all higher beds in the Martinsburg Shale. Rosenkrans (1936, p. 102-105) drew the Moccasin-Martinsburg contact 8 feet higher.

The equivalent of the Spechts Ferry Formation at Scales is overlain by about 60 feet of dark gray thin-bedded limestone and calcarenite containing brown to black shale partings. These beds are equivalent to the Kings Lake and Guttenberg Formations. Because they are poorly exposed and considerably deformed, they were not studied in detail.

LEE COUNTY

The upper part of the Black River–Trenton is well exposed at Hagan Siding, Lee County, Virginia (Huffman, 1945, p. 161). At Hagan Siding the sequence is in a relatively pure, gray limestone facies that is more easily correlated with the Illinois succession than is the red to black, very argillaceous sequence of Tazewell County.

Blackriveran Stage

Platteville Group Equivalents

Grand Detour Equivalents.—The lower 140 feet of the Hagan Siding section has been assigned to the Moccasin Formation. These strata are at the top of the Ben Hur Formation of Miller and Brosgé (1954, p. 56, 122). The basal 35 feet consists of very argillaceous, greenish gray, platy limestone that is believed to be equivalent to the Forreston Member at the top of the Grand Detour Formation in Illinois.

Nachusa Equivalents.—The overlying strata consist of 105 feet of slightly argillaceous, partly cherty, lithographic limestone that is mainly medium to thick bedded but has some shale partings. This is the Hardy Creek Limestone of Miller and Brosgé (1954, p. 58, units 2-10, p. 121-122). It contains *Lichenaria carterensis* (Safford), a characteristic Nachusa fossil. This unit is correlated with the basal Eldena Member of the Nachusa Formation, although the thickness is about seven times that of the type area in Illinois. The Forreston-Nachusa contact is the boundary between Zones 13 and 14 of Huffman's Moccasin Formation. A bentonite 8 feet below the top of the Eldena representative matches a widespread bentonite just below or at the top of the Eldena equivalents in Kentucky, Tennessee, and Missouri. This bentonite marks the contact, as drawn by Huffman, between the Moccasin and the overlying Eggleston Formation. We believe that a bentonite reported 12 feet below the top of the Eldena position is actually the first bentonite repeated by thrust faulting, whereas another bentonite, 28 feet below the top of the Eldena, is the V-1 bentonite of the Scales section (Rosenkrans, 1936, p. 105), not yet found west of Virginia.

Above the Eldena equivalents are 39 feet of very argillaceous, blue-gray, massive limestone grading to shaly mudrock that we correlate with the Elm Member of the Nachusa. This is the lower member of the Eggleston Limestone as differentiated by Miller and Brosgé (1954, unit 11, p. 121).

The Everett Member at the top of the Nachusa is represented by the succeeding 62½ feet of comparatively pure, dolomite-mottled, fucoidal, thin- to medium-bedded limestone. This unit is the middle member of the Eggleston Limestone as differentiated by Miller and Brosgé (1954, units 12-14, p. 121). A bentonite 40½ feet below the top probably corresponds to the bentonite near the middle of the Everett equivalents in Kentucky and Missouri. Although fossils are scarce, the beds contain the association of *Stromatocerium, Lambeophyllum, Tetradium, Öpikina,* and *Eoleperditia* so characteristic of the Everett in Tennessee and Kentucky.

Quimbys Mill Equivalents.—Overlying the Nachusa equivalents is a 3-foot bentonite (V-3, called V-4 by Huffman) representing the bentonite at the base of the Quimbys Mill Formation. Above the bentonite is 18 feet of light gray, lithographic, thin- to medium-bedded, shaly limestone. Comparison with the Scales section and with Kentucky-Tennessee sections suggests that this unit represents a local shaly facies of the Hazel Green Member plus the Shullsburg Member. A shale parting at the top of the unit appears to replace the bentonite normally found at the top of the Shullsburg.

The succeeding 26 feet of limestone is similar but is chiefly massive and nonshaly and is correlated with the Strawbridge Member at the top of the Quimbys Mill. Two unique features of the Strawbridge at Hagan Siding, not seen elsewhere, are the presence of a 5-foot shaly unit 20 inches below the top and of a 2-inch bentonite 11 feet below the top.

The Quimbys Mill consists of units 15 to 23 of the Hagan Siding section as described by Miller and Brosgé (1954, p. 120-121). It is the upper member of the Eggleston Limestone except for the upper bentonite and limestone (units 24, 25), which we place in the Spechts Ferry.

Trentonian Stage

Galena Group Equivalents

Spechts Ferry Equivalents.—Above the Quimbys Mill equivalents the Hagan Siding section shows the following sequence, as correlated with the Mississippi Valley section, from the top:

Spechts Ferry Formation
- Glencoe Member
  - Calcarenite, medium grained, thin bedded, very shaly, 22′6″
  - Calcarenite, coarse grained, medium bedded, slightly shaly, 12′6″
  - Bentonite (V-11), 6″
  - Limestone, chalky, very thin bedded and shaly, 2′
- Castlewood Member
  - Calcarenite, coarse grained, thin to medium bedded, partly shaly, 29′6″
  - Limestone, argillaceous, thin to thick bedded, shaly, 10′
  - Bentonite (V-4, called V-7 by Huffman), 4′

The Spechts Ferry sequence at the Hagan Siding section differs from that at Scales in that (1) it is much less shaly, (2) it has fewer bentonites, and (3) the Castlewood Member has gained considerably in thickness at the expense of the Glencoe Member. The beds are blue-gray to greenish gray and carry a profuse Trentonian fauna.

Huffman drew the Eggleston-Curdsville contact at the top of the basal bentonite of the Spechts Ferry (V-4) and placed the Curdsville-Hermitage contact at the base of the bentonite (V-11) in the Glencoe Member.

Differences in the use of the term Eggleston pose a major problem in comparing published sections at Hagan Siding and Scales. At Scales, Cooper and Prouty drew the base of the Eggleston Formation 7 feet below the top of the Nachusa equivalents. They drew the top of the Eggleston 20 feet above the base of the Curdsville (Spechts Ferry) Formation. At Hagan Siding, Huffman used Eggleston to include all beds between the base of the upper bentonite of the Eldena and the top of the basal bentonite (V-4) of the Spechts Ferry, thus placing the Eggleston base 85 feet lower and the top 16 feet lower than at Scales. Miller and Brosgé put the Eggleston base at Hagan Siding 26 feet higher and the top 12 feet higher than Huffman did. The top of the Eggleston at Hagan Siding as drawn by Huffman nearly coincides with the top of the Eggleston as originally defined (Mathews and Pegau, 1934, p. 11).

Kings Lake Equivalents.—Forty-two feet of brown, calcareous, silty shale containing only a few *Dalmanella fertilis* (Ulrich) overlies the Spechts Ferry equivalents at Hagan Siding. This unit very closely resembles the lower part of the Logana Formation in Kentucky and the Laminated Argillaceous Limestone Member of the Hermitage Formation in Tennessee, both of which are equivalent to the Kings Lake Formation. A bentonite 10 feet above the base appears to correspond to the lower bentonite (T-5) of the Kentucky and Tennessee units. The top of the Kings Lake corresponds to the top of the Hermitage as used by Huffman.

Guttenberg Equivalents.—Above the shale equivalent to the Kings Lake, 31 feet of fossiliferous strata are very similar lithologically and faunally to the upper part of the Logana Formation in Kentucky, which is equivalent to the Guttenberg Formation. The bottom 9½ feet consists of brown-gray, coarse-grained, medium-bedded calcarenite interlayered with shaly limestone in the lower 2 feet. This unit is correlated with the Garnavillo Member. The remaining 21½ feet is composed of brownish-gray, lithographic, white-weathering limestone and coarse-grained calcarenite in thin to medium beds separated by prominent brown to gray shale partings. This unit is correlated with the Glenhaven Member.

Dunleith Equivalents.—Argillaceous, lithographic to coarse-grained, thin-bedded shaly limestone and calcarenite 83 feet 8 inches thick succeeds the Guttenberg equivalents at Hagan Siding. These beds have the lithology and stratigraphic position of the Buckhorn to Sherwood Members of the Dunleith Formation. They are overlain by 67 feet 4 inches of distinctly less argillaceous, thicker bedded strata that have some pure calcarenite ledges in the upper 26 feet 4 inches and that probably represent the Wall and Wyota Members. The Dunleith equivalents contain *Prasopora simulatrix* Ulrich, *Hebertella frankfortensis* Foerste, *Dalmanella fertilis* (Ulrich), and *Strophomena vicina* Foerste.

Wise Lake Equivalents.—The next 126 feet of the Hagan Siding sequence consists of pure, light gray, medium- to coarse-grained calcarenite in medium to thick beds. Some layers of lithographic limestone are present in the upper part, which is poorly exposed in the hillslope northeast of the water tower. This unit contains a Woodburn-like faunal assemblage including *Stromatocerium pustulosum* (Safford), *Constellaria teres* Ulrich & Bassler, *Platystrophia colbiensis* Foerste, and *Rhynchotrema increbescens* (Hall). Because of its relative purity it is tentatively correlated with the Wise Lake Formation.

Dubuque Equivalents.—Overlying the Wise Lake equivalents is 207 feet of argillaceous, lithographic, thin- to medium-bedded limestone, which is more or less shaly and which has some calcarenites in the upper part. The fauna includes *Hebertella sinuata* (Hall), *Orthorhynchula linneyi* (James), and *Cyclonema varicosum* Hall. This unit is believed to be of Dubuque (Cynthiana) age. Above the Dubuque equivalents is a 12-foot massive ledge of fine-grained calcarenite with abundant bryozoans which is very much like the Nicholas Limestone (uppermost Cynthiana) of Kentucky and may be equivalent to the Cape Limestone in the Mississippi Valley. As a rock unit it is allied to the strata below, but it may be the initial deposit of Cincinnatian age.

Cincinnatian Series

The position of the Champlainian-Cincinnatian boundary at Hagan Siding is supported by the following nearly complete Cincinnatian sequence, exposed in cuts on the east side of the north-south railroad track and along another railroad track curving westward:

Sequatchie–Juniata Formations (Richmondian)
- Shale, red, fossiliferous, 50′
- Shale, gray; contains sandstone beds, 135′
- Shale, gray; contains thin limestone beds, 105′
- Shale, gray, becoming red at top, 90′

Reedsville Formation
- Limestone (Maysvillian), shaly but mostly medium to thick bedded, 275′
- Shale and limestone (Edenian), thinly interbedded, 215′

The sequence along the westward curve is cut off at the top by a thrust fault that dips gently eastward.

The Blackriveran-Trentonian Boundary

The occurrence in Blackriveran strata in southwestern Virginia of *Receptaculites* and *Sowerbyella,* genera limited to the Trentonian in the interior stable region, might be taken as indicative of Trentonian age for beds as old as the Lincolnshire Limestone. However (1) the species differ from Trentonian forms, (2) such characteristic Trentonian genera as *Rafinesquina* and *Dalmanella* are lacking, (3) the remainder of the fauna has a Blackriveran aspect, and (4) the lithologic sequence matches that in the Blackriveran strata elsewhere. The evidence suggests that the genera *Receptaculites* and *Sowerbyella* originated in a geosynclinal environment in Blackriveran time, but were prevented by ecologic conditions from migrating into bordering shelf regions until Trentonian time.

The Moccasin and Eggleston Formations have been classified as Trentonian on the basis of correlations with New York strata via Pennsylvania (Huffman, 1945, p. 171; Kay, 1948, p. 1412; 1956, p. 95; Prouty, 1948, p. 1615; Twenhofel et al., 1954; Cooper, 1956). However, correlations from New York to Pennsylvania and Virginia via the Mississippi Valley indicate that the Moccasin and Eggleston Formations are of Blackriveran age.

WYOMING

The Ordovician sequence in Wyoming (fig. 27), compiled largely from Tomlinson (1917, p. 126-134, 255-256, 390), is given below with our correlations:

Cincinnatian Series
- Bighorn Formation
  - Member 7
    - Dolomite, white, gray or buff, chalky, mainly thin bedded, weak, 4′–17′
  - Member 6
    - Dolomite, white to brown-gray, fine grained, thin bedded to massive; basal breccia or conglomerate, 10′–181′

Unconformity

Champlainian Series
- Trentonian Stage
  - Bighorn Formation (continued)
    - Member 5
      - Dolomite, argillaceous, mostly white, very fine grained, in thin to thick, smooth-weathering beds, 0–89′
    - Member 4
      - Dolomite, brown, fine grained, massive in lower half; upper half like member 3 but massive, 70′–302′
    - Member 3
      - Dolomite, light colored, medium to very coarse grained, partly brecciated, mainly thin bedded and weak, 0–60′
    - Member 2
      - Dolomite, cream to buff, fine grained, in 2-foot beds, 0–10′
    - Lander Member (Miller, 1930)
      - Sandstone, partly ferruginous and quartzitic, medium to coarse grained, fossiliferous, 0–10′

Unconformity
- Blackriveran Stage
  - Harding Formation (Darton, 1906, p. 552; Kirk, 1930, p. 460-462)
    - Sandstone, mainly fine grained, thin bedded, partly shaly; contains fish plates, 0–42½′

The Ordovician succession rests unconformably on the Upper Cambrian Deadwood or Gallatin Formations and is overlain unconformably by Devonian or Mississippian limestones. The Harding Sandstone, found in the Bighorn and Bridger Mountains in central Wyoming, may be equivalent to only the lower Harding Member (St. Peter-Glenwood?) of Colorado. The middle member of the Harding (Platteville-Spechts Ferry?) of Colorado appears to be missing in Wyoming along the Harding-Lander unconformity.

The Lander Sandstone was described (Miller, 1930) from the Wind River Mountains of western Wyoming, where it unconformably overlies Gallatin strata and conformably underlies the Bighorn Dolomite. Judging from Kirk's descriptions (1930, p. 460-464), it also is present in the Bridger and Bighorn Mountains, where again it is conformable beneath the Bighorn but rests unconformably on the Harding Sandstone. The entire Bighorn Formation, including the Lander, has been classed as Cincinnatian, and part of the fauna of the Lander was interpreted by Miller as equivalent or closely allied to Richmondian species. However, the position of the sandstone beneath the Galena portion of the Bighorn Dolomite and the presence of *Receptaculites oweni* Hall and other forms show that the age of the Lander Member is lower Trentonian (lower Galena). It seems most likely that the Lander Sandstone corresponds to the upper part of the upper member of the Harding of Colorado and to the "transitional member" (upper Roughlock) of the Winnipeg Formation in South Dakota, and that it is of Buckhorn-St. James (Ion) age.

The Bighorn Dolomite is widespread in northern Wyoming and extends into southern Montana (Tomlinson, 1917, p. 253-254; Sloss and Moritz, 1951, p. 2148), but it has been removed by pre-Mississippian erosion from most of southern Wyoming. Bighorn Members 2 and 4 carry a typical Trentonian fauna including *Receptaculites oweni* Hall, *Halysites gracilis* (Hall), *Streptelasma corniculum* (Hall), and *Maclurites manitobensis* (Whiteaves). It appears probable that Members 2 and 3 are lower Dunleith, that Member 4 is upper Dunleith and Wise Lake, and that Member 5 is Dubuque. Cherty dolomite believed to represent the top of the Dunleith Formation occurs about 100 feet above the base of Member 4 in Shoshone Canyon west of Cody, Park County, Wyoming (Stipp, 1947a, p. 279; 1947b, p. 127).

Members 6 and 7 lack the Trentonian fauna, except for *Halysites,* but contain *Calapoecia* cf. *C. anticostiensis* Billings, *Calapoecia huronensis* Billings and many other Cincinnatian fossils (Ulrich, *in* Darton, 1906, p. 28). Tomlinson recognized Members 8 and 9 but these may duplicate 6 and 7. Also, it appears that in some areas limestone and dolomite strata as young as Devonian may be included in the upper part of the Bighorn. In western Wyoming, where Member 5 (Dubuque?) is missing, Members 6 and 7 have been called the Leigh Member (Blackwelder, *in* Tomlinson, 1917, p. 256; Blackwelder, 1918, p. 419-420). More recently the Leigh has been differentiated as a formation and its Ordovician age questioned (Wanless, Belknap, and Foster, 1955, p. 15).

In Shoshone Canyon, Stipp's lower member of the Bighorn seems equivalent to the Dunleith Formation exclusive of Lander (Buckhorn-St. James?) strata, which are absent. His middle member of the Bighorn, and possibly part of his upper member, is thought to include Wise Lake, Dubuque, and Cincinnatian beds, although at least a portion of the upper member is said to be of Devonian (Jefferson) Age.

Twenhofel et al. (1954) considered the Lander and Bighorn to be entirely Richmondian. Duncan (1956) classified the Bighorn as Cincinnatian on the basis of corals. Stone and Furnish (1959) assigned the Bighorn to early Cincinnatian on the basis of conodonts. Foerste (1936, p. 373) and Miller et al. (1954, p. 41), largely on the basis of cephalopods, classified the Bighorn as Cincinnatian, and specifically correlated the Lander with the Dog Head of southern Manitoba and the Stewartville of the Mississippi Valley.

EXTENT OF THE TRENTONIAN SEA IN NORTH AMERICA

Trentonian faunas have been recovered from dolomite and limestone in northwestern Greenland, in the Arctic Archipelago of Canada, along the west shore of Hudson Bay, and at Great Slave Lake, Northwest Territories, Canada (Foerste, 1927; 1928, p. 1-12; 1929a; 1929b, p. 129-146; Teichert, 1937a; 1937b; Roy, 1941; Miller and Carrier, 1942, table 1; Miller and Youngquist, 1947a; 1947b; Washburn, 1947; Troelson, 1949; Miller et al., 1954). Most of the species are characteristic of the Red River Formation of Manitoba or of the Galena Group of the Mississippi Valley. Collections from Greenland and parts of the Arctic Archipelago include *Maclurites cuneata* (Whitfield), a fossil characteristic of Stewartville strata. A similar fauna containing *Maclurites subrotunda* (Whitfield), another Stewartville index fossil, occurs in limestones along Porcupine River, northeastern Alaska (Kindle, 1928, p. 322-324). Trentonian fossils including *Maclurites manitobensis* (Whiteaves) have been found in part of the Port Clarence Limestone, Seward peninsula, western Alaska (Kindle, 1911, p. 344-346; Kirk, 1922, p. 25-26). Faunal lists indicate that Cincinnatian beds also are present in parts of the Arctic and Alaska.

In Idaho, Utah, Nevada, and California the Fish Haven and equivalent dolomites rest on the Ordovician Eureka Quartzite and equivalent or older strata (Mansfield, 1927, p. 58; Hintze, 1951, p. 23). Stratigraphic tracing by Tomlinson (1917) suggested that the Fish Haven Dolomite of Utah and the Hanson Creek (basal Lone Mountain) Formation of central Nevada correspond to the Bighorn Dolomite of Wyoming and are of both Trentonian and Cincinnatian age. The Fish Haven lithologic succession also resembles the Fremont sequence in several respects. The fauna of the Fish Haven and contemporaneous dolomites includes the Trentonian species *Zygospira recurvirostris* (Hall), and *Cryptolithus tesselatus* Green? (Hague, 1892, p. 59) and the Cincinnatian species *Calapoecia* cf. *C. anticostiensis* Billings, *Streptelasma trilobatum* (Whiteaves), and *Strophomena* cf. *C. planumbona* (Hall).

In Texas and New Mexico the Montoya Group (Richardson, 1909, p. 4; 1914, p. 4-5; Darton, 1928, p. 11-14; Kelley and Silver, 1952; Kottlowski et al., 1956; Howe, 1959) intervenes unconformably between the Canadian El Paso Limestone and the Silurian Fusselman Limestone. The basal formation of the Montoya, the Cable Canyon Sandstone, is up to 50 feet thick, consists of sandstone and sandy dolomite, and may partly correspond to the Harding Sandstone of Colorado. The overlying Upham Dolomite, commonly 75 to 100 feet thick, is composed of dark, fine-grained, slightly cherty, massive, dolomitic limestone and contains the Trentonian fossils *Receptaculites oweni* Hall, *Hormotoma major* (Hall)?, *Maclurites manitobensis* (Whiteaves), *Zygospira recurvirostris* (Hall), and others. It appears equivalent to the post-St. James Dunleith and Wise Lake strata of the Galena Group. The overlying Aleman Limestone, 100 to 200 feet thick, consists of limestone and dolomite with interbedded and nodular chert. It has been referred to the Cincinnatian, but it has the stratigraphic position of the Dubuque Formation and in its high chert content resembles Member 1 at the top of the Viola Limestone of Oklahoma. The upper Montoya Cutter Formation, up to 200 feet thick, consists of gray dolomite, is mostly thick bedded, and contains an abundant Cincinnatian fauna.

In the Marathon–Solitario Uplifts of west Texas (Sellards, 1932, p. 76-80; King, 1937, p. 34-42), the Woods Hollow Shale is at least partly of Trentonian age and the overlying Maravillas Chert is correlated with the Montoya. Lower Maravillas strata contain a Trentonian fauna (Baker and Bowman, 1917, p. 91), including *Climacograptus antiquus* Lapworth, *Diplograptus amplexicaulis* (Hall), *Parastrophina* aff. *P. hemiplicata* (Hall), and *Eoharpes*.

From the above data and discussions of the individual states, it is evident that the Trentonian sea spread widely over North America. The extent, purity, and massiveness of Wise Lake strata suggest that this mid-Trentonian formation was deposited during the greatest submergence ever experienced by the continent. The extent of the Trentonian sea has been underestimated because in arctic regions and western states Trentonian beds commonly have been included with Cincinnatian strata.

GEOLOGIC SECTIONS

Sections Containing Type Sequences of Units Named in This Report

1. Starved Rock Section

Exposures at Starved Rock, Lovers' Leap, and French Canyon, in Starved Rock State Park, LaSalle County, Illinois (W ½ NW and NW NW SW 22, 33N-2E, Ottawa Quad.). Type sections of Starved Rock and Tonti Members of St. Peter Sandstone.

Pennsylvanian System

Shale, clay, coal .... 30′

Ordovician System

Platteville Group

Pecatonica Formation

Chana Member

Dolomite, buff, medium grained, thick bedded; exposed in French Canyon above the falls .... 10′

Ancell Group

St. Peter Formation

Starved Rock Member (90′)

Sandstone, white to light brown, medium grained, well sorted, thick bedded .... 71′

Sandstone, silty, white, fine .... 7″

Sandstone, gray, medium, massive .... 4′

Sandstone, argillaceous, buff; bimodal with fine and coarse grains (Glenwood texture), thin bedded .... 3′ 3″

Sandstone, very fine and medium; silty streaks .... 4′ 2″

Sandstone, medium, well sorted .... 7′

Tonti Member

Sandstone, fine grained, well sorted, thick bedded; base concealed at low water of Illinois River .... 20′

2. Oak Ridge School Section

Exposures in ravine a third of a mile east of Oak Ridge School on Ridge Road, 3 miles north of Grand Detour, Ogle County, Illinois (NE SE NW 36, 23N-9E, Dixon Quad.). Type section of Kingdom Member of Glenwood Formation.

Ancell Group

Glenwood Formation

Daysville Member

Dolomite, argillaceous, silty, sandy, yellow-buff, chalky, conglomeratic, thin bedded; ferruginous cavities and worm-borings .... 1′ 3″

Kingdom Member (7′11″)

Sandstone, silty, argillaceous, green to buff, largely very fine grained, thin bedded .... 2′

Siltstone, sandy, argillaceous, green, thin bedded; streaks of very fine grained sandstone .... 1′ 3″

Sandstone, very argillaceous, silty, green to buff, thin bedded, bimodal; flakes and streaks of green clay .... 2′ 3″

Sandstone, silty, argillaceous, greenish gray and very fine grained at top to brown and coarse grained at base, massive; worm-borings .... 2′ 5″

St. Peter Formation

Tonti Member

Sandstone, white to light brown, mostly fine grained but largely medium grained in upper 10″, well sorted, in 4-12″ beds; green clay flecks locally; worm-borings in upper part .... 5′10″

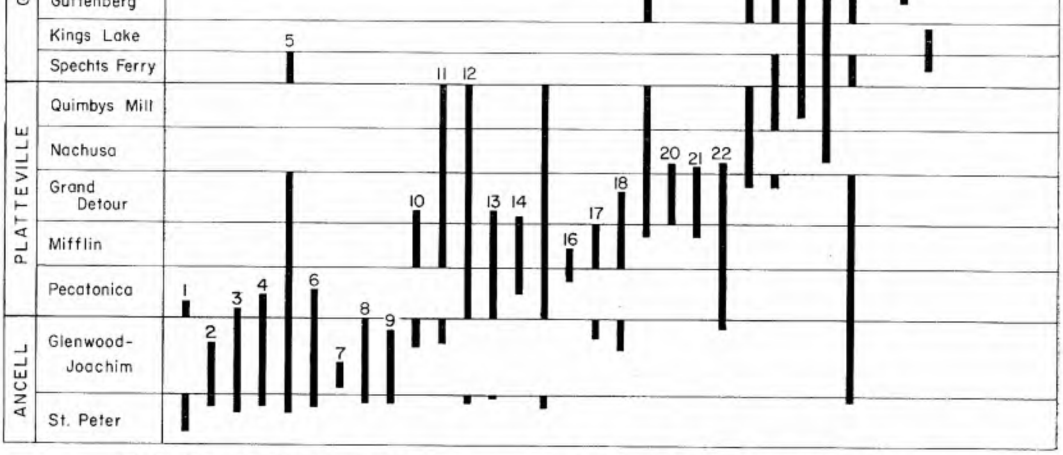


FIG. 41.—Index to stratigraphic units described in the geologic sections.

3. Daysville Northeast Section

Ravine north of Illinois Highway 64, 2½ miles northeast of Daysville, Ogle County, Illinois (NW NW SW 6, 23N-11E, Oregon Quad.). Type section of Daysville Member of Glenwood Formation.

Platteville Group
Pecatonica Formation
Chana Member

Sandstone, dolomite cemented, brown, medium grained, thin bedded ... 1′

Ancell Group
Glenwood Formation
Harmony Hill Member

Shale, silty, sandy, green in upper half, maroon in lower half, mottled buff; lenses of argillaceous sandstone ... 3′ 1″

Loughridge Member

Sandstone, silty, argillaceous, greenish gray to buff, mostly very fine grained, thin bedded ... 6′

Daysville Member (23′9″)

Dolomite, silty, argillaceous, buff, chalky; green shale partings; interbedded with very fine-grained, locally conglomeratic dolomite with worm-borings ... 11′10″
Dolomite, very sandy, silty, argillaceous, greenish gray to brown, chalky, thin bedded ... 4′ 4″
Dolomite, as above but partly conglomeratic, with blocks of St. Peter Sandstone ... 5′ 2″
Dolomite, as above with coarse sand ... 2′ 5″

St. Peter Formation
Tonti Member

Sandstone, white to brown, locally mottled with green clay, mainly fine grained, thin bedded ... 5′ 2″
Sandstone, as above but thicker bedded ... 10′ 6″

4. Harmony Hill School South Section

Ravine 1½ miles south of Harmony Hill School, a third of a mile east of Ridge Road, 4 miles north of Grand Detour, Ogle County, Illinois (N ½ NW NE NE 25, 23N-9E, Dixon Quad.). Type section of Loughridge Member of Glenwood Formation.

Platteville Group
Pecatonica Formation
Chana Member

Dolomite, sandy, gray to brown, fine to medium grained, thin bedded, fossiliferous ... 5′ 8″

Hennepin Member

Sandstone, dolomitic, pyritic, gray to brown, medium grained, thin bedded; contains phosphatic nodules ... 2′ 4″

Ancell Group
Glenwood Formation (32′7″)
Harmony Hill Member (8′9″)

Shale, silty, sandy, gray, green, maroon ... 6′ 9″
Shale, sandy, green; lenses of argillaceous sandstone ... 9″
Sandstone, very argillaceous, silty, green, very fine grained, thin bedded ... 1′ 3″

Loughridge Member (9′9″)

Sandstone, silty, argillaceous, gray to brown, bimodal, massive to thin bedded; lower part largely coarse grained ... 6′10″
Sandstone, very silty, argillaceous, green to buff, very fine grained, thin bedded; green clay streaks; dolomite fragments and coarse sand in lower part ... 2′11″

Daysville Member (7′10″)

Siltstone, dolomitic, argillaceous, sandy, green ... 4″
Dolomite, argillaceous, silty, sandy, buff, conglomeratic except upper 2′, thin bedded; dark clay streaks ... 6′ 9″
Sandstone, dolomite cemented, buff, bimodal ... 9″

Kingdom Member (6′2″)

Sandstone, very silty, argillaceous, green, very fine grained, thin bedded ... 1′
Sandstone, silty, argillaceous, very fine grained in upper part, coarse grained in lower part, massive to thin bedded; worm-borings ... 5′ 2″

St. Peter Formation
Tonti Member

Sandstone, mainly fine grained ... 1′ 8″

5. Minneapolis Section

Exposure in west bluff of Mississippi River at Lock and Dam No. 1 in Minneapolis, Hennepin County, Minnesota (NE SW NW 17, 28N-23W, St. Paul Quad.). Described in terms of the Illinois section. Type sections of Nokomis Member of Glenwood Formation and Hennepin Member of Pecatonica Formation.

Galena Group
Decorah Subgroup
Spechts Ferry Formation (7′7″)
Glencoe Member (6′2″)

Shale, light greenish gray ... 1′ 1″
Limestone, argillaceous, light gray, very fine grained, massive ... 9″
Shale, light to dark gray; local layer of calcarenitic and argillaceous limestone near top ... 2′
Limestone, slightly argillaceous, calcarenitic, in 1-3″ beds with shale partings ... 1′ 1″
Shale, brownish gray ... 1-2″
Limestone, as above; bryozoans abundant ... 11″
Bentonite, cream to orange-buff ... 2″

Castlewood Member

Limestone, pure, brown, medium grained, in 1-3″ beds (*Lingula elderi* bed) ... 1′ 5″

Platteville Group
Grand Detour Formation (13′3″)
Forreston Member

Limestone, argillaceous, gray, very fine grained, slightly fucoidal, in 1-2″ beds; very fossiliferous with molluscan coquina beds; pyritic corrosion surface at top (*Vanuxemia* bed) ... 8′

Clement Member

Limestone, gray-green, fine to medium grained, porous; gray carbonaceous flecks ... 2″

Stillman Member (5′1″)

Limestone, argillaceous, greenish gray, in medium beds, fucoidal at top ... 2′
Shale, calcareous, gray; grades to argillaceous limestone with molluscan molds at top ... 1′ 5″
Limestone, argillaceous, massive; contains phosphatic nodules ... 1′ 8″

Mifflin Formation (11′7″)
Briton Member (2′5″)

Limestone, greenish gray; shaly, fucoidal; corrosion surface at top ... 5″
Limestone, gray, shaly ... 2′

Hazelwood Member

Limestone, pure, lithographic, dolomite mottled, fucoidal; 4-5″ calcarenite at base ... 2′ 1″

Establishment Member

Limestone, gray, white weathering, thin bedded, slightly fucoidal; abundant fossil debris; 3″ calcarenite 1′8″ below top ... 5′ 7″

Brickeys Member

Limestone, argillaceous, greenish gray, fine grained, massive ... 1′ 6″

Pecatonica Formation (3′2″)
Chana Member

Dolomite, argillaceous, sandy, gray to buff, fine grained; phosphatic nodules in lower 3″; ferruginous pitted surface at top ... 11″

Hennepin Member (2′3″)

Limestone, very argillaceous, greenish gray, nodular; and shale, calcareous, green; corrosion surface at top ... 1′ 6″
Limestone, very argillaceous, greenish gray, slightly sandy; contains phosphatic nodules ... 6″
Sandstone, dolomitic, brown, medium grained, well sorted; contains phosphatic nodules ... 3″

Ancell Group
Glenwood Formation (11′7″)
Harmony Hill Member

Shale, yellow-green ... 9″

Nokomis Member (10′10″)

Sandstone, silty, white, soft, massive; bimodal texture 4-7″
Sandstone, very argillaceous, silty, mainly very fine grained with bimodal texture, partly ferruginous, greenish buff to red-brown, thin bedded ... 1′11″

Sandstone, very silty, bimodal, white to yellow-buff, friable, massive — 7' 4"

St. Peter Formation

Sandstone, white, ferruginous in places, fine grained, well sorted, friable, massive; base concealed — 26'

6. Harmony Hill School Section

Ravine three-fourths of a mile southeast of Harmony Hill, one-third of a mile east of Ridge Road, 5 miles north of Grand Detour, Ogle County, Illinois (W½ SE SE NE 24, 23N-9E, Dixon Quad.). The section measured is in the second ravine north of the house, but recently the sequence has become better exposed in the ravine immediately southeast of the house below the dam. The latter section contains a 3-foot lens of sandstone of the Hennepin Member at the base of the Pecatonica Formation. Type sections of Harmony Hill Member of Glenwood Formation and Chana Member of Pecatonica Formation.

Platteville Group

Pecatonica Formation (16'6")

Dane Member

Dolomite, gray to brown, medium grained, sparsely fossiliferous, thin bedded — 10' 4"

Chana Member

Dolomite, like above but sandy, nearly sandstone at base, medium bedded; lower 2' pyritic and contains phosphatic nodules — 6' 2"

Ancell Group

Glenwood Formation (27')

Harmony Hill Member (5'10")

Shale, silty, sandy, dark gray; phosphatic nodules at top — 8"

Sandstone, very argillaceous, silty, brown, mainly very fine grained — 3"

Shale, silty, increasingly sandy towards base, green; rare fragments of *Lingula* — 3' 9"

Sandstone, very silty and argillaceous, green-gray, very fine grained, thin bedded — 1' 2"

Loughridge Member (7'7")

Sandstone, silty, argillaceous, greenish gray, bimodal, massive to thin bedded — 3' 2"

Sandstone, gray to brown, mostly medium to coarse grained; base wavy — 10"

Sandstone, very silty and argillaceous, greenish gray, ferruginous at top, mainly very fine grained, thin bedded; base wavy — 3' 7"

Daysville Member (4'7")

Shale, dolomitic, silty, sandy, green — 5"

Dolomite, argillaceous, silty, sandy, pyritic, green to buff, thin bedded — 4' 2"

Kingdom Member (9')

Siltstone, grading downward to very fine grained sandstone, bimodal, argillaceous, green to buff, thin bedded — 3' 7"

Sandstone, silty, white to buff, mostly very fine grained, thin bedded — 9"

Sandstone, silty, argillaceous, greenish gray, mottled brown, massive to thin bedded, bimodal; worm-borings in lower part; ferruginous at base — 3'10"

Sandstone, very silty and argillaceous, green, mottled brown, coarse grained near base, bimodal; green shale partings and pebbles of St. Peter Sandstone near base; base wavy — 10"

St. Peter Formation

Tonti Member

Sandstone, white to brown, largely medium grained; upper part mottled with green clay and limonite; lower part contains worm-borings — 1' 9"

Sandstone, white to brown, largely fine grained — 5' 9"

7. Pecan Grove West Section

Exposure in bluff on north side of Missouri Highway 74, half a mile west of Pecan Grove School and 1¾ miles east of Dutchtown, Cape Girardeau County, Missouri (SE NW NE 20 projected, 30N-13E, Cape Girardeau Quad.). Type section of Abernathy Member of Joachim Formation.

Ancell Group

Joachim Formation

Augusta Member (18'10")

Dolomite, silty, light gray, with faint carbonaceous streaks — 1' 2"

Covered — 2'

Dolomite, silty, light gray, in thin and medium beds; conglomeratic at top; 1" shale at base makes re-entrant — 1'11"

Dolomite, silty, sandy, very fine grained, massive — 9"

Dolomite, argillaceous, dark gray, very fine grained, platy — 4"

Dolomite, silty, light buff, thick bedded; brown carbonaceous streaks; mud-cracks 1'4" below top — 10'

Dolomite, silty, massive; calcite-filled vugs in lower part — 1' 7"

Dolomite, silty, light gray, in thin regular beds — 1'11"

Abernathy Member (25'7")

Sandstone, dolomite cemented, light brown, fine to medium grained, massive, slightly cross bedded — 3' 7"

Shale, gray — 0-1"

Dolomite, silty, thin bedded — 1' 9"

Dolomite, sandy, conglomeratic — 10"

Dolomite, silty, massive except ½" shale 1'7" above base — 4' 2"

Dolomite, argillaceous, dark brown; brown shale partings; top of bench — 5"

Dolomite, silty, massive — 1' 9"

Dolomite, laminated, massive — 1'

Dolomite, argillaceous, silty, platy — 2"

Dolomite, silty, laminated — 3' 3"

Dolomite, slightly silty, finely vuggy, thin to medium bedded — 1' 3"

Dolomite, silty, laminated; 1" shaly dolomite at base and 6" above — 1' 8"

Dolomite, silty, light gray, massive, weakly laminated; base concealed — 5' 8"

The basal 2 feet of the Abernnathy (light gray silty dolomite) overlies 1 foot of the Dutchtown Formation (dark gray limestone) just above the road at the west edge of the exposure, but is on the upthrown side of a fault.

8. St. Albans West Section

Railroad cut and bluffs above the cut, along Chicago, Rock Island and Pacific Railroad, on south side Missouri Valley, a mile southwest of the hamlet of St. Albans, Franklin County, Missouri (SW NE SW 10, 44N-2E, Augusta Quad.). Type section of Augusta Member of Joachim Formation.

Platteville Group (not measured)

Ancell Group

Joachim Formation (110')

Metz Member (10')

Matson Member (30')

Defiance Member (20'6")

Dolomite, silty, massive, white weathering; contains brown argillaceous laminae; shale parting at base makes most prominent break in face — 5' 6"

Boles Member (20'4")

Dolomite, pure, in thin to medium beds interlayered with silty dolomite (about 40%); both rock types contain abundant dark brown and dark gray argillaceous laminae; 1' conglomeratic dolomite with black pebbles occurs 2'9" below top — 15'

Shale, green, mottled yellow; scour surface at base (persistent marker bed) — 4"

Dolomite, pure, vuggy, massive — 9"

Dolomite, silty, dense; weathers white — 2"

Dolomite, pure, vuggy, massive — 1' 2"

Shale, brownish green — 2"

Dolomite, pure, calcite-filled vugs — 5"

Shale, green — 2"

Dolomite, silty, massive — 8"

Shale, greenish gray — 1"

Dolomite, silty, gray, massive — 1' 1"

Shale, greenish gray — 4"

Augusta Member (29')

Dolomite, silty, medium bedded, calcite-filled vugs; shale parting at base; locally has chert lenses — 1' 4"

Dolomite, pure, porous, massive — 1'

Dolomite, silty — 4"

Shale and argillaceous dolomite — 5"

Dolomite, silty, medium beds with shale partings — 2' 2"

Shale, greenish gray; scour surface at base — 3"

Dolomite, silty, white, dense, thin bedded — 2' 3"

Dolomite, pure, coarse; conglomeratic at top	1'
Dolomite, silty, thinly interbedded with brown shale	1'
Sandstone, dolomite cemented	1–2"
Dolomite, conglomeratic; algal domes	1' 2"
Dolomite, silty, thin bedded to massive	1'
Sandstone with bimodal texture; interbedded green shale	7"
Dolomite, white, dense, massive	11"
Dolomite, very sandy, dense	1' 2"
Shale, brown; white sandy streaks	1"
Dolomite, silty, very sandy, massive	1'10"
Shale, sandy, brown	3"
Dolomite, silty, sandy, buff	1' 9"
Sandstone, bimodal; brownish green shale partings	6"
Sandstone, medium grained, silty, dolomitic	1'
Dolomite, silty, sandy, gray-brown, massive	1'10"
Sandstone, dolomite cemented, coarse	1' 2"
Dolomite, silty, sandy	5"
Dolomite, massive; weathers thin bedded	11"
Shale, sandy; makes reentrant	5"
Sandstone, yellow, massive	8"
Dolomite, massive	6-12"
Sandstone, gray, bimodal; scour surface at top	2' 7"

St. Peter Formation

Sandstone, fine; green clay streaks at top; base concealed	4' 6"

9. Matson West Section

Quarry in the north bluffs of Missouri Valley, one mile southwest of the village of Matson, St. Charles County, Missouri (NE cor. SE NE SW 4, 44N-2E, Augusta Quad.). Type sections of Boles and Defiance Members of Joachim Formation.

Ancell Group

Joachim Formation (59'7")

Matson Member

Dolomite, pure, brown, laminated	15'

Defiance Member (20'6")

Dolomite, silty, light buff, in 2 beds	1' 1"
Dolomite, silty, argillaceous at base, thin bedded	1' 2"
Shale, green to buff	1'10"
Dolomite, very argillaceous	5"
Dolomite, argillaceous, massive	2' 6"
Shale, gray-green	2-6"
Dolomite, silty, white weathering, massive, smooth faced	3' 4"
Shale, greenish gray	5"
Dolomite, as above but has brown argillaceous laminae in lower 7"	1' 5"
Dolomite, pure, finely porous, weakly laminated, massive	10"
Dolomite, as above with strong brown argillaceous laminae	2'
Dolomite as above, but with weak laminae; brown shale parting and scour surface at base	2' 8"

Boles Member (19'1")

Dolomite, silty, thin to medium bedded, with wavy brown shale partings	1'10"
Dolomite, silty, massive; worm-borings	1' 8"
Dolomite, argillaceous, shaly	2"
Dolomite, silty, massive; dark gray penetration marks	7"
Shale, dark greenish gray	2"
Dolomite, silty, massive	8"
Shale, gray-green	1"
Dolomite, silty, massive; dark shale laminae	1' 2"
Dolomite, pure, vuggy; calcite-filled vugs	10"
Shale, greenish gray	2"
Dolomite, massive, laminated	10"
Dolomite with shale partings	2'
Shale, greenish gray	2"
Dolomite with shale partings; scour surface at base	1' 1"
Dolomite and shale interbedded	1' 1"
Dolomite, silty, in 4–9" beds with shale partings; lenses of pure porous dolomite	2' 6"
Shale, dark greenish gray, yellow weathering; broadly undulatory scour surface at base (marker bed)	4"
Dolomite, pure, vuggy, massive; wavy shale partings 2'5" below top	1' 8"
Dolomite, silty, argillaceous, massive	10"
Dolomite, pure, massive	7"
Shale, greenish gray	2"
Dolomite, silty, overlying pure dolomite	6"

Augusta Member (5')

Dolomite, silty; scour surface at top	1'
Shale, greenish gray	7"
Dolomite and shale interbedded	9"
Dolomite, pure, porous	1'
Dolomite, sandy	1' 7"
Covered	3' 5"

St. Peter Formation

Sandstone, white, massive; exposed in bluff west of quarry; base concealed	20'

10. Matson Section

Quarry and bluff exposure in north bluff of Missouri Valley, half a mile west of the village of Matson, St. Charles County, Missouri (NE NE NE 4 projected, 44N-2E, Augusta Quad.). Type section of Matson Member of Joachim Formation.

Platteville Group

Grand Detour Formation

Limestone, dolomite mottled, pure, brown, lithographic, fossiliferous, thick bedded; may include Hazelwood Member of Mifflin Formation	25'

Mifflin Formation

Brickeys Member (8')

Dolomite, shaly	2"
Dolomite, very silty, buff, chalky, massive	1' 3"
Shale, dolomitic	2"
Limestone, pure, brown, lithographic, conglomeratic, massive	7"
Dolomite, very argillaceous; scour surfaces at top and bottom	5"
Limestone, like 7" bed above	5"
Dolomite, argillaceous, light brown with dark brown carbonaceous mottling, massive	1' 6"
Limestone, dolomitic, light brown, very finely oolitic, massive	3' 6"

Ancell Group

Joachim Formation

Metz Member (10')

Dolomite, argillaceous, shaly, greenish gray; makes reentrant	5"
Dolomite, silty, brownish gray, medium bedded	1'
Dolomite, sandy, conglomeratic with fragments of dense brown dolomite, massive	1'10"
Dolomite, very silty, thin bedded; thin oolitic streaks	2' 7"
Dolomite, pure, massive, laminated at base	2' 9"
Dolomite, very argillaceous, silty	1' 5"

Matson Member (29'9")

Dolomite, pure, massive; prominent scour surface with 8" relief on top	3'
Dolomite, argillaceous, dense, thick bedded; lenses and beds of porous pure dolomite	4' 3"
Dolomite, pure, gray, vuggy, with dense silty mottled areas; scour surface on top	3' 1"
Dolomite, silty and pure interbedded	9"
Dolomite, silty, light gray; small worm-borings in upper 7"	2' 5"
Shale, sandy, green	0–1"
Dolomite, pure, massive, laminated; silty lenses; upper 1'2" conglomeratic	4' 2"
Dolomite, argillaceous; weathers white	6"
Dolomite, slightly argillaceous, dense, smooth faced	3' 9"
Dolomite, pure, very massive, vuggy, laminated	7' 9"

Defiance Member (8'11")

Dolomite, argillaceous, gray and yellow mottled, medium bedded	2' 1"
Dolomite, very argillaceous	3"
Shale, dolomitic, gray-green; layers of argillaceous dolomite	1' 6"
Dolomite, very argillaceous	6"
Dolomite with dark brown argillaceous laminations	5"
Dolomite, silty, thin to thick bedded; dark gray carbonaceous flecks and penetration mottling	1' 9"
Shale and argillaceous dolomite interbedded	5"
Dolomite, argillaceous, with zones of dark gray flecking; base concealed	2'

11. West Point Landing Section

Quarry in east bluff of Mississippi River, and exposures in bluff north of quarry, a quarter of a mile north of West Point Landing, Calhoun County, Illinois (SE NE SE 19, 7N-2W, Hardin Quad.). Type sections of Metz Member of Joachim Formation and Victory Member of Grand Detour Formation.

Galena Group

Spechts Ferry Formation (not measured)

Platteville Group

Plattin Subgroup

Quimbys Mill Formation (14′1″)

Strawbridge Member (6′)

Shullsburg Member (7 11″)

Hazel Green Member

Bentonite with lenses of limestone	2″

Nachusa Formation (40′9″)

Everett Member

Limestone, dolomite mottled, very fucoidal, cherty in upper part, massive; deeply pitted surface	24′

Elm Member (7′3″)

Calcarenite	3″
Limestone, buff, fine grained, in irregular thin to medium beds with thin shale partings; fucoids rare; contains beds of conglomerate and calcarenite; face smooth	6′ 8″
Limestone, medium to coarse grained, conglomeratic	4″

Eldena Member

Limestone, lithographic, dolomite mottled, buff, fucoidal, massive; chert common in upper 7′6″; top of quarry is 6′ above base	9′ 6″

Grand Detour Formation (45′3″)

Forreston Member (19′)

Limestone, light gray, streaked with brown, very fine to coarse grained, massive	2′ 1″
Limestone, argillaceous, light gray, lithographic, medium bedded, cherty at top	2′ 5″
Limestone, as above but in thin beds with red-brown shale partings	2′ 8″
Limestone, gray, lithographic, medium bedded	6′ 6″
Limestone, gray, fine grained, in thin beds with shale partings	1′11″
Limestone, argillaceous, gray, lithographic, slightly fucoidal; chert nodules 6″ above base	3′ 5″

Victory Member

Limestone, pure, very light gray, nearly white, lithographic, brittle, conchoidal fracture, massive, faintly laminated; floating fine calcite crystals and fossil debris (distinctive marker bed)	5′ 6″

Strata above the Victory Member measured in bluff north of quarry.

Hely Member

Limestone, lithographic, dolomite streaked, in thin beds with thin shale partings	5′

Stillman Member

Limestone, gray, lithographic, dolomite mottled, fucoidal, thick bedded; 6″ thin bedded and shaly 1′6″ below top	5′

Walgreen Member

Limestone, gray, lithographic, fucoidal, in thin beds; partings of gray shale with red mottling	4′

Dement Member (6′9″)

Limestone, gray, lithographic, dolomite mottled, fucoidal, thick bedded, cherty; 2″ calcarenite and conglomerate at base	4′ 9″
Limestone, gray, lithographic to coarse grained, partly fucoidal, medium to thin bedded	2′

Mifflin Formation (13′7″)

Establishment Member

Limestone, argillaceous, lithographic, in thin beds with green shale partings; small pelecypods abundant in some bedding planes	3′ 4″

Brickeys Member (10′3″)

Limestone, lithographic, oolitic, massive	1′ 4″
Dolomite, argillaceous, very fine grained, in 2-9″ beds; black carbonaceous flecks; scour surface 5″ above base and at base	3′
Limestone, calcarenitic, massive; scour surface at base	2′ 4″
Dolomite, argillaceous, buff, medium bedded, mud-cracked	1′
Dolomite, argillaceous, laminated, chalky	6″
Shale, dolomitic, green	3″
Dolomite, argillaceous, buff, laminated	4″
Shale, dolomitic, green	1″
Dolomite, argillaceous, buff, very fine grained, massive	14–23″

Ancell Group

Joachim Formation (31′10″)

Metz Member (9′6″)

Dolomite, argillaceous, buff, very fine grained; prominent scour surface with 9–12″ relief on top	37–46″
Dolomite, argillaceous, with dark red-brown laminae, interbedded with shale	1′ 4″
Dolomite, very fine grained, laminated, massive, brecciated	1′
Dolomite, pure, medium to coarse grained; calcite-filled vugs	9″
Dolomite, fine grained, cross bedded	1′ 9″
Dolomite, pure, medium to coarse; brown shaly streaks at top	1′

Matson Member (21′4″)

Dolomite, light gray, mottled brown, very fine grained, finely porous, locally vuggy, massive, laminated with thin films of dark brown shale	13′
Dolomite, argillaceous, gray, strongly laminated	1′
Dolomite, like 13′ bed above	6′ 4″
Covered	1′

Defiance Member

Dolomite, argillaceous, greenish gray, chalky, thin bedded; base concealed	1′

12. Woodford Section

Quarries on East Branch of Pecatonica River just north of Woodford, Lafayette County, Wisconsin (W ½ NW NE 14, 2N-5E, South Wayne Quad.). Suggested type section for the Pecatonica Formation.

Platteville Group

Quimbys Mill Formation (13′)

Nachusa Formation (15′7″)

Grand Detour Formation (11′4″)

Mifflin Formation (13′)

Pecatonica Formation (22′2″)

Medusa Member

Top is 9 feet below the top of the south quarry.

Limestone, argillaceous, dolomitic, gray, fine grained, slightly fucoidal, in 2-20″ beds	5′

New Glarus Member

Dolomite, slightly argillaceous, gray to buff, fine to medium grained, porous, in beds about 18 inches thick	4′

Dane Member (9′1″)

Shale and dolomite interbedded	4″
Dolomite, slightly argillaceous, medium grained, vuggy, in 2-12″ beds	1′ 8″
Dolomite, argillaceous, thin bedded	7″
Dolomite, like 1′8″ bed above	3′
Dolomite, argillaceous, gray to buff, fine grained, dense, in 1-12″ beds with shale partings	3′ 6″

Chana Member

Dolomite, very sandy, fine grained; contains phosphatic nodules (base of south quarry)	9″

Hennepin Member (3′4″)

Sandstone, dolomitic, ferruginous, in thin lenticular beds; sand has St. Peter texture	4″
Sandstone, dolomitic, ferruginous, thin bedded; green sandstone lenses in lower part	3′

Ancell Group

St. Peter Sandstone

Exposed in road cut below quarry; base concealed.

13. New Glarus North Section

Quarry and roadcut in Dane County, Wisconsin, 4 miles north of New Glarus in Green County (SW NW NE 34, 5N-7E, New Glarus Quad.). Type sections of New Glarus and Dane Members of Pecatonica Formation.

Platteville Group

Grand Detour Formation (19′)

Dolomite, in thin beds with brown shale partings	8′
Dolomite, massive	5′
Dolomite, massive, fucoidal	1′ 6″
Dolomite, massive; strong bedding reentrant at base	1′ 6″
Dolomite, argillaceous, massive	3′

Mifflin Formation (15′2″)

Briton Member

Dolomite, thin bedded, shaly, fossiliferous	2′ 9″
Hazelwood Member	
Dolomite, argillaceous and pure interbedded, medium bedded; thin shale partings in a few beds	9′ 4″
Establishment Member	
Dolomite, thin bedded, shaly	3′ 1″
Pecatonica Formation (22′)	
Medusa Member	
Dolomite, mottled buff and orange, fucoidal, massive with wavy discontinuous argillaceous streaks; 1″ red-brown fossiliferous calcarenite at top	5′ 2″
New Glarus Member	
Dolomite, pure, massive, without shale partings	5′ 8″
Dane Member	
Dolomite, medium to thick bedded with shale partings; lower 2′ exposed in roadcut below quarry	8′ 2″
Chana Member	
Dolomite, pure, massive; lower 6″ sandy	3′

Ancell Group

St. Peter Sandstone

14. Dixon North Section

Quarry on east side of Rock Valley, 3½ miles north of Dixon, Lee County, Illinois (SW SW NW 22, 22-N-9E, Dixon Quad.). Type sections of Medusa Member of Pecatonica Formation and Hazelwood and Briton Members of Mifflin Formation.

Platteville Group

Grand Detour Formation

Dement Member (6′8″)

Limestone, dolomite mottled, gray, whitish weathering, medium bedded, fossiliferous, poorly exposed	5′
Limestone, as above but thinner bedded; at top of quarry face	1′ 8″
Mifflin Formation (25′)	
Briton Member (10′)	
Limestone, argillaceous, gray, lithographic, fossiliferous, slightly mottled and streaked with dolomite next to bedding planes; thin wavy beds with shale partings	2′
Limestone, same but less argillaceous	1′ 6″
Limestone, like 2′ bed above but massive; much fossil debris	1′
Limestone, like 2′ bed above but with thicker shale partings, especially in lower part; makes reentrant	3′ 9″
Limestone, as above but thicker bedded; few shale partings	1′ 5″
Limestone, thin bedded; thick shale parting at base	4″
Hazelwood Member	
Limestone, dolomite mottled, gray, lithographic, very fucoidal, thick bedded; corrosion surface at top	5′ 8″
Establishment Member	
Limestone, gray, lithographic, in thin wavy beds with shale partings; makes weak reentrant	4′ 7″
Brickeys Member	
Limestone, as above but medium bedded	1′11″
Blomeyer Member	
Limestone, gray, lithographic, very fossiliferous, in ¼″ beds with shale partings; 1″ dolomitic shale at base	2′10″
Pecatonica Formation (14′)	
Medusa Member	
Limestone, dolomite mottled, fucoidal, thick bedded; contains wavy argillaceous streaks; deeply pitted weathered surface	7′
New Glarus Member	
Dolomite, pure, medium grained, slightly vuggy, thick bedded	3′ 2″
Dane Member	
Dolomite, argillaceous, slightly silty and sandy; in thin to thick beds with thin shale partings; base concealed	3′10″

15. Deer Park Section

Compiled from exposures in the north wall of Deer Park Canyon near its mouth and in the east bank of Vermillion River south of the mouth of the canyon, in Matthiessen State Park, just east of Oglesby, LaSalle County, Illinois (NE NE NE 31, 33N-3E, LaSalle Quad.). Type section of Oglesby Member of Pecatonica Formation.

Pennsylvanian System

Shale, sandstone, clay (not measured)

Ordovician System

Galena Group

Dunleith Formation

Buckhorn Member

Limestone, dolomite mottled, gray, lithographic to coarse grained, fucoidal, crinoidal, dark gray speckled; *Dalmanella, Sowerbyella,* abundant bryozoans	8′
Platteville Group	
Quimbys Mill Formation (13′6″)	
Covered. Compared with outcrops along Hollinger Branch, 1½ miles south, this interval is largely Quimbys Mill	4′ 6″
Limestone, dolomite mottled, brown, lithographic, "glassrock", very fucoidal, thin bedded, locally cherty; abundant *Öpikina*	4′ 8″
Limestone, as above but less fucoidal; contains thin beds with argillaceous flecks and a few thin shale partings	4′ 4″
Nachusa Formation (20′2″)	
Dolomite, buff, fine grained, very fucoidal with fucoids larger than above, very cherty, thin bedded	2′
Dolomite, as above but slightly cherty, massive	2′ 6″
Covered. Compared to Hollinger Branch section this interval is largely Nachusa	15′ 8″
Grand Detour Formation	
Forreston Member (5′2″)	
Limestone, brownish gray, lithographic, hackly fractured, slightly fucoidal, massive	1′ 6″
Limestone, as above but thin bedded	4″
Limestone, dolomite mottled, gray, lithographic, fucoidal, in 2–6″ beds with red shale partings	3′ 4″
Victory Member	
Limestone, gray, white weathering, lithographic, massive	1′ 1″
Limestone, as above, in thin lenticular beds	1′
Limestone, as above, massive	1′ 3″
Hely Member	
Limestone, gray, whitish weathering, in medium beds with red shale partings; several thin calcarenite beds	2′ 6″
Clement Member	
Calcarenite, purplish gray, fine grained	4″
Stillman Member	
Limestone, dolomite mottled, gray, lithographic, fucoidal, in 2′ beds weathering thin bedded; a few thin calcarenite layers	10′ 4″
Walgreen and Dement Members	
Beds cut by small vertical northwestward-trending faults.	
Limestone, as above, but not fucoidal	2′
Limestone, as above, thin bedded	1′ 8″
Limestone, as above, massive	1′ 6″
Mifflin Formation	
Limestone, dolomite mottled, gray, lithographic, mostly in thin beds with shale partings, locally nodular; a few beds near top are fucoidal; scour surface at base	17′ 6″
Pecatonica Formation	
Oglesby Member (16′2″)	
Calcarenite, white, coarse grained, massive, laminated; a few large chert nodules; lenses of gray lithographic limestone near top	8′ 6″
Calcarenite, mottled with lithographic limestone, thin bedded	1′ 6″
Calcarenite, massive	1′ 1″
Calcarenite, thin bedded	1′
Breccia; angular blocks of pinkish brown and gray, medium-grained, dense limestone in a matrix of	

buff, fine-grained, laminated cherty dolomite; bedding contorted; scour surface at base; probably a slide breccia	2′ 6″
Limestone, gray to pinkish brown, medium to coarse grained, dense, massive; like blocks in breccia above	10–19″
Medusa Member	
Dolomite, buff, fine to medium grained, finely porous, cherty, fucoidal; bedding thin and disturbed by flowing before lithification; 2–3″ calcarenite 1″ below top	6′10″
New Glarus Member	
Dolomite, buff to red-brown, in 2–6″ beds with disturbed bedding	3′ 3″
Covered. Probably includes some St. Peter	10′ 2″
Ancell Group	
St. Peter Formation	
Starved Rock Member	
Sandstone, white, medium grained, friable, massive; dips 13 degrees west; not measured	

16. Rock Levee East Section

Small quarry on north side of Missouri Highway 74, a quarter of a mile east of highway junction at Rock Levee, Cape Girardeau County, Missouri (NW cor. NE NW 24, 30N-13E, Cape Girardeau Quad.). Type section of Blomeyer Member of Mifflin Formation.

Platteville Group	
Plattin Subgroup	
Mifflin Formation	
Brickeys Member (9′2″)	
Limestone, brown, lithographic to fine grained; weathers thin bedded and slightly shaly	4′ 4″
Limestone, as above but in thin to medium beds, locally shaly; poorly exposed	4′
Limestone, brown, lithographic, massive, laminated, oolitic	10″
Limestone and shale; makes reentrant	3″
Limestone, brown, thin to medium beds, shaly; thick shale partings in lower 11″	2′ 2″
Shale, brown with lenses of limestone; makes reentrant	2″
Limestone, very shaly	9″
Blomeyer Member (12′1″)	
Limestone, brown, lithographic, massive	2′ 6″
Limestone, gray, weathering white, lithographic, massive	1′ 2″
Limestone, brown, lithographic, thin bedded	3′10″
Shale, calcareous, red-brown	1″
Limestone, brown, lithographic, thin to medium bedded	1′ 2″
Base of Plattin Subgroup	
Pecatonica Formation	
Oglesby Member (9′8″)	
Limestone, light gray, weathers white, lithographic, laminated, massive, thick bedded; contains scattered fine fossil debris; corrosion surface with 2″ relief at top	6′10″
Limestone, argillaceous, brown, fine to medium grained, banded; *Stromatocerium* abundant at top	6″
Limestone, light gray, weathering white, massive	6″
Limestone, as above but darker gray; base concealed	1′10″

17. Kinsey Creek Section

Exposures in quarry on the east side of Missouri Highway 25, 0.3 mile south of the side road to Brickeys, in hillside above quarry, and along the road below quarry, 4 miles northwest of Bloomsdale, Ste. Genevieve County, Missouri (SE SW SE 28, 39N-7E, Crystal City Quad.). Type section of Brickeys Member of Mifflin Formation.

Platteville Group	
Plattin Subgroup	
Mifflin Formation (81′9″)	
Briton Member	
Limestone, dolomite mottled, brown, lithographic; thin to medium irregular beds; contains layers of crinoidal calcarenite	51′
Hazelwood Member	
Limestone, dolomite mottled, gray, lithographic, thick bedded, locally finely fucoidal	10′ 2″
Establishment Member (5′1″)	
Shale, green	3′
Limestone, argillaceous, calcarenitic	2″
Limestone, argillaceous; shale partings at top	2″
Limestone, argillaceous, thinly interbedded with green shale	1′ 2″
Limestone, argillaceous, thin bedded	3″
Shale, green	4″
Brickeys Member (15′6″)	
Limestone, mainly pure, gray, very fine grained, laminated, massive; contains a few argillaceous streaks; locally oolitic and conglomeratic	1′ 4″
Shale, green; contains lenses of argillaceous dolomite	5″
Limestone, lithographic, conglomeratic, oolitic; locally dolomitic in lower half; scour surface at base	5″
Shale, green	2-4″
Limestone, pure, gray, lithographic; shale parting at base	4″
Limestone, pure, oolitic, finely conglomeratic; shale parting at base	10″
Limestone, argillaceous, dolomitic, oolitic	7″
Shale, green	2″
Limestone, argillaceous, gray, faint dark gray mottling, thin bedded	2″
Shale, dark gray	2″
Limestone, argillaceous, massive	3″
Dolomite, argillaceous, blue-gray	3″
Limestone, light brownish gray, white weathering, lithographic, laminated; calcite flecks	1′ 3″
Limestone, oolitic, brown, lithographic; shale parting 7 inches above base	1′ 5″
Limestone, dolomitic, gray, mottled brown, thin bedded; mud-cracked surfaces; floor of upper bench in quarry	1′ 5″
Limestone, oolitic, brown, lithographic, massive; scour surface at base	0-12″
Dolomite, silty, algal domes	0-5″
Limestone, dolomitic, argillaceous, laminated; partly conglomeratic and oolitic; contains algal structures	6-13″
Shale, dark gray	3″
Limestone, pure, lithographic, gray, white weathering, laminated; calcite flecks; conglomeratic at top	1′ 3″
Limestone, argillaceous, gray, thin bedded, mud-cracked; green shale partings	4″
Shale, gray-green, lenses of argillaceous limestone	8″
Limestone, lithographic, massive, brown, white weathering, partly oolitic; *Stromatocerium* at top; base at floor of quarry	1′ 7″
Ancell Group	
Joachim Formation	
Metz Member (17′8″)	
Covered	8′
Dolomite, silty, thin to medium bedded	6″
Dolomite, same, massive	8″
Dolomite, same, thin bedded, shaly	1′ 5″
Dolomite, same, massive	9″
Dolomite, same, shaly	7″
Dolomite, pure, vuggy, massive	9″
Dolomite, silty, gray, dark gray streaks, medium bedded	1′ 6″
Dolomite, same, thin bedded, shaly	3′10″
Matson Member	
Dolomite, buff, finely vuggy, laminated, thick bedded; base concealed	5′

18. Zell Section

Compiled from exposures along a ravine just north of the village of Zell, Ste. Genevieve County, Missouri (W¼ 34, 38N-8E, Weingarten Quad.). Type sections of Establishment Member of Mifflin Formation and Clement Member of Grand Detour Formation. The top of the section is about a quarter of a mile north (upstream) of the east-west road crossing the ravine.

Platteville Group	
Plattin Subgroup	
Grand Detour Formation (84′4″)	
Hely Member	
Limestone, gray, white weathering, lithographic, in thin beds with shale partings, fossiliferous; contains cephalopods filled with quartz crystals	3′

Clement Member

Calcarenite, pure, purplish gray, white weathering, medium to coarse grained, in thin to medium beds.. 13′

Stillman Member (39′4″)

Limestone, dolomitic, lithographic, fucoidal, thin bedded ... 2′
Calcarenite, medium to coarse, laminated ... 1′
Limestone, like 2′ bed above ... 1′
Calcarenite, fine grained ... 8″
Limestone, like 2′ bed above ... 4′
Limestone, brown-gray, lithographic, mostly conglomeratic, in thin beds with shale partings ... 14′
Limestone, brown-gray, dolomite mottled, lithographic, fucoidal ... 8′
Limestone, brown, white specked, lithographic, cherty, medium bedded ... 2′ 6″
Limestone, like 8′ bed above but cherty at top ... 4′
Calcarenite, white, fine grained ... 8″
Limestone, like 8′ bed above but heavily mottled with dolomite and very fucoidal ... 1′ 6″

Walgreen Member

Limestone, brown-gray, lithographic, thin bedded and shaly, partly fucoidal; thin conglomerate and calcarenite beds near top ... 9′

Dement Member

Limestone, dolomite mottled, pure, brown-gray, lithographic, fucoidal, medium bedded ... 20′

Mifflin Formation (89′2″)

Briton Member

Limestone, brown-gray, lithographic, partly dolomite mottled and fucoidal, in thin irregular rough-surface beds with thin shale partings; lower 10′ is medium bedded, calcarenitic, and without shale; *Tetradium* common at base ... 55′

Hazelwood Member

Limestone, pure, purplish brown, fine grained, thick bedded ... 13′ 8″

Establishment Member

Shale, calcareous, blue-green; contains a few thin beds of argillaceous limestone; exposed at bridge on E-W road, but better exposed at road junction 100 yards east ... 5′ 6″

Brickeys Member (16′)

Limestone, gray-brown, fine grained, thin bedded ... 4″
Limestone, argillaceous, gray, carbonaceous mottling.. 2″
Covered ... 7″
Limestone, light gray, red mottled, lithographic ... 5″
Limestone, brown, very fine grained, conglomeratic, oolitic ... 3–5″
Dolomite, silty, thin bedded ... 3–4″
Limestone, brown, lithographic, dark gray; calcite flecks ... 11″
Covered ... 1′ 6″
Limestone, as above; *Tetradium* ... 1′ 4″
Limestone, ripple marked at top ... 3″
Limestone, calcarenitic, brown, fine grained, massive.. 6″
Limestone, brown, lithographic, oolitic, conglomeratic; *Tetradium* ... 2′ 6″
Dolomite, silty, in thin beds with brown shale partings ... 1′ 2″
Limestone, gray; carbonaceous mottling ... 11″
Shale, green; contains thin beds of silty dolomite with carbonaceous flecks ... 6″
Shale, green ... 1′
Dolomite, silty, massive; thin bedded at base ... 1′ 2″
Limestone, pure, brown, lithographic, oolitic, fossiliferous; *Stromatocerium* at top, *Tetradium*, ostracodes ... 1′ 4″
Limestone, pure, light gray, lithographic, massive; *Tetradium* ... 6″
Limestone, argillaceous, brown ... 2″

Ancell Group

Joachim Formation (43′6″)

Metz Member (8′)

Dolomite, silty, thin bedded; carbonaceous mottling and brown shale partings ... 1′ 9″
Dolomite, oolitic, thin bedded ... 6″
Dolomite, like 1′9″ bed above ... 5′ 9″

Matson Member (24′6″)

Dolomite, finely porous, massive; large algal domes 4′ below top ... 7′
Limestone, heavily dolomite mottled, gray brown, weathering whitish, in thin to medium beds, laminated ... 10′ 6″
Limestone, pure, heavily dolomite mottled, gray-brown, strongly laminated; contains brachiopods, trilobite fragments, ostracodes ... 7′

Defiance Member (11′1″)

Dolomite, argillaceous, silty, buff, thin to medium bedded; mud-cracks and ripple-marks ... 6′ 6″
Limestone, pure, gray, laminated, massive ... 7″
Dolomite, very argillaceous, massive; base concealed ... 4′
Joachim strata dip about 5 degrees northeast and thicknesses are approximate.

19. Walgreen Section

Quarry and nearby exposures in west bluff of Rock River on the Walgreen estate, 2 miles north of Dixon, Ogle County, Illinois (NE 20, 22-N-9E, Dixon Quad.). Type sections of Grand Detour Formation and Walgreen and Dement Members.

Galena Group

Dunleith Formation

Buckhorn and St. James Members

Dolomite, buff, medium grained, porous; silicified *Dalmanella;* poorly exposed at top of bluff 100 yards north of quarry ... 8′

Guttenberg Formation

Dolomite, buff, whitish weathering, very fossiliferous, red specked, poorly exposed ... 3′

Platteville Group

Quimbys Mill Formation

Dolomite, gray to buff, chalky; numerous fucoids at top; in thin smooth-faced beds with buff shale partings, poorly exposed; lower 2 feet exposed at top of quarry ... 10′

Nachusa Formation (17′3″)

Everett Member

Dolomite, gray to brown, medium grained, very fucoidal, fossiliferous with molluscan molds, massive; several bands of white chert nodules ... 7′

Elm Member

Dolomite, argillaceous, gray, fine grained, not fucoidal, in medium beds, smooth faced; covered in quarry but exposed in bluff north of quarry ... 1′10″

Eldena Member (8′5″)

Dolomite, brown, fucoidal, massive ... 1′
Limestone, dolomite mottled, brown, fucoidal; scattered chert nodules ... 7′ 5″

Grand Detour Formation (52′3″)

Forreston Member (25′)

Limestone, dolomite mottled, light brown, slightly fucoidal ... 9″
Limestone, dolomite mottled, gray, lithographic, in thin wavy beds with buff fucoidal shale partings ... 1′ 9″
Limestone, as above but fewer shale partings; several corrosion surfaces ... 2′10″
Limestone, as above, more shaly; corrosion surface at base ... 1′ 1″
Limestone, as above; contains bands of chert nodules.. 2′ 3″
Limestone, as above but massive; corrosion surfaces at top and bottom ... 1′ 9″
Limestone, light brown, whitish weathering, lithographic, massive; basal bedding plane very fucoidal.. 3′
Shale, with lenses of argillaceous limestone ... 0–4″
Limestone, like 3′ bed above; weathers thin bedded ... 1′
Limestone, as above but massive ... 1′ 2″
Limestone, as above, in thin to medium beds with red-brown shale partings ... 2′ 8″
Calcarenite, coarse grained, fossiliferous ... 0–2″
Limestone, dolomite mottled, gray, lithographic, 2″ calcarenite at base ... 1′ 3″
Limestone, gray, lithographic, medium bedded ... 3′ 3″
Limestone, as above, in thin beds with red-brown shale partings ... 2′ 1″

Victory Member

Limestone, light tan, white weathering, lithographic, massive ... 10″

Hely Member

Limestone, brown, red specked; in 3–6″ beds with red brown shale partings ... 3′ 5″

Stillman Member

Limestone, dolomite mottled, gray, lithographic, fucoidal, massive; weathers to medium beds; bands of white chert nodules; few thin red-brown shale partings ... 6′ 9″

Walgreen Member (8′3″)

Limestone, gray, lithographic, fossiliferous, in 1-6″ wavy beds with red-brown shale partings; upper part cherty; quarry floor is 6″ below top — 2′ 9″
Limestone, as above but in 4-8″ beds and has less shale — 5′ 6″

Dement Member (8′)

Limestone, gray, lithographic, medium bedded — 4′ 9″
Calcarenite; top of section in ravine south of quarry — 4″
Limestone, dolomite mottled, gray, lithographic, massive — 9″
Limestone, gray, lithographic, in thin wavy beds; 1″ calcarenite at base — 2′ 2″

Mifflin Formation

Briton Member (12′5″)

Limestone, gray, lithographic, in thin wavy beds, with thick greenish gray shale partings — 6′ 6″
Limestone, as above, but largely a coquina of brachiopods — 3″
Limestone, like 6′6″ bed above; base concealed — 5′ 8″

20. Byron North Section

Quarry just north of Byron, Ogle County, Illinois (NE NE SE 30, 25N-11E, Oregon Quad.). Type section of Stillman Member of Grand Detour Formation.

Platteville Group

Nachusa Formation

Eldena Member

Dolomite, pure, gray to buff, fine to medium grained, fucoidal, massive; rough weathered face — 5′

Grand Detour Formation (43′)

Forreston Member (18′4″)

Shale, dolomitic, buff — 1″
Dolomite, argillaceous, gray, fine grained, slightly fucoidal; in medium beds — 1′ 2″
Dolomite, as above; contains thin red-brown shale partings and lenticular beds of calcarenite — 2′ 1″
Dolomite, as above but cherty — 3′ 1″
Dolomite, as above but thin bedded; contains brown argillaceous streaks — 2′11″
Dolomite, as above but massive; *Streptelasma, Tetradium* — 2′
Shale, red-brown — 1″
Dolomite, argillaceous, gray, very fine grained, laminated, thin to medium bedded; contains wavy gray and red-brown shale partings, dark gray carbonaceous flecks and laminae, and many thin layers of calcarenite — 4′ 7″
Dolomite, as above but without calcarenite or thick shale partings — 1′ 8″
Dolomite, argillaceous, buff; interbedded with shale, dolomitic, gray to red-brown — 8″

Victory Member

Dolomite, very fine grained to lithographic, light gray, medium bedded — 1′

Hely Member (3′11″)

Dolomite, argillaceous, gray, thin to medium bedded; shale partings — 1′ 4″
Dolomite, as above but massive; calcarenite at base — 5″
Dolomite, as above, thin bedded; thin red-brown shale partings — 1′ 5″
Dolomite, as above, massive, ferruginous — 5″
Dolomite, as above with thick shale parting at top and bottom — 4″

Stillman Member (5′4″)

Dolomite, gray, medium grained, vuggy, massive, fucoidal; weathers to 2-6″ beds with rough face — 3′ 8″
Dolomite, argillaceous, yellow-buff, thin bedded; thick buff shale partings — 0-3″
Dolomite, massive, fucoidal — 1′ 6″

Walgreen Member (11′5″)

Dolomite, argillaceous, gray to yellow-buff; in 1—3″ wavy beds with thin dolomitic shale partings; 1″ buff to red-brown shale at base makes a reentrant — 1′11″
Dolomite, as above but slightly argillaceous — 11″
Dolomite, pure, massive, medium grained, vuggy; contains several corrosion surfaces — 3′ 9″
Dolomite, buff, coarse grained — 3″
Dolomite, argillaceous, thin bedded, very fossiliferous; contains buff wavy shale partings — 3″
Dolomite, as above but less shale; green shale parting at base — 5′ 2″

Dement Member (3′)

Dolomite, argillaceous, massive, fossiliferous; weathers to 7-8″ beds with slightly wavy surfaces; contains a few thin green shale partings — 2′ 5″
Calcarenite; thick green shale partings at top and bottom — 2″
Dolomite, argillaceous, gray, thin bedded; wavy shale partings (possibly the top of the Mifflin); base concealed — 5″

21. Cape Girardeau South Section

Composite section of exposures in three quarries—the abandoned Hely quarry (northernmost), Federal Stone Company quarry, and the Marquette Cement Company quarry—south of Cape Girardeau, Missouri (NW NE and SE NW 18, 30N-14E, Cape Girardeau Quad.). Type section of Hely Member of Grand Detour Formation. The sequence down to the base of the Victory Member was measured in the Hely quarry, south of a fault with north side upthrown 40 feet; from the Victory Member to the base of the Clement Member in the Federal quarry; and below the Clement Member in the face of the Marquette quarry just south of the Federal quarry.

Platteville Group

Plattin Subgroup

Nachusa Formation

Eldena Member

Limestone, dolomite mottled, brownish gray, fine grained, dense, laminated, fucoidal, cherty, massive, silicified *Foerstephyllum* — 5′

Grand Detour Formation (210′10″)

Forreston Member (40′6″)

Limestone, dark gray, white weathering, massive — 9″
Limestone, brownish gray, lithographic, conglomeratic; contains much black chert; lower part calcarenitic — 3′ 6″
Limestone, brown, fine to coarse grained, medium bedded, contains argillaceous streaks and thin shaly partings; black chert band at top — 2′
Limestone, dolomite mottled, brown, very fine grained; contains a little black chert — 9′
Limestone, brown, fine grained, massive; shale parting at base — 2′ 2″
Limestone, lithographic to fine grained — 5′
Limestone, brown, white weathering, lithographic; in thin to medium, irregular, wavy beds separated by thin shale partings; contains floating fossil debris — 12′
Limestone, dark gray, fine grained, massive, shaly at base — 2′ 2″
Limestone, light gray, laminated, slightly shaly — 9″
Limestone, light brownish gray, lithographic, thin bedded; contains prominent gray shale partings — 3′ 2″

Victory Member (6′8″)

Limestone, very light gray, nearly white, lithographic, massive; weathers thin bedded — 2′10″
Limestone, same, massive; little chert in upper part — 3′10″

Hely Member (73′2″)

Limestone, dark gray at base to gray at top, weathers whitish, lithographic, in thin to medium beds; argillaceous and dolomitic next to bedding planes; contains coarse calcarenite streaks and dark gray chert nodules — 22′ 2″
Limestone, same as above but brown, less argillaceous, without calcarenite streaks, and black chert in basal 2 feet only — 51′

Clement Member

Limestone, brown, lithographic, medium bedded; much fine floating fossil debris; fucoidal in upper part — 6′ 6″

Stillman Member (64′)

Limestone, brown, lithographic, massive, very fucoidal; mottled with fine to medium-grained dolomite — 14′ 6″
Limestone, brown, lithographic, massive; contains white to black chert nodules — 19′
Limestone, brown, lithographic; contains calcarenite lenses and brown shale partings — 1′ 6″
Limestone, brown, lithographic; contains calcarenite lenses, much fossil debris, and black chert at the base — 5′
Limestone, same, without calcarenite and chert — 3′

Limestone, brown, lithographic, massive, very fucoidal; mottled with brown fine- to medium-grained dolomite ... 21′

Walgreen Member

Limestone, brown, lithographic, massive; contains streaks of fossil debris and calcarenite lenses ... 7′

Dement Member

Limestone, brown, lithographic, medium bedded; dolomitic along bedding surfaces ... 13′

Mifflin Formation

Briton Member

Limestone, brown, lithographic, in weakly defined thin to medium beds; contains fine floating fossil debris ... 23′

Floor of quarry in 1950.

22. Brookville Northwest Section

Quarry on north side of a ravine northeast of U. S. Highway 52, one mile northwest of Brookville, Carroll County, Illinois (NE SE NW 21, 24N-7E, Forreston Quad.). Type section of Forreston Member of Grand Detour Formation.

Platteville Group

Nachusa Formation

Eldena Member (8′2″)

Dolomite, pure, gray to buff, fine to medium grained, slightly fucoidal, in 1-4″ beds ... 3′

Dolomite, as above but very fucoidal and cherty ... 6″

Dolomite, as above but not cherty; wavy shale parting in middle ... 8″

Dolomite, as above, very fucoidal, in 4-8″ beds ... 1′11″

Dolomite, as above; *Öpikina* abundant ... 2″

Dolomite, as above, very fucoidal ... 1′11″

Grand Detour Formation (35′6″)

Forreston Member (17′10″)

Dolomite, buff, fine grained, cherty ... 1′ 7″

Dolomite, buff, fine to medium grained, interbedded with red-brown shale ... 2′ 8″

Dolomite, as above but fewer shale partings ... 2′

Dolomite, gray, medium grained, thicker bedded than above; contains lenses of argillaceous dolomite with dark gray carbonaceous streaks ... 2′10″

Dolomite, argillaceous, brown, fine grained; in 3-4″ beds with red-brown shale partings ... 6″

Dolomite, as above but very cherty ... 2′ 6″

Dolomite, as above but relatively pure; contains thin red-brown shale partings; chert nodules at base and 8″ above ... 2′ 7″

Dolomite, dark gray to red brown, thin bedded, slightly fucoidal; contains red-brown shale partings; several bands of chert nodules ... 3′ 7″

Victory Member

Dolomite, light gray, very fine grained, massive ... 1′

Hely Member (3′2″)

Dolomite, argillaceous, brownish gray, fine grained, thin bedded, cherty, very fossiliferous; contains red-brown shale partings ... 3′ 2″

Stillman Member

Dolomite, gray to buff, medium grained, fucoidal, in 1-8″ rough-surfaced beds without shale partings; base at stream below quarry ... 6′10″

Along the valley downstream from the quarry the Stillman Member is completely exposed, is 8′9″ thick, and overlies the following strata:

Walgreen Member (4′10″)

Dement Member (1′10″)

Mifflin Formation (19′6″)

Briton Member (10′)

Hazelwood Member (3′6″)

Establishment and Brickeys Members (6′)

Pecatonica Formation (poorly exposed) (18′3″)

Ancell Group

Glenwood Formation

Harmony Hill Member (6″), base concealed

23. Dixon East Section

Quarry on east side of Dixon, Ogle County, Illinois, east of State Highway 2 at curve where highway descends to floor of Rock Valley (SE SE SW 33, 22N-9E, Dixon Quad.). Type sections of Nachusa Formation and Everett, Elm, and Eldena Members.

Galena Group

Dunleith Formation

St. James Member

Dolomite, buff, gray specked, medium grained; contains a few green shale partings and abundant silicified *Dalmanella* ... 8″

Buckhorn Member

Dolomite, as above, more gray specked and with more green shale ... 5′ 7″

Decorah Subgroup

Guttenberg Formation (3′4″)

Glenhaven Member

Dolomite, buff, whitish weathering, medium to coarse grained, vuggy; contains red-brown shale partings and abundant silicified fossils ... 2′11″

Garnavillo Member

Dolomite, buff, dense, massive; contains a few thin red-brown shale partings ... 5″

Platteville Group

Quimbys Mill Formation (11′8″)

Strawbridge Member (5′11″)

Dolomite, buff, fine grained, dense; in thin beds with shale partings; chert nodules at top ... 10″

Dolomite, yellow-gray to buff, fine to medium grained, dense to vuggy, finely fucoidal, massive, weathering thin bedded; cherty, especially in lower half; *Streptelasma* in upper half ... 2′ 6″

Dolomite, as above, very fossiliferous; corrosion surface at base ... 5-8″

Dolomite, gray-buff, in 1-4″ beds with shale partings; bedding surfaces smooth with mud cracks and fine fucoids ... 1′ 5″

Shullsburg Member

Dolomite, argillaceous, gray to buff, fine grained, dense, locally laminated; 2-8″ beds with smooth, wavy, finely fucoidal bedding surfaces; shale partings ¼ to 1″ thick ... 3′ 6″

Hazel Green Member (2′3″)

Dolomite, as above but not argillaceous, fine to medium grained ... 1′ 7″

Dolomite, argillaceous, buff, chalky, fine grained, dense, laminated, in thin beds with shale partings ... 8″

Nachusa Formation (17′10″)

Everett Member (7′6″)

Dolomite, gray to buff, medium grained, dense, massive; many white chert nodules in basal 4″; corrosion zone at base ... 7″

Dolomite, as above, very fucoidal; contains large white chert nodules and silicified *Foerstephyllum* and *Tetradium* ... 6′11″

Elm Member

Dolomite, argillaceous, light buff, fine grained, dense, slightly fucoidal, cherty in upper 1′2″, in 1-12″ beds with a few shale partings; relatively smooth weathered face ... 2′10″

Eldena Member

Limestone, dolomitic, gray to buff, fine to medium grained, very fucoidal at top to slightly fucoidal at base; contains *Foerstephyllum* ... 7′ 6″

Grand Detour Formation

Forreston Member (9′10″)

Limestone, dolomitic, gray, weathers buff, fine grained, dense, slightly fucoidal and cherty in upper 8″; hummocky bedding surfaces; contains thin discontinuous shale partings and dark gray carbonaceous streaks ... 2′ 1″

Limestone, as above but argillaceous; contains pelecypod molds ... 2′ 7″

Limestone, as above but contains more and thicker shale partings ... 1′ 7″

Shale, calcareous; makes reentrant	2″
Limestone, argillaceous, dolomitic, gray to buff, in 1-8″ beds; contains dark gray carbonaceous streaks; prominent shale partings; corrosion surface at base	1′ 2″
Limestone, as above but thicker beds; contains band of chert nodules 6-8″ below top; base concealed	2′ 3″

24. Quimbys Mill Section

Quarry at Quimbys Mill, near Etna, Lafayette County, Wisconsin (SE SE 11, 11N-1E, Mineral Point Quad.). Type sections of Strawbridge, Shullsburg, and Hazel Green Members of Quimbys Mill Formation.

Galena Group

Dunleith Formation

Buckhorn Member

Dolomite, argillaceous, weathered buff, fine grained; green shale partings	2′

Guttenberg Formation

Glenhaven Member (13′11″)

Limestone, tan, very fine grained, fossiliferous, in thin wavy beds separated by red-brown shale partings	13′ 9″
Shale, brown; contains thin bentonite	2″

Garnavillo Member (1′5″)

Limestone, silty, brownish gray, medium bedded; phosphatic nodules at base	1′ 5″

Spechts Ferry Formation (1′2″)

Limestone, gray, thin bedded; thin green shale at top; coquina layer at base; *Pionodema* and bryozoans abundant	10″
Shale, green, and bentonite	4″

Platteville Group

Quimbys Mill Formation (12′)

Strawbridge Member (7′10″)

Limestone, light brown, fucoidal	7″
Limestone, light brown, lithographic, dense, in 2-4″ beds separated by thick dark red-brown shale partings	5′ 5″
Limestone, dark brown, lithographic, in wavy beds as much as 6″ thick with thin shale partings	1′
Limestone, as above, massive; corrosion surfaces at top and bottom	10″

Shullsburg Member

Limestone, as above, very fossiliferous, in regular beds separated by 2-3″ beds of shale	2′ 6″

Hazel Green Member

Limestone, as above, but lacking prominent shale partings; scour surface in middle	1′ 8″

Grand Detour Formation

Forreston Member (7′2″)

Limestone, argillaceous, gray, lithographic, massive; 1″ shale at top	1′ 3″
Limestone, as above; thin shale partings	5″
Dolomite, argillaceous, massive; weathers shaly; corrosion surface 3″ above base	1′ 4″
Shale, buff	1″
Dolomite, argillaceous, massive; upper 4″ weathers shaly	1′10″
Shale, buff	1″
Dolomite, argillaceous, massive; base concealed	2′ 2″

25. Mincke Section

Exposure in south bluff of Meramec River along the St. Louis-San Francisco Railroad, a quarter of a mile northeast of Mincke Siding, St. Louis County, Missouri (near cen. E ½ SE SE 21, 44N-4E, Manchester Quad.); reached from U. S. Highway 66 by road via Morschels to mouth of Tyson Hollow, thence on foot half a mile southwest. Type sections of Mincke and Tyson Members of Kings Lake Formation and Glencoe and Castlewood Members of Spechts Ferry Formation.

Galena Group

Kimmswick Subgroup

Dunleith Formation (73′6″)

Moredock Member

Calcarenite, coarse; contains large chert nodules in 3-foot zone 9′ below top	35′ 8″

Eagle Point Member (11′2″)

Calcarenite, slightly argillaceous, fine grained; in thin lenticular beds; contains abundant bryozoans	1′ 1″
Calcarenite, fine, cherty	6′ 7″
Calcarenite, medium, weakly bedded, knobby weathering	3′ 6″

Beecher Member (15′6″)

Calcarenite, coarse to fine, massive	6′
Calcarenite, fine, massive, weathering platy	2′11″
Calcarenite, coarse at base to fine at top, massive	6′ 7″

St. James Member (10′2″)

Calcarenite, fine to medium; 2-7″ beds; abundant bryozoans at top; *Dalmanella* common	2′
Calcarenite, fine, vuggy, massive; abundant bryozoans and crinoidal debris; *Sowerbyella*	3′ 1″
Calcarenite, as above; *Dalmanella* abundant	1′ 4″
Bentonite; forms deep reentrant	1″
Calcarenite, fine; *Dalmanella* abundant; small *Receptaculites*	3′ 8″

Decorah Subgroup

Kings Lake Formation (13′6″)

Tyson Member (7′6″)

Limestone, dolomitic, very silty, argillaceous, buff; thin to medium beds; 1″ greenish buff shale 7″ below top	2′ 1″
Limestone, as above, massive, calcarenitic streaks in upper 6″	1′ 6″
Shale, platy, white to orange, possibly bentonitic	1″
Limestone, light gray to buff, very fine to chalky; in irregular medium beds; 2″ bed of calcarenite with abundant *Rafinesquina* 7″ below top; large pelecypods near base	1′ 4″
Shale, buff, wavy	1″
Limestone, argillaceous, silty, buff; interbedded with purplish gray, massive coquina; *Pionodema* and *Zygospira* abundant	2′ 5″

Mincke Member (6′3″)

Coquina of *Pionodema;* thin buff shale partings at base	11″
Limestone, argillaceous, dolomitic, light brown	6″
Bentonite	2″
Limestone, argillaceous, dolomitic, light brown to buff-green, very fine grained; contains black fossil debris	1′
Limestone, brown, lithographic, thin bedded, argillaceous and chalky near bedding planes; calcarenite at top; *Pionodema* abundant, *Zygospira, Calliops*	7″
Limestone, argillaceous, massive	4″
Limestone, light brown, very fine grained; contains shale partings	8″
Shale, blue-gray to light red-brown	1″
Limestone, argillaceous, light brown, very fine grained, massive	6″
Mudstone, greenish buff	1″
Limestone, very fine grained, greenish gray; black phosphatic debris at base; contains beds of purplish gray calcarenite	1′ 5″

Spechts Ferry Formation (12′2″)

Glencoe Member (5′3″)

Shale, gray-green; in 2-7″ beds separated by 1-2″ lenses and beds of calcarenite and coquina	3′ 5″
Calcarenite, coarse, purplish gray, massive; argillaceous mottling	8″
Limestone, very argillaceous, fossiliferous, laminated	3″
Bentonite and hard, pinkish gray, feldspathic siltstone (pink bed)	2″
Bentonite, light gray	3″
Shale, green	1″
Mudstone, calcareous, gray-green	5″

Castlewood Member (6′11″)

Limestone, argillaceous, gray-green; contains black fossil debris	8″
Limestone, dolomite mottled, lithographic, massive; 1-2″ calcarenite 7″ below top	1′
Limestone, argillaceous, gray, massive; contains black fossil debris	5″

Limestone, pure, light brown, fine grained, massive; contains thin shale parting 5" below top; interbedded with calcarenite in lower 5"	10"
Limestone, argillaceous at top and bottom	5"
Limestone, brown-gray, very fine grained; contains much dark fossil debris and thin calcarenite at base	7"
Limestone, light gray, lithographic; in thin tight wavy beds; thin calcarenite beds in upper 8" and at bottom	1' 8"
Limestone, slightly argillaceous, dolomitic, light buff, very fine grained, massive; contains carbonaceous and calcarenitic streaks	11"
Bentonite, light gray	5"

Platteville Group

Plattin Subgroup

Quimbys Mill Formation

Strawbridge Member (12'9")

Shullsburg Member (5'4")

Base of exposure

26. Kings Lake Section

Exposure at top of Mississippi River bluff 1.6 miles north of Foley, Lincoln County, Missouri, about 500 feet north of road junction at Kings Lake (SE SE NE 26, 50N-2E, Hardin Quad.). Type section of Kings Lake Formation.

Galena Group

Kimmswick Subgroup

Dunleith Formation

Limestone; largely coarse-grained calcarenite	10'

Decorah Subgroup

Guttenberg Formation (11'2")

Glenhaven Member (8'10")

Limestone, light brown, fine grained, in 2-4" wavy beds with red-brown shale partings; contains very fossiliferous beds including 2-4" coquina at base; large chert nodules in band on top of the coquina, and a few nodules occur 7" higher; grayer, coarser textured, and thicker bedded than below	2' 5"
Limestone, brown, very fine grained; in thin wavy beds separated by red-brown shale; lower 1'10" more massive	6' 4"
Bentonite	1"

Garnavillo Member (2'4")

Limestone, very fine grained; contains worm-borings filled with red-brown shale	6"
Limestone, dolomitic, silty, buff-gray, in 3-6" even beds; contains thin layers of calcarenite	1'10"

Kings Lake Formation (9'2")

Tyson Member (4'3")

Limestone, dolomitic, argillaceous, silty, buff; contains 1-6" beds of calcarenite and coquina; *Pionodema, Sowerbyella, Zygospira,* and bryozoans	4' 3"

Mincke Member (4'11")

Calcarenite; contains thin beds of coquina and dolomitic limestone; red chert in lower 4"	1'
Limestone, argillaceous, light brown, very fossiliferous; brown shale partings	4"
Shale, brown; ½" bentonite ½" above base	3"
Limestone, light gray; in 1-4" beds; interbedded with calcarenite and brown shale	2' 3"
Limestone, silty, green-buff, massive; contains a little fine sand	1' 1"

Spechts Ferry Formation (9'7")

Glencoe Member (4')

Calcarenite, medium grained; in 1-4" beds; interbedded with brown shale	1'11"
Shale, green	4"
Coquina, brown, coarse grained; fossil fragments occur in matrix of greenish brown lithographic limestone mottled with green clay	1' 1"
Limestone, gray-brown, medium to coarse grained, fossiliferous	6"
Bentonite	2"

Castlewood Member (5'7")

Limestone, lithographic, fucoidal, thin to medium bedded; upper 6" is white weathering and has argillaceous mottling; lower 1'3" is dolomite mottled	5' 3"
Limestone, yellow, coarse grained; contains phosphatic nodules	1"
Bentonite	3"

Platteville Group

Plattin Subgroup

Quimbys Mill Formation (7'1")

Shullsburg Member (5'1")

Limestone, argillaceous, buff; in medium, partly irregular beds	2' 9"
Limestone, argillaceous, buff, massive, cherty	1'
Limestone, argillaceous, buff, thin to medium bedded	1' 4"

Hazel Green Member (2')

Limestone, slightly argillaceous, very fine grained, massive, smooth faced; chert band at top and at base	1'
Limestone, dolomite mottled, slightly argillaceous, light buff, massive; weathers in thin to medium beds	1'

Nachusa Formation (33'11")

Everett Member (21'8")

Limestone, very light gray (white bed)	9"
Chert; prominent bed of nodules	3"
Limestone, heavily mottled with dolomite, gray, very fine grained, very fucoidal, massive; rough weathered face; contains several bands of chert nodules and near the base a few thin layers of calcarenite	20' 8"

Elm Member (12'3")

Limestone, as above but medium bedded, smooth faced; many beds conglomeratic and contain much fossil debris	2' 2"
Limestone, as above but interbedded with fine-grained, cross-bedded calcarenite; contains a little chert; *Foerstephyllum* 4' above base; base concealed	10' 1"

27. Guttenberg North Section

Roadcut of U. S. Highway 52 where it ascends to the upland from the Mississippi River bottomland on the northwest side of Guttenberg, Clayton County, Iowa (SW SW 5, 92N-2W, Elkader Quad.). Type sections of Glenhaven and Garnavillo Members of Guttenberg Formation.

Galena Group

Wise Lake Formation

Sinsinawa Member

Dolomite, pure, vuggy, in 2-4' beds; a few beds moderately dense with thin argillaceous streaks; scattered small chert nodules in lower part; prominent reentrant at base	27'

Dunleith Formation (138')

Wyota Member (16'7")

Dolomite, slightly argillaceous, dense, very cherty	6' 8"
Dolomite, mostly pure and vuggy alternating with dense and slightly argillaceous beds; contains thin argillaceous-flecked beds, many bands of chert nodules, and 6 corrosion surfaces	9'11"

Wall Member (11'1")

Dolomite and limestone interbedded, cherty; many thin shale partings	2' 4"
Limestone, dolomite mottled, dense, cherty	3' 9"
Bentonite; makes reentrant	0-½"
Limestone, lithographic to medium grained; cherty bands in lower part; prominent corrosion surface at base	5'

Sherwood Member (20'1")

Limestone, lithographic, gray speckled; black shale partings	1'
Limestone, as above, cherty; red-brown shale partings	1'
Limestone, lithographic, calcarenitic; red-brown chert; few shale partings; corrosion zone in middle and scour surface at base	2'
Limestone, lithographic, gray; argillaceous-flecked beds; many wavy red-brown shale partings	2' 4"
Limestone, pure, medium and very fine grained, cherty, massive; *Receptaculites*	8' 2"
Bentonite	2"
Limestone, lithographic, thin bedded, shaly	1' 1"
Limestone, pure, lithographic, fucoidal; several corrosion surfaces; prominent bedding reentrant at base may contain a bentonite	4' 4"

Rivoli Member (18'1")

Limestone, pure, calcarenitic, fine to coarse grained; corrosion surface near bottom; *Receptaculites*	1'11"

Limestone, argillaceous, in 7-13″ beds with thick shale partings; lower part cherty; *Receptaculites* abundant	3′ 7″
Calcarenite, dark gray	4-6″
Shale, gray	2″
Limestone, dolomite mottled, pure, in 4-12″ beds; chert in middle; lower 3″ argillaceous-flecked	7′ 1″
Limestone, very shaly, cherty	7″
Limestone, dolomite mottled, pure, massive	4′ 3″
Mortimer Member (11′3″)	
Calcarenite, fine grained; thin shale partings	1′ 1″
Calcarenite, pure, medium grained, massive	2′
Limestone, dolomite mottled, slightly argillaceous, cherty	4′ 3″
Limestone, shaly, prominent reentrant	2″
Limestone, argillaceous, cherty	3′ 9″
Fairplay Member (20′2″)	
Limestone, argillaceous; prominent corrosion surface at base	1′ 1″
Limestone, pure, vuggy; chert near top; *Receptaculites* abundant	5′ 5″
Limestone, dolomite mottled; shale partings	5″
Limestone, pure, massive	2′
Bentonite, thin; makes reentrant	
Limestone, pure, dolomite mottled; thick bedded; chert bands in lower half; *Receptaculites* abundant	11′ 3″
Eagle Point Member (13′1″)	
Limestone, slightly argillaceous, dolomite mottled, cherty; *Receptaculites*	2′ 3″
Limestone, pure, dolomite mottled, in 1-6″ beds; many bands of chert nodules; *Receptaculites*, *Prasopora*	10′10″
Beecher Member (7′10″)	
Limestone, pure, massive	1′ 6″
Limestone, shaly; corrosion surface at top	3″
Limestone, pure, massive	1′ 4″
Limestone, shaly	2″
Limestone, pure, fossiliferous, in 1-5″ beds with shaly partings; lower 1′ vuggy	4′ 7″
St. James Member (top of Ion) (9′4″)	
Shale, green; large *Prasopora*	4″
Limestone, pure, gray, massive; argillaceous at base	1′
Shale and limestone interbedded; small *Prasopora*	1′ 1″
Limestone, slightly argillaceous, massive	6″
Shale and limestone interbedded; corrosion surface at base	1′ 1″
Limestone, pure to slightly argillaceous, vuggy at base, slightly shaly in middle; corrosion surface 1′6″ above base	5′ 4″
Buckhorn Member (10′6″)	
Limestone and shale interbedded	8″
Calcarenite, dark gray; *Dalmanella* abundant	2″
Limestone, argillaceous	7″
Shale, green	7″
Limestone, calcarenitic	6″
Shale, green; limestone nodules and lenses	1′
Limestone, argillaceous, and shale, green, interbedded	2′ 5″
Limestone, shaly	2′ 2″
Shale, green; contains a thin gray clay bed, possibly bentonite	4″
Limestone, calcarenitic; strong corrosion surface at base	1″
Limestone, massive	1′
Shale, green; grades to shaly limestone	1′
Decorah Subgroup	
Guttenberg Formation (16′6″)	
Glenhaven Member (14′10″)	
Limestone, light brown, weathering whitish, dolomite mottled, very fine grained, in relatively regular beds with major bedding planes 8-13″ apart and minor planes 1-2″ apart; red-brown shale partings; much fossil debris and calcarenite streaks	6′
Limestone, as above but argillaceous, lithographic, more shaly, with thicker red-brown shale beds, more wavy bedding and whiter weathering	8′10″
Bentonite	½-1½″
Garnavillo Member (1′8″)	
Limestone, argillaceous, brownish gray	7″
Shale, green	4″
Limestone, argillaceous, massive; abundant small black phosphatic nodules in basal 2″; lower part grades laterally to green shale	9″
Spechts Ferry Formation (6′4″)	
Shale, green; contains several thin beds of coquina and beds of nodules of argillaceous limestone	1′ 4″
Limestone, argillaceous, interbedded with coquina	2-3″
Shale, green; lenses of dark gray calcarenite	4-5″
Coquina, dark gray	1″
Shale, green; lenses of argillaceous limestone	1-2″
Limestone, argillaceous, interbedded with coquina	4-6″
Shale, dark gray-green	5″
Shale, dark brownish and dark greenish gray, fossiliferous	2′ 3″
Dolomite, very argillaceous and silty, light brownish gray, massive; weathers platy; *Pionodema* abundant	3″
Bentonite, orange	¼-1″
Shale, green	3″
Shale, dark greenish gray; abundant *Pionodema*	7″
Platteville Group	
Grand Detour Formation (17′)	
Forreston Member (9′9″)	
Limestone, dark purplish gray, red flecked, dolomite mottled, very fine grained	1-2″
Limestone, silty, argillaceous, gray, black flecked; lower 1″ dolomite mottled; calcarenite at base	1′11″
Limestone, dolomite mottled, gray, very fine grained, fucoidal; corrosion surface above thin calcarenite 2″ above base	1′
Limestone, as above, with prominent brownish gray argillaceous partings; several beds of calcarenite; weathers thin bedded	6′ 8″
Clement Member (4″)	
Calcarenite, dark purplish gray, medium grained	2-5″
Stillman Member (4′11″)	
Limestone, gray, lithographic, thin bedded, shaly; ½″ orange clay at top may be bentonite	1′ 3″
Limestone, lithographic, nodular	8″
Limestone, gray, fine to medium grained; corrosion surface 4″ below top	1′ 2″
Limestone, white, lithographic; corrosion surface at top; lower half locally replaced by calcarenite	4″
Limestone, gray, lithographic, thin bedded, shaly	1′ 6″
Walgreen Member	
Limestone, dolomite mottled, gray, weathering white, lithographic, in 2-5″ beds	1′
Dement Member	
Limestone, as above, but massive	1′
Mifflin Formation (16′10″)	
Briton Member (7′4″)	
Limestone, gray, weathering white, lithographic, thin bedded	1′10″
Limestone, as above but has thick shale partings	5′ 6″
Hazelwood Member	
Limestone, as above but massive	1′
Establishment Member	
Limestone, as above but has thick shale partings	5′
Brickeys Member	
Limestone, as above but in 1-4″ beds with thin shale partings	3′ 1″
Blomeyer Member	
Limestone, gray, lithographic, and shale, calcareous, green to buff	5″
Pecatonica Formation	
Medusa Member (5′2″)	
Dolomite, buff, fine grained, massive; contains red fucoids; strongly pitted ferruginous top surface	10″
Dolomite, pure, gray to buff, medium grained, in 8-24″ beds	4′ 4″
New Glarus Member	
Dolomite, pure, massive	2′ 1″
Dane Member	
Dolomite, argillaceous, gray to buff, fine grained, in 2-6″ beds	3′ 3″
Covered	5′
Ancell Group	
Glenwood Formation	
Harmony Hill Member	
Shale, green, mostly covered	5′ 3″
St. Peter Formation	
Sandstone, white, fine grained, friable, ferruginous and quartzitic at top; base concealed	5′

28. East Dubuque Section

Compiled from exposures in the Mississippi River bluffs at East Dubuque, Jo Daviess County, Illinois, at and above the tunnel of the Illinois Central Railroad and north of the tunnel (SE 19, 29N-2W, East Dubuque Quad.). Type sections of Dunleith Formation and Wyota, Wall, Sherwood, Rivoli, Mortimer, Fairplay, Eagle Point, and Beecher Members.

Galena Group

Wise Lake Formation

Sinsinawa Member

Dolomite, pure, vuggy; few chert nodules near base; exposed in small quarry above south tunnel entrance	10′

Dunleith Formation (113′5″)

Wyota Member (19′9″)

Dolomite, shaly; prominent reentrant	2″
Dolomite, argillaceous; chert nodules in middle	1′ 5″
Dolomite, vuggy; argillaceous streaks	1′ 6″
Dolomite, argillaceous; thin bed of coquina with argillaceous flecks at base	8″
Dolomite, pure, vuggy; argillaceous streaks; bands of chert nodules; locally prominent bedding break 1′4″ below top; base at floor of small quarry	3′
Dolomite, pure, vuggy, massive; several beds with argillaceous flecks in upper half; chert nodules in well defined bands common throughout	13′

Wall Member (9′8″)

Dolomite, argillaceous, dense, cherty	3′ 3″
Dolomite, slightly argillaceous, lower 6 inches more argillaceous; purer and more vuggy than below; chert bands in upper half and near base; persistent shaly bedding plane at base	6′ 5″

Sherwood Member (13′7″)

Dolomite, argillaceous, dense, yellow; some argillaceous flecks, chert rare at top, *Receptaculites*	1′10″
Dolomite, more argillaceous than above; contains some chert; bed with argillaceous flecks at base; prominent bedding surface at base	1′
Dolomite, contains argillaceous mottling but less argillaceous than above; red-brown chert nodules; 3″ bed with argillaceous flecks at base; *Receptaculites*	3′ 9″
Dolomite, massive, dense to finely vesicular, slightly argillaceous at top, less argillaceous than below; much calcite; prominent smooth bedding surface at base	3′ 8″
Dolomite, slightly argillaceous; few chert nodules 1′ above base and nearly continuous 2-6″ band of chert at base; *Receptaculites*	3′ 4″

Rivoli Member (19′)

Dolomite, argillaceous (the most argillaceous unit); contains many chert bands; *Receptaculites;* fucoidal bedding surface at base	5′ 6″
Dolomite, interbedded pure and argillaceous; corrosion surface 10″ below top; *Receptaculites* common; prominent bedding surface at base	4′ 6″
Dolomite, slightly argillaceous, rare chert nodules; prominent bedding surface at base	3′ 6″
Dolomite, slightly argillaceous; prominent corrosion surface 3′4″ below top; scattered chert nodules below the upper 2 feet and in 2-4″ bands 4″ and 14″ above base	5′ 6″

Mortimer Member (11′3″)

Dolomite, very shaly reentrant; at top of north entrance to railroad tunnel	2″
Dolomite, argillaceous, dense, cherty; lower 10″ is thin bedded and shaly and makes a reentrant	2′ 1″
Dolomite, finely vesicular to vuggy; few argillaceous streaks, chert rare, *Receptaculites* at base	5′ 6″
Dolomite, slightly argillaceous; many bands of chert nodules; *Receptaculites* common; prominent bedding surface at base	3′ 6″

Fairplay Member (19′7″)

Dolomite, argillaceous, dense, very cherty, lower 6″ shaly; lower dense bed at north tunnel entrance	2′
Dolomite, vuggy, more massive and purer than above, chert in the middle, *Receptaculites* at top; prominent bedding surface at base	3′ 6″
Dolomite, massive, pure, in 3 ledges; exposed in ravine ¼ mile north of the tunnel	3′ 4″
Dolomite, shaly; deep reentrant	8″
Dolomite, vuggy, mottled; strong bedding reentrant making bench at base	3′ 1″
Limestone, dolomite mottled; *Receptaculites* common in upper part; few chert nodules in lower 2′6″	7′

Eagle Point Member

Limestone, lithographic, dolomite mottled; contains many bands of chert nodules	11′10″

Beecher Member

Limestone, lithographic; lower 3 feet exposed at railroad culvert ¼ mile north of the ravine section	8′ 3″

St. James Member

Limestone, lithographic; contains thin green shale partings; base concealed	6″

29. Buena Vista Section

Quarry on west side of Richland Creek, north of bridge at Buena Vista, Stephenson County, Illinois (NW SW NE 15, 28N-7E, Freeport Quad.). Type sections of St. James and Buckhorn Members of Dunleith Formation.

Galena Group

Dunleith Formation (39′7″)

Eagle Point Member

Dolomite, pure, buff, vuggy, thin bedded; bands of chert nodules	12′ 6″

Beecher Member

Dolomite, as above but more massive and not cherty	5′ 6″

St. James Member

Dolomite, buff, gray speckled; lower 4 feet is pure, massive, and vuggy, except for 2-4″ shaly zone at base; upper part is thinner bedded and has green shale partings	13′ 3″

Buckhorn Member (8′4″)

Dolomite, gray to buff, thick shaly parting at top	1′11″
Dolomite, shaly, gray; *Dalmanella, Glyptorthis*	7″
Dolomite, dark gray, thin bedded to shaly, thicker bedded towards base, fossiliferous	5′10″

Guttenberg Formation

Glenhaven Member

Dolomite, brown, white weathering, porous, thin to medium bedded, fossiliferous; red-brown shale beds up to ½-inch thick; base concealed	3′

30. Valmeyer Section

Quarry of Columbia Quarry Company and exposure in Mississippi River bluff just north of the crushing plant (cen. N line SW 3, 3S-11W, Kimmswick Quad.). Type section of Moredock Member of Dunleith Formation.

Maquoketa Group

Scales Formation

Elgin Member (12′)

Shale, greenish gray	2′ 6″
Conglomerate; phosphatic pellets and small fossils (depauperate zone)	3″
Shale, greenish gray; contains beds of siltstone, fine-grained sandstone, and phosphatic nodules; lower 5 feet poorly exposed	9′ 3″

Cape Formation

Limestone, coarse grained, very fossiliferous	1′ 6″

Galena Group

Kimmswick Subgroup

Dunleith Formation (93′11″)

Moredock Member (58′5″)

Calcarenite, medium grained; *Receptaculites* abundant in upper 2′, some truncated at pitted surface at top	4′ 6″
Calcarenite, light brownish gray, medium grained, massive; prominent bedding planes at top, and 5′6″ and 11′ below top; lower 4′ laminated	15′
Calcarenite, coarse, vuggy, very fossiliferous	10′ 8″
Calcarenite, as above, color banded; pink to red bed 3′ above base	9′ 7″
Calcarenite, as above, light and dark bands	2″
Calcarenite, relatively fine grained, cross bedded; coarse streaks	5′

Calcarenite, very coarse grained; coquina of bryozoans	2′10″
Main quarry floor	
Calcarenite, coarse, pink to buff, massive, fossiliferous; faint 1-4″ beds	8′10″

Eagle Point Member

Calcarenite, massive, brownish gray at base to buff at top, fine grained at base to coarse at top; many bands of chert nodules	10′ 6″

Beecher Member

Calcarenite, pink and buff, very coarse grained, entirely massive	13′

St. James Member

Calcarenite, light gray to brownish gray, faintly laminated, very coarse grained at base; upper 4′ finer grained than above or below; bryozoans abundant; *Dalmanella* abundant near top	12′

Decorah Subgroup

Kings Lake Formation

Limestone, argillaceous, silty, gray, very fine grained (detailed in figure 23)	13′ 7″

Spechts Ferry Formation

Glencoe Member

Limestone, calcarenitic, dark gray	2′ 2″
Shale, green; exposed by digging through talus; base concealed	2″

31. New London North Section

Roadcut of U. S. Highway 61 on north side of Salt Creek, 2 miles north of New London, Ralls County, Missouri (NE SW 25, 56N-5W, Hannibal Quad.). Type section of New London Member of Dunleith Formation.

Galena Group

Kimmswick Subgroup

Dunleith Formation (97′3″)

New London Member (31′9″)

Limestone, dolomite mottled, fine grained, vuggy, cherty; *Receptaculites*	1′ 7″
Calcarenite, fine grained; large *Receptaculites*	4″
Limestone, dolomite mottled, fine to medium, vuggy; *Receptaculites* abundant	1′ 3″
Calcarenite, coarse, very fossiliferous, cherty	7″
Calcarenite, coarse; *Receptaculites* and gastropods abundant	1′10″
Limestone, lithographic to medium; chert at top and bottom; 11″ bed with shaly partings 9″ below top; *Receptaculites*	4′ 6″
Limestone, very fine, cherty; many thin calcarenite lenses; *Receptaculites* abundant at base	4′ 2″
Limestone, shaly; makes reentrant	1″
Limestone, fine; bands of chert nodules; 1′ zone with red-brown shale partings 1′5″ below top; this and higher units mostly weathered brown	3′ 2″
Limestone, gray, fine to coarse; many black to red-brown shale partings; much dark fossil debris; corrosion surfaces at top and 12″ below top; *Receptaculites*	1′ 8″
Limestone, as above but thin bedded and shaly; makes reentrant	5″
Limestone, as above, less shaly; *Receptaculites* abundant	9″
Limestone, lithographic, in wavy beds separated by thick red-brown shale partings; coarse calcarenite bed at base	10″
Limestone, dolomite mottled, fine to medium, cherty; thin shaly streaks near top; *Receptaculites, Ischadites* abundant	4′ 5″
Limestone, buff to gray, cherty; red-brown shale partings	7″
Limestone, dolomite mottled, fine to medium, vuggy, cherty; coarse calcarenite lenses	5′ 7″

Moredock Member (65′6″)

Bentonite; makes reentrant	1″
Limestone, dolomite mottled, fine to coarse grained, vuggy; in 6-12″ beds; upper 2′ cherty; contains coarse calcarenite beds; *Receptaculites* very abundant	12′ 4″
Calcarenite, medium, vuggy, cross bedded; thin shale partings	1′ 4″
Calcarenite, medium to coarse, vuggy, fossiliferous	9′11″
Calcarenite, coarse, in alternating vuggy and dense beds; many white fossils	4′ 7″
Calcarenite, very coarse; *Dalmanella* and *Sowerbyella* abundant	1′ 3″
Calcarenite, fine to medium, dense, in thin wavy beds; bryozoans abundant, *Receptaculites*	2′ 3″
Calcarenite, dolomite mottled, medium, vuggy	1′ 6″
Calcarenite, very coarse; abundant white fossils	3-4″
Calcarenite, fine to medium; bryozoans abundant	3′ 5″
Base of roadcut section. Lower beds exposed in bluff east of road.	
Limestone, fine, calcarenitic, massive, vuggy; silicified *Streptelasma;* prominent reentrant at base	2′ 9″
Limestone, slightly argillaceous; denser than above and below	2′ 5″
Limestone, dolomite mottled, fine, fossiliferous, vuggy	10′ 5″
Calcarenite, dolomite mottled, coarse, massive, very fossiliferous	2′ 9″
Limestone, dolomite mottled, medium to coarse, vuggy, massive	8′
Limestone, calcarenitic, fine grained	11″
Calcarenite, coarse, massive; base concealed 15′ above floodplain	1′ 3″

32. Wise Lake Section

Compiled from two exposures in the Mississippi River bluffs 6 miles south of Galena, Jo Daviess County, Illinois. One exposure (called the ravine section) is in a small inconspicuous ravine, 100 feet south of the house at the mouth of a prominent ravine (near cen. W line NE SE 21, 27N-1E, Galena Quad.). The second exposure (called the bluff section) is half a mile farther north at the north end of a prominent bluff (north of cen. NE 21). The bluff section is the type section of the Wise Lake Formation. Most of the sequence is exposed in the bluff section, but the upper part is more accessible in the ravine section, which is as follows:

Galena Group

Dubuque Formation (41′)

The top of the exposure is at a bench marking the top of the Galena, but the contact with the Maquoketa Shale is not exposed. In wells nearby, the Dubuque has a maximum thickness of 45 feet.

Dolomite, argillaceous; contains coarse dolomite crystals and crinoidal debris in a fine-grained matrix; in 1-6″ beds with prominent shale partings	13′ 3″
Shale, dolomitic, green	8″
Dolomite, argillaceous, thin bedded	2′ 2″
Dolomite, argillaceous; in ¼-½″ beds with red shale partings	2″
Dolomite, shaly	2″
Dolomite, argillaceous but slightly purer than above; in 1-10″ beds separated by shaly partings and shaly beds up to 6″ thick	5′ 6″
Dolomite, as above but massive	1′ 5″
Shale, green	2″
Dolomite, moderately argillaceous but purer than above; in 6-12″ beds with thinner shale partings than above	6′
Dolomite, massive, weathering to 3″ beds	2′11″
Dolomite, shaly, reentrant	1″
Dolomite, slightly argillaceous; prominent bed set off by shaly partings; a widely traceable marker bed	4″
Dolomite, shaly; makes reentrant	1″
Dolomite, slightly argillaceous to pure, vuggy; well defined 7-24″ beds separated by thin beds of shaly dolomite up to 3″ thick; rare *Pseudolingula iowensis;* base at lowest shaly reentrant	8′ 1″

Wise Lake Formation

Stewartville Member (27′)

Dolomite, pure, vuggy, massive; faint 1-5′ beds; gastropods common	22′ 1″
Dolomite, thin bedded; makes reentrant; persistent marker bed	8″
Dolomite, pure, vuggy, massive; *Receptaculites* abundant (top of the Upper *Receptaculites* Zone)	4′ 3″

Base of exposure

In the bluff section, the contact of the massive Wise Lake with the thin-bedded Dubuque is well exposed at the top of the nearly vertical cliff. The lower 27 feet of the Dubuque can be examined on the more accessible slope north of the cliff. The section below the base of the Dubuque follows:

Galena Group

Wise Lake Formation

Stewartville Member (32′8″)

Dolomite, pure, vuggy, massive; few *Receptaculites;* prominent bedding surface 9′8″ below top	22′ 6″
Dolomite, shaly; makes reentrant	6″
Dolomite, very pure, vuggy, massive, slightly shaly at base; many *Receptaculites* (Upper *Receptaculites* Zone)	9′ 8″

Sinsinawa Member (29′2″)

Dolomite, pure, vuggy, massive; prominent bedding surface 7′6″ below top	21′
Bentonite	2″
Dolomite, as above; base of exposure	8′

An excavation for a railroad culvert at one time exposed the cherty dolomite at the top of the underlying Dunleith Formation at a depth of 9 feet below the base of the section.

33. Galena Roadcut Section

Roadcut of U. S. Highway 20 on the east side of Galena River in Galena, Jo Daviess County, Illinois (SW SE NE 20, 28N-1E, Galena Quad.). Type section of Sinsinawa Member of Wise Lake Formation.

Galena Group

Wise Lake Formation

Sinsinawa Member (33′)

Dolomite, pure, buff, medium grained, thick bedded, vuggy	9′ 2″
Bentonite, thin; makes reentrant	
Dolomite, as above, a few thin dense beds	6′10″
Bentonite, light gray; makes prominent reentrant	1″
Dolomite, very slightly argillaceous, dense, massive	1′ 7″
Dolomite, pure, vuggy	2′ 6″
Dolomite, dense	1′ 8″
Dolomite, vuggy	3′11″
Dolomite, dense	1′ 3″
Dolomite, vuggy; 1-4″ dense bed in middle	3′ 3″
Dolomite, vuggy; 2″ dense bed at top	1′ 9″
Dolomite, vuggy; a few chert nodules	10″

Dunleith Formation

Wyota Member (12′9″)

Dolomite, dense, slightly fucoidal	1′
Dolomite, dense; argillaceous flecks and streaks; band of chert nodules at base	1′ 2″
Dolomite, shaly	1″
Dolomite, vuggy and dense; some beds argillaceous; 2 bands of chert nodules; strong bedding reentrant at base	2′ 6″
Dolomite, as above; several beds with argillaceous flecking; 8 bands of chert nodules; base concealed	8′

34. Cape Girardeau Main Street Section

Exposure on Main Street just north of Broadway Street in Cape Girardeau, Cape Girardeau County, Missouri (Cape Girardeau Quad.). Type section of Cape Formation.

Cincinnatian Series

Maquoketa Group

Scales Formation

Thebes Member

Thebes badly slumped but formerly showed the following:

Siltstone, dark brown	5′ 6″
Shale	8-12′

Cape Formation

Calcarenite, gray to dark gray, largely medium grains of fossil debris; crinoidal, very fossiliferous with brachiopods abundant; upper 2′ massive; lower part in 2-6″ beds with wavy shale partings; sharp contact at base	8′ 6″

Champlainian Series

Galena Group

Kimmswick Subgroup

Dunleith Formation

New London Member (7′11″)

Calcarenite, gray, weakly bedded, very crinoidal	5″
Limestone, calcarenitic, brownish gray, fine grained, crinoidal, massive; tubular openings give strongly pitted surface	1′10″
Calcarenite, like 5″ bed above; this and 2 units above called the *Vanuxemia* bed	4″
Limestone, brownish gray, medium grained, crinoidal, massive	2′ 2″
Limestone, dolomite mottled, light brownish gray, fine to medium, a few thin red-brown shale partings; lower 14″ very crinoidal; this and unit above called the *Echinosphaerites* bed	3′
Bentonite, light gray, plastic; overlies knobby surface with 2-3″ relief	1-2″

Moredock Member (5′8″)

Calcarenite, pure, light gray, medium to coarse grained, crinoidal; contains lenses of light greenish gray, laminated, argillaceous limestone; *Receptaculites* abundant	6-8″
Calcarenite, as above, stylolitic, massive; *Receptaculites* common; base concealed	5′

35. Scales Mound Section

Illinois Central Railroad cut on west side of Scales Mound in Jo Daviess County, Illinois (SW NE SW 26, 29N-2E, Galena Quad.). Type section of Scales Formation.

Cincinnatian Series

Maquoketa Group

Scales Formation (30′)

Shale, weathered	5′
Shale, gray; beds of dolomitic siltstone up to 6″ thick in upper 3′	5′
Shale, light to medium gray	7′
Shale, light greenish gray	2′ 6″
Dolomite, silty, argillaceous	0-2″
Shale, greenish gray	3′
Shale, dark greenish gray, fissile	3′
Depauperate zone; shale and dolomite with pyritic and phosphatic small fossils	8″
Shale, silty, dark brownish gray	3′ 6″
Depauperate zone; shale, dark greenish gray with phosphatic pellets and small fossils	2″

Champlainian Series

Galena Group

Dubuque Formation

Dolomite, fine grained, crinoidal; 4-8″ beds with wavy shale partings; base concealed	10′

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