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STRATIGRAPHIC CLASSIFICATION OF THE PENNSYLVANIAN ROCKS OF KANSAS

By RAYMOND C. MOORE

BULLETIN 22

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NOTE

Attention is called to discussion of the stratigraphic rank which should be assigned to the Pennsylvanian rocks in North America, given as an appendix to this paper (see page 246).

The conclusion is reached that the beds classed as Pennsylvanian should be recognized as a subdivision of the Carboniferous system. This system should be defined in North America, as in Europe, to include the strata between the Devonian and Permian systems.

STRATIGRAPHIC CLASSIFICATION OF THE PENNSYLVANIAN ROCKS OF KANSAS

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Introduction

The state of Kansas contains an extremely interesting succession of marine and continental deposits of Pennsylvanian age. These deposits offer exceptional opportunity not only for studies bearing on classification of Pennsylvanian rocks in North America, but for investigations that have general application on principles of stratigraphic classification, on sedimentation, on the paleoecology of faunas and floras, and on the operation of diastrophic forces in the earth's crust. The area of Pennsylvanian outcrops occupies approximately the eastern one fourth of Kansas and is continuous with extensive exposures in the neighboring states of Missouri, Nebraska, Iowa, Oklahoma, and Arkansas. The strata dip gently outward from the Ozark uplift and in eastern Kansas the direction of dip is thus to the west and northwest. Because of the simple structure and the presence of numerous stratigraphic horizons that can be traced long distances it is possible to determine with accuracy and a fair degree of completeness the stratigraphic column of various parts of the Pennsylvanian system in the district.

Perhaps the outstanding feature of the Pennsylvanian rocks of Kansas is the large number of alternating limestone, shale and sandstone units, part of which are marine and part continental. It is evident that these represent conditions of sedimentation almost continuously changing as represented by the vertical succession, but remarkably similar for long distances horizontally, as shown by lateral persistence of many of the formational and smaller divisions. The relation of faunas and floras to these lithologic types permits study of changing ecologic conditions. The characters of the Pennsylvanian stratigraphic column and the recognition of unconformities at certain horizons provide a basis for conclusions as to the stability of the continental platform in this region during the Pennsylvanian period.

It is not the purpose of this report to describe in detail the Pennsylvanian formations of Kansas and adjacent parts of the northern Mid-Continent region, but rather to consider the problems of stratigraphic classification and nomenclature that are needed for description of the system and for treatment of the historical geology of Pennsylvanian time in this region.

Previous Work[1]

The presence of Carboniferous or Coal Measures strata in the northern Mid-Continent region was recognized more than a century ago, but the beginning of stratigraphic investigations of these rocks may be placed in the early 1850's when the first geological survey of Missouri was organized. The application of names to various rock units has been a matter of gradual development. The most prominent scarp-forming limestones were among the first units to receive geographic designation, in part taken from the name of towns where the rocks were quarried for commercial uses or from other geographic features that were locally well known. Examples are "Manhattan stone" and Cottonwood limestone. It was almost certainly in this sense rather than as formal proposal of stratigraphic names that G. C. Swallow, state geologist of Kansas in 1865, used the names Fort Scott, Stanton and Fort Riley as applied to limestone beds described in sections. Swallow did not use geographic names for other equally prominent units described by him, and he miscorrelated the Stanton with beds (Burlingame) 750 feet or more stratigraphically above the limestone at Stanton, Kan. Introduction of these now well-known names is, however, credited to Swallow. F. B. Meek, in 1865 and subsequently, published descriptions of "Coal Measures" rocks and fossils of Kansas and Nebraska, but did not apply definite stratigraphic names. The first really noteworthy early work on Pennsylvanian stratigraphy in the Missouri-Kansas-Nebraska region is that of G. C. Broadhead, who prepared a series of remarkably accurate general sections. Most of the stratigraphic units, designated by numbers, are readily identifiable, and reference to them by modern workers is still not uncommon. In 1868 to 1872 Broadhead published certain proposed major groupings of the Pennsylvanian rocks of Missouri. Some of these groups, designated mostly by letter symbols, are practically identical with divisions now recognized, but Broadhead largely

1. Specific references to the rather voluminous literature on the Pennsylvanian rocks in the northern Mid-Continent region are omitted from this section of the report, since detailed citations are given subsequently for each stratigraphic unit.

avoided use of geographic names as applied to the rocks. Another early worker in the Kansas Carboniferous area is Robert Hay who, in the period from 1887 to 1896, published several short papers describing these rocks. He proposed names for some stratigraphic units but these have been largely overlooked. Charles R. Keyes, in the period from 1888 to the present, has contributed many papers to the subject of Carboniferous stratigraphy and nomenclature in the Mid-Continent, but the value of most of this writing is lowered by lack of first-hand field knowledge.

The work of Erasmus Haworth and assistants (especially Bennett and Kirk), of the University Geological Survey of Kansas, organized in 1895, is of outstanding importance. A number of east-west cross-sections of the Pennsylvanian strata of Kansas were measured and many stratigraphic units were traced in reconnaissance mapping across the state. A large number of formation names that are now in common use were introduced by Haworth in 1898 or before. Schrader, in 1908, and Haworth, in 1909, added and revised various formational units. The larger stratigraphic divisions, Cherokee, Marmaton, Pottawatomie, Douglas, Shawnee, and Wabaunsee, were introduced by Haworth in the period 1895-'98, and excepting Pottawatomie, have remained unchanged in subsequent publications. The 1909 report of the University Geological Survey (volume 9) contains a rather detailed faunal study of the Kansas Pennsylvanian by Beede and Rogers, which distinguishes faunal divisions with boundaries corresponding almost precisely with the stratigraphic divisions recognized by Haworth. This coincidence is, indeed, surprising, indicating an exceptionally prescient subdivision by Haworth, or perhaps an unrecognized adjustment of paleontologic testimony to fit existing classificatory units. Some of these boundary lines are plainly of physiographic or cartographic significance only.

Studies of much importance on the Upper Pennsylvanian and "Permian" strata of Kansas are reported in papers by Charles S. Prosser published in the period from 1894 to 1910. Many stratigraphic units are described and named in these contributions which laid the groundwork of classification that has been followed for many years. Associated with Prosser in part of his work, but in part independent, is J. W. Beede who, from 1898 to 1914, published additions to knowledge of the stratigraphy of the northern Mid-Continent area. Beede is the author of numerous stratigraphic names. One of Haworth's assistants in the early geologic work on the Carboniferous of Kansas was George I. Adams, whose most important papers are a general summary of the stratigraphy of these rocks (with paleontologic notes by G. H. Girty and David White) published in 1903 and a description of the rocks of the Iola quadrangle, issued in 1904. Various new stratigraphic units are described and named in these papers.

Hinds and Greene, in 1915, published a very important contribution to knowledge of Pennsylvanian stratigraphy of Missouri. The Kansas classification developed by Haworth was mainly used, but certain miscorrelations were corrected and Haworth's "Pottawatomie" formation was divided into two parts, the lower termed Kansas City, and the upper, Lansing. The Marmaton formation, also, was subdivided into the Henrietta formation, below, and the Pleasanton formation, above. The group terms, Des Moines and Missouri, proposed by Keyes, were adopted for "lower Coal Measures" and "upper Coal Measures," respectively, as used in the Kansas reports.

Some work was done on the Pennsylvanian of Iowa during the nineties and subsequently, the most recent studies being contributed by J. L. Tilton, who differentiated and named certain units in southwestern Iowa.

For many years G. E. Condra, state geologist of Nebraska, has been at work on the Pennsylvanian stratigraphy of southeastern Nebraska, and in the course of his investigations has made extended trips into adjacent Pennsylvanian areas. In 1927 the results of Condra's stratigraphic studies were published as a report of the Nebraska Geological Survey. Many measured sections were described in detail and the rocks were correlated with named units in neighboring states. A feature of the Nebraska report is the proposal of many new stratigraphic names, drawn chiefly from localities in Nebraska and northern Kansas, for seemingly minor units, which, however, were shown to be amazingly uniform and persistent. A chief reason for the addition of these many names is the need for detailed stratigraphic zoning in connection with paleontologic studies and precise correlation with sections in various distant places where the same units may be recognized. Condra's work is a step in the direction of more painstaking, detailed and accurate stratigraphic correlations. Because of the disconnected outcrops of Pennsylvanian strata in southeastern Nebraska stream valleys (intervening areas being deeply mantled by glacial draft), because of the existence of an unrecognized structural uplift along Platte river, and because of a peculiarly deceptive repetition of sequences of beds, the section of the Platte river valley was erroneously correlated in the 1927 Nebraska report. Condra subsequently discovered and corrected the error, making necessary revision of the nomenclature of a number of units.

Acknowledgments

The studies on which this paper is based include work by Dr. N. D. Newell, of the University of Kansas, Dr. R. G. Moss, now of the Phillips Petroleum Company, and Prof. J. M. Jewett, of the University of Wichita, carried on as members of the Kansas Geological Survey under my direction. Critical points in the field investigations of these men have been checked by me. Introduction and definition of several new stratigraphic units that will be credited to these men in forthcoming publications come from phases of the general study assigned to them, and have been developed in part as a result of collaboration. Acknowledgments are also due Mr. F. C. Greene, of the Missouri Bureau of Geology and Mines, and especially to Dr. G. E. Condra, state geologist of Nebraska, who have joined me in field investigations of problems involving stratigraphic classification and nomenclature, and who in many other ways have contributed to progress of the work.

Stratigraphic Definition of the Pennsylvanian System in the Northern Mid-Continent Region

The Mississippian-Pennsylvanian Boundary

The base of the Pennsylvanian system is very clearly defined in Missouri, Iowa, Nebraska, and Kansas. The lowermost Pennsylvanian beds, called Cherokee, consist of shale, sandstone, thin limestone, coal, and conglomerate that rest unconformably on a somewhat uneven surface of massive Middle or Lower Mississippian limestone. Extensive subsurface data, as well as outcrop observations, indicate that there was a long period of nondeposition and of considerable erosion between the time of formation of the youngest Mississippian rocks still present and the oldest Pennsylvanian rocks observed in the area. Prior to the beginning of Cherokee deposition, Mississippian rocks that were once continuous over the Ozark uplift were removed, so that Pennsylvanian rocks now are found resting directly on Devonian, Silurian or Ordovician strata. Information from deep wells in the central part of Kansas and southeastern Nebraska shows that Pennsylvanian strata overlap Mississippian rocks and are in contact with Devonian (?), Silurian, Ordovician, Cambrian, and pre-Cambrian rocks.

Northeastern Oklahoma and northern Arkansas contain outcrops of Late Mississippian (Chester) strata overlain unconformably by rocks called Morrow, which in turn are unconformably overlain by beds equivalent to the Cherokee. The Morrow beds are classed as Early Pennsylvanian.

The Pennsylvanian-"Permian" Boundary

The upper boundary of the Pennsylvanian rocks in the northern Mid-Continent region has been arbitrarily placed at various horizons by different workers at different times. The transition from rocks that are regarded by all as Pennsylvanian to those that have been classed as Permian is apparently unbroken. The practice of the United States Geological Survey and of state surveys in drawing the boundary at the base of the Cottonwood limestone has served for many years to fix an arbitrary boundary in official geologic reports.

Beede[2] has called attention to paleontologic evidence indicating that the base of the "Permian" should be drawn at least 70 to 75 feet lower than the Cottonwood, so as to include the Neva limestone, which contains the first appearance of *Schwagerina.* Similarly, on a basis of fossils and of distinctive lithologic features, I have advanced the opinion that the Pennsylvanian-"Permian" boundary should be drawn still lower, at least so as to include in the "Permian" the beds classed as Foraker and Elmdale.[3] Subsequently evidence has been discovered pointing to a discontinuity in sedimentation that appears to be coincident with the most marked faunal and lithologic changes in this part of the stratigraphic column, and which indicates that perhaps the most logical boundary is located above the Brownville limestone and below the Aspinwall limestone.[4] In the present paper the upper boundary of the Pennsylvanian system in the northern Mid-Continent is placed at this disconformity.

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2. Beede, J. W., The Neva limestone in northern Oklahoma: Oklahoma Geol. Survey, Bull. 21, 1914. Species of the genus *Schwagerina* and their stratigraphic significance: Texas Univ. Bull. 2433, 1925.

3. Moore, R. C., Reclassification of Pennsylvanian rocks in the northern Mid-Continent region: Kan. Geol. Soc. Guidebook, Sixth Ann. Field Conf., p. 89, 1932.

4. Moore, R. C., and Moss, R. G., Pennsylvanian-Permian boundary in the northern Mid-Continent area: Geol. Soc. America, Proc. for 1933, p. 100, 1934.

Subdivision of the Pennsylvanian System in Kansas

Objectives of Classification

For many years I have been interested in the stratigraphy of the Pennsylvanian rocks. The conclusion was reached very soon after the beginning of my studies in Kansas in 1916, that the major grouping of these beds in the northern Mid-Continent region was apparently lacking in any very definite relation to the historical geology of the period. That is to say, the previous grouping of beds had been established primarily on the basis of conveniently spaced, persistent and prominent mappable escarpments. This was certainly a desirable or necessary procedure in the initial classification and tracing of the rock strata. There is a close relationship, of course, between lithology and the topographic expression of beds, but it does not follow that because one bed is slightly thicker and more resistant than another, the topographically prominent stratum defines a major plane of division in the stratigraphic succession. It may be selected arbitrarily as a cartographic datum, but it is possible that an inconspicuous horizon may be really much more important in the light of paleontologic studies or of physical evidence of widespread disconformity. The validity of this approach to the subject of stratigraphic classification is evident.

It may be added that the long accepted grouping of Kansas Pennsylvanian beds, if determined by physiographic or lithologic considerations, as seems to be the case, is inconsistent. For example, the Douglas formation, as defined by Haworth, begins with a shale (Weston) and ends with a prominent scarp-making limestone (Oread) at the top. The succeeding Shawnee formation begins with a shale (Kanwaka) but also ends with a shale (Scranton) at the base of a prominent scarp-making limestone (Burlingame). This matter is not of very much importance, even though it has definite bearing on areal mapping.

The fact that paleontologic zonal boundaries, defined subsequent to the differentiation of formational or group units, coincide with lines of division between formations or groups has little real significance, especially when the nature of the faunal evidence, as presented by Beede and Rogers, is analyzed. The faunal distinctions in Pennsylvanian stratigraphic divisions that are now being recognized, depend largely on a close study of mutations in a few groups, such as the fusulinids, the chonetid brachiopods, and (in Texas) the ammonoid cephalopods.

Despite the conviction that the major grouping of Pennsylvanian beds introduced by Haworth was arbitrary and artificial in several particulars, it has seemed unwise to make changes until a thorough general restudy had been made. The immediate purpose of recent Pennsylvanian studies in Kansas has been to determine the correctness of previous stratigraphic correlations and mapping, and to supply needed additional information for a new geological map of the state on a scale of 1:500,000. Most of the mapping of the Haworth survey has been found good, especially considering conditions of field work at the time the maps were prepared. The recent field studies have made use of some hundreds of detailed plane-table maps by oil-company geologists and independent petroleum geologists. In areas little studied by commercial workers the survey geologists have carried on detailed field work. Field work done by me includes the measurement and study of hundreds of stratigraphic sections, mapping and correlation of strata in all parts of the Pennsylvanian section, and the supervision and checking of work done by assistants in various areas. Opportunity to examine typical sections in Missouri, Nebraska and Oklahoma has aided in reaching an understanding of certain Kansas stratigraphic problems. General familiarity through personal field study in Texas, Arkansas, southern Oklahoma, the Rocky Mountain region and parts of the East, has also aided in formulating the proposed major divisions of the Kansas Pennsylvanian section.

Consideration of the subject of Pennsylvanian classification in the northern Mid-Continent region should be prefaced by a brief statement of some of the principles of stratigraphic classification that apply.

The purpose of subdivision of rocks in a stratigraphic succession is to differentiate major and minor portions of unlike lithology, faunal content, or both, as a basis for mapping, for correlation with rocks of the same age in other areas, and for economic development. Subdivision on a purely lithologic basis may differ radically from that outlined on paleontologic data, and it is clear that a classification established on purely economic considerations may have little relation to these other lines of study. An almost endless variety of arbitrary and artificial classifications might be formulated. The geologist presumably seeks to ascertain and apply the most "natural" classification, however; that is, one that expresses with maximum fidelity and completeness the *nature* of the sedimentary, paleontologic and diastrophic history of the portion of geologic time recorded by the stratigraphic section. Such a classification will have largest significance in historical geology. It should also conform, with special emphasis on certain features, to requirements of economic geology.

Criteria for Designation of Major Stratigraphic Units

The larger divisions of geologic time, and some of the smaller ones, are characterized by paleontologic features that are readily determined by the trained student of fossils. Thus distinguished, characters of fauna and flora furnish definite basis for differentiation of geologic systems, even though there are in some cases questions as to the precise definition of the intersystemic boundaries. Paleontologic changes of lesser moment may be expected to define the series within a system, and this is commonly the case. The faunas of the marine Pennsylvanian rocks, however, appear to have undergone comparatively little change during the period, and accordingly no definite, readily applicable subdivision of Pennsylvanian rocks on a paleontologic basis has been advanced. Nevertheless, it appears that close study will lead to differentiation of significant and definite faunal stages.

Lithologic characters vary regionally and have no necessary relationship to major subdivisions within a geologic system. They do furnish certain evidence of importance, however, indicating, for example, times of prominent elevation of the land, or protracted times of marine sedimentation. Evidence from lithologic characters is secondary as regards major stratigraphic units. It merely supplements information obtained from other sources.

The structural attitude of rocks, and especially the existence of widespread unconformities, may be very important in differentiating major stratigraphic units. Deformation of the earth crust, involving folding or warping of previously deposited strata, is commonly accompanied by the recession of seas and the occurrence of erosion on lands, and this serves to limit clearly the rocks formed prior to deformation from those deposited subsequently. Either because of accelerated biologic changes at times of diastrophism or because of considerable lapse of time during which no sedimentary formations are laid down in a given region, unconformities of the type described commonly coincide with major changes in the paleontologic record. This combined diastrophic and paleontologic evidence furnishes punctuation points in the geologic record that provide the basis for definition of geologic systems as now recognized, and within the system, similar punctuation points of lesser magnitude define series.

Series

Whether the Pennsylvanian rocks should be regarded as constituting a geologic system, presumably depends on whether these and equivalent rocks are deemed to constitute a natural division of the geologic column recognizable in all parts of the world and whether the boundary separating Pennsylvanian strata from contiguous parts of the stratigraphic column have major importance in historical geology and are recognizable very widely.[5] The major subdivisions of a system, called series, are presumably recognized on the same qualitative criteria as those that define systems, but they are of lesser magnitude. Such subdivisions may be well defined and clearly recognizable in a given province or in a continent, but it is generally believed that they are not necessarily recognizable in other parts of the world. The same type of physical evidences, consisting of stratigraphic and structural relations, general lithologic characters, and of organic evidence consisting of the nature of faunas and floras, may be used to differentiate successive series as are employed in definition of systems.

The Pennsylvanian rocks of the Mid-Continent region are divisible into major parts based on the recurrence of diastrophic movements in the geosynclinal regions, accompanied by widespread interruption of sedimentation and in some cases by gentle deformation and more or less erosion in the adjacent stable platform areas. The Pennsylvanian rocks are here regarded as constituting a geologic system, and the major subdivisions of the Pennsylvanian are classed as series.

Groups

A group is "a local or provincial subdivision of a system, based on lithologic features. It is usually less than a standard series and contains two or more formations."[6] Properly determined, these

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5. See G. H. Ashley and others, Classification and nomenclature of rock units: Geol. Soc. America, Bull., vol. 44, pp. 429-445, 1933.

6. Classification and nomenclature of rock units: Geol. Soc. America, Bull., vol. 44, p. 429, 1933.

aggregates "express the natural relations of the formations of a particular region."[7] They are useful units of stratigraphic classification for purposes of description and in some cases for mapping. Since lithologic characters are accepted as the controlling basis in defining formations and are also the main feature in establishing groups, a group may well be regarded as a sort of "super-formation."

The Pennsylvanian rocks of the northern Mid-Continent region are conveniently divisible into a number of lithologic aggregates that are of larger order than formations and smaller than the divisions classed as series. These intermediate units may be termed groups. The groups here defined are based both on dominance of certain kinds of rocks and on differences in the development of cyclic rhythms of sedimentation. There is a general correspondence between most of these groups and the larger stratigraphic units previously recognized in the northern Mid-Continent area, but there are differences in many of the boundaries, and some of the groups here proposed are subdivisions of former larger aggregates. The question of revision of existing nomenclature so that well known terms, such as Shawnee, Wabaunsee, and others, might be retained, and the alternative of abandoning a majority of these familiar names to make way for entirely new terms has been considered carefully. This consideration has included conference with many of the geologists who are working in the northern Mid-Continent region. The conclusion has been reached that it is decidedly preferable to revise and redefine at this time the stratigraphic units that are already established than wholly to discard the old and construct a new classification from previously unused names. We have purposely delayed modifications of stratigraphic definition of various parts of the Pennsylvanian column in Kansas until extended general studies had been completed. There seems now a fair prospect of reasonably stable classification on the basis of these studies, and after a transition in which there may be need for explicit statement of stratigraphic boundaries, it is expected that the old names will become employed in their revised application.

7. Idem, p. 437.

Criteria for Designation of Minor Units

Minor stratigraphic units in a system like the Pennsylvanian may be defined in different ways. Presumably, lithologic and faunal characters are of special importance. Each compact group of beds of similar lithologic nature and faunal content should be classed as a formation, or perhaps in some cases as a member of a formation.

Formations

It has been a common practice in the Mid-Continent region to define as formations the strata lying between two readily mappable beds, such as scarp-making limestones or sandstones. Defined on this basis, the boundary between adjacent formations should be

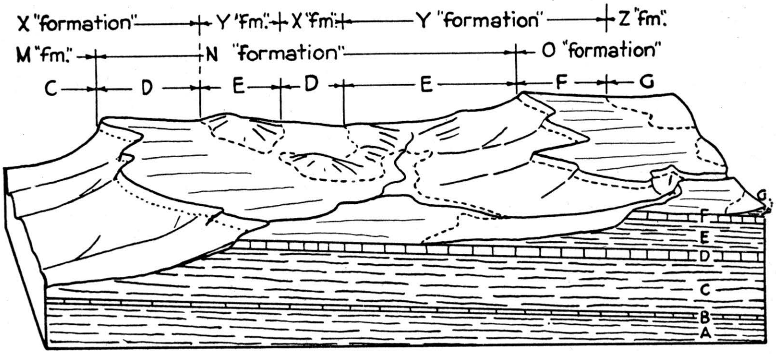

Fig. 1.—Generalized diagram of formation boundaries. A to G, limestone and shale members. M to O, formations defined from base of one hard member to next. X to Z, formations defined from top of one hard member to next. Clearly, the boundaries between units C and D, E and F, are the most readily mapped.

drawn at the base of resistant strata. This is illustrated in the accompanying diagram (formations M, N, O, fig. 1). It is obvious, however, that there is no necessary relation between "formations" that are based on convenience in mapping and the "natural" relationship of the beds.

The recognition of a cyclic rhythm in sedimentation in the Pennsylvanian section of the Eastern Interior and Appalachian coal field basins, and the discovery likewise of a somewhat dissimilar but very definite sedimentation cycle in different parts of the Mid-Continent region, have an important bearing on stratigraphic classification. In Illinois each of these cycles is separated from adjacent ones by disconformities. Weller and his associates of the Illinois Geological Survey propose logically to regard each of the cyclic groups of beds as a formational unit. It is certainly true that each unit in these sequences of beds has definite relation to others in the same sequence. The sedimentation cycle in the Mid-Continent region differs from that of Illinois and other eastern states in the greater prominence of the marine deposits, especially limestone, and in the absence in most cases of definitely recognizable disconformities. There is perhaps some question as to the lines of division between certain cycles of the Kansas Pennsylvanian, but there is no doubt as to the definite relationship of each element in the succession of beds comprising the cycle.

The lateral continuity of beds as observed in the Pennsylvanian of the Mid-Continent region is a factor that bears on stratigraphic classification. The general persistence of beds, including many minor stratigraphic units, provides basis for differentiation of units which are certainly different from those that would be recognized if the deposits were highly variable along the strike.

Relation to cyclothems.—The deposits that form a sedimentary cycle are designated by Weller as a cyclothem.[8] The cyclothem is regarded by Weller as equivalent in rank to formation, as this term is commonly used in stratigraphic nomenclature, and geologists of the Illinois Geological Survey have employed cyclothems as cartographic units. It is doubtless true that the grouping together of the sandstone, shale, coal and various types of limestone beds of a cyclothem expresses an exceedingly important genetic relationship, and this grouping is of decided value in stratigraphic study. The fitness of a cyclothem to serve as the fundamental unit of stratigraphic nomenclature may be doubted, however, for in practical use, rocks are to be classified and named on the basis of characters that can be observed readily in the field. The boundaries between cyclothems, as these are known in the Mid-Continent area, are not always precisely determinable even in well-exposed sections, and they are almost without exception extremely ill-suited for mapping. On the other hand, certain lithologic units of the cyclothem, such as the escarpment-forming limestones, are readily differentiated from associated less resistant strata. It is these clearly defined lithologic entities that seem to be the natural units of classification and nomenclature. Boundaries between them can be determined precisely and they can be mapped without difficulty. Because they are

8. Weller, J. M., Geol. Soc. America, Bull., vol. 43, p. 1003, 1932.

evident and definite they are best suited to general requirements of description, mapping and economic use.

If we reject the cyclothem as the basic unit of classification and nomenclature, it is nevertheless possible and desirable to take due account of the cyclic relationships of the beds in defining formational units. Most of the limestone formations as previously classified, and as I shall define them, comprise the calcareous deposits of one cyclothem, but the intervening shales generally include parts of two cyclothems. In a majority of cases no change in the boundaries of established formations is necessary, but in some a revision of boundaries has been deemed advisable in order to include in a limestone formation a bed that previously had been considered as belonging in the adjoining shale. A reliable guide in such reclassification is furnished by knowledge of cyclic relationships.

For consideration of the genetic relations of stratigraphic elements in the Pennsylvanian section of the Mid-Continent region, it is certainly important to recognize the cyclothem. Reference to cyclothems is useful in describing the rocks and, as indicated under discussion of members, in the informal numerical indexing of cyclic subdivisions. Since it is believed that formations should be defined primarily on lithologic characters, this means that classification by cyclothems for purpose of recognizing genetic relationships is to be

Comparison of classification by formations and by cyclothems in part of the Wabaunsee group

FORMATIONS.	Index No.	Members.	Cyclothems
Dry shale	.8–.9	Shale	
Dover limestone	.7	Limestone, algal (local)	Dover cyclothem
	.6	Shale (local)	
	.5	Limestone, fusulinid	
	.4	Shale, molluscan fauna	
	.3	Limestone, molluscan (generally absent)	
Table Creek shale	.2	Shale, molluscan fauna	
	.1	Shale, nonmarine, and coal	
	.0	Sandstone, nonmarine	
	.9	Shale, nonmarine	Maple Hill cyclothem
	.8	Shale, molluscan fauna	
Maple Hill limestone	.7	Limestone, algal (generally absent)	
	.6	Shale, molluscoid fauna	
	.5	Limestone, fusulinids	
	.4	Shale, molluscoid fauna	
	.3	Limestone, molluscan (generally absent)	
Pierson-Point shale (upper part)	.2	Shale, molluscan fauna	
	.1	Shale, nonmarine, and coal	
	.0	Sandstone, nonmarine	

superimposed on the classification by formations. There is seemingly no source of ambiguity in such dual classification, providing use of the word formation is restricted to aggregates of beds having general lithologic similarity (that is, cartographic units) and of the word cyclothem to the cyclic succession of beds of all sorts. It does not seem desirable, however, to introduce a separate list of names for the cyclothems. Therefore, we propose to designate the cyclothems of the northern Mid-Continent Pennsylvanian by the name of the limestone formation that each contains. This use of terms is illustrated by reference to part of the Wabaunsee group (fig. 2).

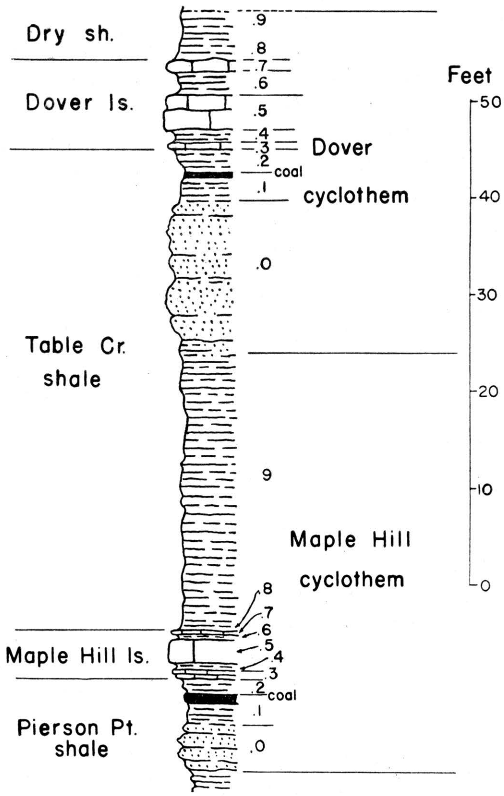

FIG. 2.—Diagram showing two typical cyclothems in the Wabaunsee group. The relation of formational stratigraphic divisions to the cyclothems is also indicated.

Members

Any lithologic or paleontologic subdivision of a formation that has stratigraphic significance and reasonable persistence may be classed as a member of the formation. Many such members in the Pennsylvanian section of the northern Mid-Continent area have received formal stratigraphic names. To some extent this is desirable, but the number of named units is already so great that even one who is familiar with the section has difficulty in remembering them. Surely, the addition of scores of new names for members now recognized but unnamed is to be avoided, even if the lack of names necessitates some circumlocution or perhaps an arbitrary letter or number symbol in order to designate them exactly in descriptions. This informal method of designating members, based on the typical succession of units in a formation or cyclothem, may be extended advantageously to include members that have received formal stratigraphic names. The classification and designation of members that has been found most flexible and best adapted to field use is a sort of Dewey system. Thus far it has been employed as a convenient supplement rather than as a substitute for geographically named subdivisions. One of its main advantages is the indication contained in the index number of the type of rock and place in the ideal cyclothem of the member catalogued. The index numbers for members are given in the form of decimals because this suggests the subordinate status of the subdivision and because the decimals can be combined with whole numbers assigned to indicate a given complete cyclothem.

In dividing the cyclothem and in assigning index numbers to subdivisions, effort has been made to formulate a scheme that, with appropriate modification of detail, will be applicable to all cyclothems in the Pennsylvanian and "Permian" of the Mid-Continent region. Each of the subdivisions noted can be split into as many elements as may appear desirable, but it is intended uniformly to indicate corresponding parts of different cyclothems by the same index figures. The members are numbered in upward order.

Members of an ideal cyclothem

.9. Shale (and coal).
.8. Shale, typically with molluscan fauna.
.7. Limestone, algal, molluscan, or with mixed molluscan and molluscoid fauna.
.6. Shale, molluscoids dominant.
.5. Limestone, contains fusulinids, associated commonly with molluscoids.

.4. Shale, molluscoids dominant.
.3. Limestone, molluscan, or with mixed molluscan and molluscoid fauna.
.2. Shale, typically with molluscan fauna.
.1. *c.* Coal.
.1. *b.* Underclay.
.1. *a.* Shale, may contain land plant fossils.
.0. Sandstone.

Members .0 and .1 in the initial part of the cyclothem and .9 at the end are nonmarine. The remaining members are marine.

Members of formations and cyclothems in the Wabaunsee group. The simple type of cyclothem just described is well shown in the Wabaunsee group, which may be described briefly as follows, the members being numbered in upward order:

Members of typical Wabaunsee group cyclothem

.8–.9. Shale, mostly unfossiliferous, marine or nonmarine.
.7. Limestone, light-gray, *algal,* in many cases sandy to conglomeratic, or coquinoid, locally oölitic, laminated to flaggy, may contain numerous mollusks, brachiopods and bryozoans or relatively unfossiliferous, marine.
.6. Shale, commonly somewhat sandy, marine.
.5. Limestone, blue to gray, weathers brown, granular to dense, massive, contains more or less abundant *fusulinids* with or without a varied assemblage of brachiopods, bryozoans, crinoid remains, and less commonly other fossils, marine.
.4. Shale, clayey, in many cases with rich molluscoid fauna, marine.
.3. Limestone, blue-gray, dense to shelly, contains numerous mollusks, especially pelecypods, and some brachiopods, crinoid remains, etc., marine.
.2. Shale, clayey, commonly contains *Myalina* and other pelecypods, *Derbya, Chonetes, Linoproductus* and bryozoans, marine.
.1. *c.* Coal, continental.
.1. *ab.* Shale, sandy to clayey, top few inches in some cases constituting underclay of the coal, may contain plant fossils, continental.
.0. Sandstone, shaly to massive, may contain fragments of plants, continental.

The sandstone (.0) may rest disconformably on underlying beds and appears definitely to represent the initial deposits of the cyclothem. Locally a thin conglomerate may occur at the base of the sandstone. The succeeding shale and coal (.1) are clearly continental in origin and indicate deposits made on an extremely low, flat coastal plain. The mollusk-bearing shale and limestone (.2 and .3) indicate the submergence of the coal swamps or coastal plain by a very shallow sea, and the overlying shale (.4) marks continued marine transgression that culminates in making the offshore fusulinid-bearing limestone (.5). The succeeding parts of the cyclothem appear to signify marine regression which leads to shoaling waters inhabited by mollusks and favoring growth of algae

(.6, .7 and .8). The terminal unit of the cyclothem (.9) is generally an unfossiliferous shale, but it may contain remains of land plants (see fig. 2). The entire cyclothem thus records a single marine pulsation, and it may be divided into an initial emergent phase (.0-.1) a transgressive marine phase (.2-.4), a culminating marine phase, (.5), a regressive marine phase (.6-.8) and a terminal emergent phase (.9). This nearly symmetrical or harmonic sort of rhythm might be expressed numerically by the sequence 0-1-2-3-4-5-4-3-2-1-0. That is, the index numbers .6 to .9 as previously given correspond to .1-.4, but they are arranged in reverse order. The Illinois cyclothems, as described by Weller and Wanless, seem to differ from this in representing mainly, if not entirely, the first half (transgressive hemicycle) of the complete rhythm, the latter half (regressive hemicycle) being absent or so foreshortened as to be as yet unrecognized.

The stratigraphic names that have been applied to limestones and shales of the Wabaunsee group will in most cases serve with little or no change of application to define formations. The placing of all of the limestone (and intervening shale) members of each cyclothem in a limestone formation and the assignment of remaining members to shale formations calls for revision of the boundaries of certain formations in various places, but these are mostly matters of detail. Application of stratigraphic names in this way leaves almost all of the several scores of individually recognizable members of Wabaunsee formations and cyclothems without formal names. It is seemingly an entirely unnecessary and undesirable step in this case to propose formal names even for the limestone members.

Members of formations and cyclothems in the Shawnee group. The succession of lithologic and faunal units that is seen in the Shawnee group differs mainly from that in the Wabaunsee group in the more complex character of the sequence of members and in the greater development of fusulinid-bearing limestones. It was in this part of the Pennsylvanian section of the northern Mid-Continent region that I first recognized clearly a cyclic repetition of beds, and because of the definite nature of stratigraphic relationships and apparent completeness of members that are developed this has served as a type in previous study and description of the Mid-Continent Pennsylvanian cyclothems.[9] Present knowledge indicates

9. Moore, Raymond C., Pennsylvanian cycles in the northern Mid-Continent region: Ill. Geol. Survey, Bull. 60, pp. 247-257, 1931; A reclassification of the Pennsylvanian system in the northern Mid-Continent region: Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., pp. 79-97, 1932.

that the Shawnee cyclothem contains certain significant elements that have not yet been described and that it may be of composite rather than simple character.

The outstanding elements in the Shawnee cyclic sedimentary rhythm are the three or four different types of limestone that appear in the same order in each of the four limestone formations of the group, which in upward order are called Oread, Lecompton, Deer Creek, and Topeka (see fig. 10). The limestone members have come to be designated commonly as "lower," "middle," "upper" and "super," respectively. All of the limestone members, except in some cases the fourth or topmost ("super") of each of these limestone formations, are typically fusulinid-bearing. The thin shale members that separate the limestones differ from one another in various characters and the order of succession of these is constant in each formation. Black fissile shale, for example, belongs invariably between the "middle" and "upper" limestone members and does not occur elsewhere.

These limestone formations, in which a cyclic succession is so very evident, are separated by relatively thick shale formations that are mostly rather sandy, and are mainly nonmarine. They are the Kanwaka shale, Tecumseh shale, and Calhoun shale, named in upward order. When attention is directed more closely to the content of these shales it is observed that each is typically divisible into a nonmarine shale in the lower part, one or two beds of limestone with or without fusulinids in the middle part, and a nonmarine shale, sandstone and at least locally a coal bed in the upper part. There is thus a cyclic repetition of elements in the shale formations as well as in the limestones.

Having made these observations, the problem of defining the character of unit cyclothems and the proper lines of division between contiguous cyclothems is presented. Approach to this problem calls for recognition of the genetic significance of each type of sedimentary deposit that is here encountered and for an acceptable correlation of members in the Shawnee succession with members in the seemingly more simple Wabaunsee type of cyclothem. Present knowledge of sedimentation, especially as regards the conditions responsible for the very different lithologic characters of the several limestone units, is certainly too meager for a satisfactory understanding of the genetic significance of all cyclothem members, but it is possible to distinguish homologies of elements in the Wabaunsee and Shawnee successions. Let us undertake to apply the Wabaunsee or ideal cyclothem as a yardstick in classifying and arranging a partition of the Shawnee rocks.

The ideal cyclothem, as previously described and as seen more or less typically developed in the Wabaunsee group, begins with nonmarine sandstone, shale and coal, is followed by marine shale and limestone with a molluscan fauna, attains a culminating marine phase in fusulinid-bearing limestone, that is succeeded by shale and limestone containing mollusks and algae, and closes with nonmarine shale. We find in the upper part of the Lawrence shale, Kanwaka shale, Tecumseh shale and Calhoun shale a persistent sandstone member that at least locally is conglomeratic at the base, and in each case this sandstone is overlain by sandy shale with land plant remains and by coal (fig. 10). These nonmarine deposits may be identified as equivalent to the initial members of the Wabaunsee cyclothem. Above the coals in the Shawnee group and upper Lawrence shale are a few feet of shale, unfossiliferous or containing a molluscan or molluscoid marine fauna; no limestone member with a molluscan fauna is recognized. Then comes (*a*) the relatively thick, fusulinid-bearing "lower" limestone, (*b*) shale, (*c*) the thin, also fusulinid-bearing "middle" limestone, (*d*) black fissile shale, (*e*) yellow or gray clay shale, and (*f*) the thick light gray, wavy-bedded "upper" limestone which contains fusulinids. If the fusulinid limestones, taken together, are correlated with the middle (fusulinid-bearing) member of the Wabaunsee cyclothem, the Shawnee group may be considered as distinguished by a great and somewhat complex development of the inferred culminating marine phase of the cyclothem—that part marked by presence of fusulinids. Most of the "super" limestones of the Shawnee group correspond very well to the receding molluscan and algal limestone member of the Wabaunsee cyclothem, and both are followed by nonmarine shale. There remains to consider the marine, in part fusulinid-bearing limestones, that occur in the middle or upper part of the thick shale formations of the Shawnee group. This definitely indicates a marine invasion that followed a considerable time of continental sedimentation and that was in turn followed by continental sedimentation. Seemingly these limestones and a portion of the contiguous strata must be considered as a separate cyclothem. If that is accepted, we have an alternating sequence of complex major and simple minor cyclothems, the former characterized by presence of numerous members including three or in some cases four different fusulinid limestones, and the latter marked by similarity to the simple ideal cyclothem. This repeated succession of cyclothems of differing character indicates a rhythm of larger order than that shown in the individual cycles and suggests the desirability of a term to designate a combination of related cyclothems. The word "megacyclothem" will be used in this sense to define a cycle of cyclothems. The interpretation of the Shawnee members just discussed is indicated in tabular form below.

Suggested grouping of members of a typical Shawnee megacyclothem

Minor cyclothem

.8–.9. Shale, marine or nonmarine (thick).
.7. Limestone, light-gray, *algal,* sandy to conglomeratic, oölitic, may contain mollusks, brachiopods, bryozoans, etc.
.6. Shale, may contain abundant mollusks, brachiopods, bryozoans, etc.
.5. Limestone, contains fusulinids.
.2–.4. Shale, marine, thin or absent.
.0–.1. Shale and sandstone, nonmarine, not definitely differentiated.

Major cyclothem

.9. Shale, nonmarine, thick, commonly with plant fossils.
.8. Shale, with molluscan fauna.
.7. Limestone, dark-blue or gray, like .7 member of Wabaunsee cyclothem, but less persistent and more irregular in thickness (the "super" limestone of field classification).
.6. Shale, thin or absent.
.5. *h.* Limestone, blue or gray, even-bedded, contains fusulinids, absent in many sections (and where present it has generally been classed with the "fourth" or "super" limestone).
.5. *g.* Shale, commonly somewhat sandy, marine.
.5. *f.* Limestone, light-gray, fine-grained, wavy-bedded, locally cherty, thickness generally 12 feet or more, contains abundant *fusulinids* and other fossils, at top in some cases contains algal? "super" type limestone lacking in fusulinids (the "upper" limestone).
.5. *e.* Shale, yellow or gray, clayey.
.5. *d.* Shale, black, fissile.
.5. *c.* Limestone, dark-blue, dense, single massive bed, 1 to 2 feet thick, vertical joints, contains numerous *fusulinids* and other fossils (the "middle" limestone).
.5. *b.* Shale, gray, clayey, 10 feet or more, in southern areas contains a red zone and subordinate thin sandstone and nodular limestone beds.
.5. *a.* Limestone, blue-gray weathering strongly brown, ferruginous, somewhat sandy or earthy, massive, 5 to 10 feet in average thickness, contains numerous *fusulinids* and other fossils (the "lower" limestone).
.2–.4. Shale, sandy to clayey, contains brachiopods and mollusks, may include zone with brachiopods and pelecypods at base of 5*a*.
.1. *c.* Coal, thin and very local.
.1. *ab.* Shale, yellowish, sandy, may contain plant fossils.
.0. Sandstone, yellow-brown, fairly persistent, 5 to 10 feet in average thickness, base locally conglomeratic.

If this characterization of cyclothems most accurately depicts the stratigraphic relationships in the Shawnee group, the reasons for the alternating succession of major and minor cyclothems are to be formulated, and it is also to be explained why the fusulinid phase of the socalled major cyclothem is divided into contrasting parts as noted.

An alternative classification of the Shawnee members remains to be considered. It is possible that the three or four fusulinid limestones of the limestone formations and the fusulinid limestone of the shale formations each represent the culmination of several more or less completely developed cyclothems. This would mean that instead of a major and a minor cyclothem we have to do with a succession of associated and related cyclothems of slightly differing characters. This suggested cycle of cyclothems comprises the same units that have previously been designated as a megacyclothem. The following tabulation arranges the members according to this plan, introducing certain members that are only locally developed, but that may be very important in reaching an understanding of the succession as a whole. The five cyclothems that are tentatively identified are indicated by the letters A-E and the members are designated by index numbers corresponding to those employed in describing the Wabaunsee cyclothem (see fig. 3). The most prominent, persistent and definitely recognized stratigraphic units are indicated by an asterisk (*).

Subdivisions of a typical Shawnee megacyclothem

Cyclothem E

*E.9. Shale, sandy, plant fossils, thick.
E.8. Shale, marine.
*E.7. Limestone, oölitic or pebbly, contains algae and few mollusks.
*E.6. Shale, molluscan and molluscoid fossils.
*E.5. Limestone, contains fusulinids and molluscoids.
E.4. Shale, molluscan and molluscoid fossils.
E.3. Limestone, shaly, thin, molluscan fossils.
E.2. Shale, marine, molluscan fossils.
*E.1–E.0. Shale and sandstone, plant fossils, thick.

Cyclothem D

D.9. Shale, plant fossils (in general without definite upper boundary).
D.8. Shale, molluscan fossils.
*D.7. Limestone, oölitic or flaggy, molluscan fossils, locally prominent ("super" limestone).
D.6. Shale, thin or absent.
D.5. Limestone, blue or gray, even-bedded, granular, contains abundant fusulinids, 1 to 4 feet thick, but absent in many exposures (generally included in the so-called "super" limestone).

D.2–D.4. Shale, calcareous, molluscan and molluscoid marine fossils.

D.0–D.1. Sandstone and shale, mostly unfossiliferous, locally with land plant fragments.

Cyclothem C

C.9. Shale, grades without definite boundary into next higher member.

C.8. Shale, marine molluscan fossils, mostly thin or unrecognized.

C.7. Limestone, blue or gray, granular, impure, may be algal, lacks fusulinids, clearly recognized in some outcrops (included in the "upper" limestone).

C.6. Shale, generally absent.

*C.5. Limestone, light-gray, wavy-bedded, locally chert-bearing, in general thick (5 to 25 feet), contains fusulinids and molluscoids ("upper" limestone).

*C.4–C.2. Shale, molluscan and molluscoid fossils.

*C.1. Shale, black fissile, contains conodonts, scanty brackish water molluscan fauna, locally insects, abundant macerated plant fragments.

C.0. Absent or not recognized.

Cyclothem B

B.9–B.8. Absent or not recognized.

B.7. May be represented in top of "middle" limestone by zone of abundant molluscan fossils.

B.6. Absent or not recognized.

*B.5. Limestone, dark-blue, dense, a single massive bed with vertical joints, contains fusulinids and molluscoids except commonly in thin zones at top and bottom ("middle" limestone).

B.4. Absent or not recognized.

B.3. May be represented at base of "middle" limestone by zone of molluscan fossils.

B.2. Shale, marine, generally molluscan fossils.

B.1. Shale, nonmarine, in most cases not definitely recognized, coaly streak may be present.

B.0. Sandstone or red shale.

Cyclothem A

*A.9–A.8. Shale, generally unfossiliferous.

*A.7. Limestone, oölitic or granular, molluscan fauna, locally 3 or 4 feet thick.

A.6. Shale, generally not differentiated.

*A.5. Limestone, blue-gray weathers brown, ferruginous, impure, massive or uneven thick beds, contains fusulinids and molluscoids ("lower" limestone).

A.4. Generally absent or not recognized.

A.3. May be represented at base of "lower" limestone by zone of molluscan fossils.

*A.2. Shale, marine, generally molluscan fossils.

A.1. *c.* Coal, thin or absent.

A.1. *b.* Underclay, generally recognized where coal is present.

*A.1. *a.* Shale, sandy, plant fossils.

*A.0. Sandstone, nonmarine, locally contains plant fragments, may be conglomeratic at base.

Careful analysis of this succession of units leads to the conclusion that we are dealing here not with a single unbroken rhythm in types of sedimentation, marked by the uniform direction of changes in what might be termed respectively transgressive and regressive hemicycles, but there is indication rather of oscillations that are superposed on a large cyclic movement. The actuality of existence of the lesser rhythms is marked by the repetition in varying degrees

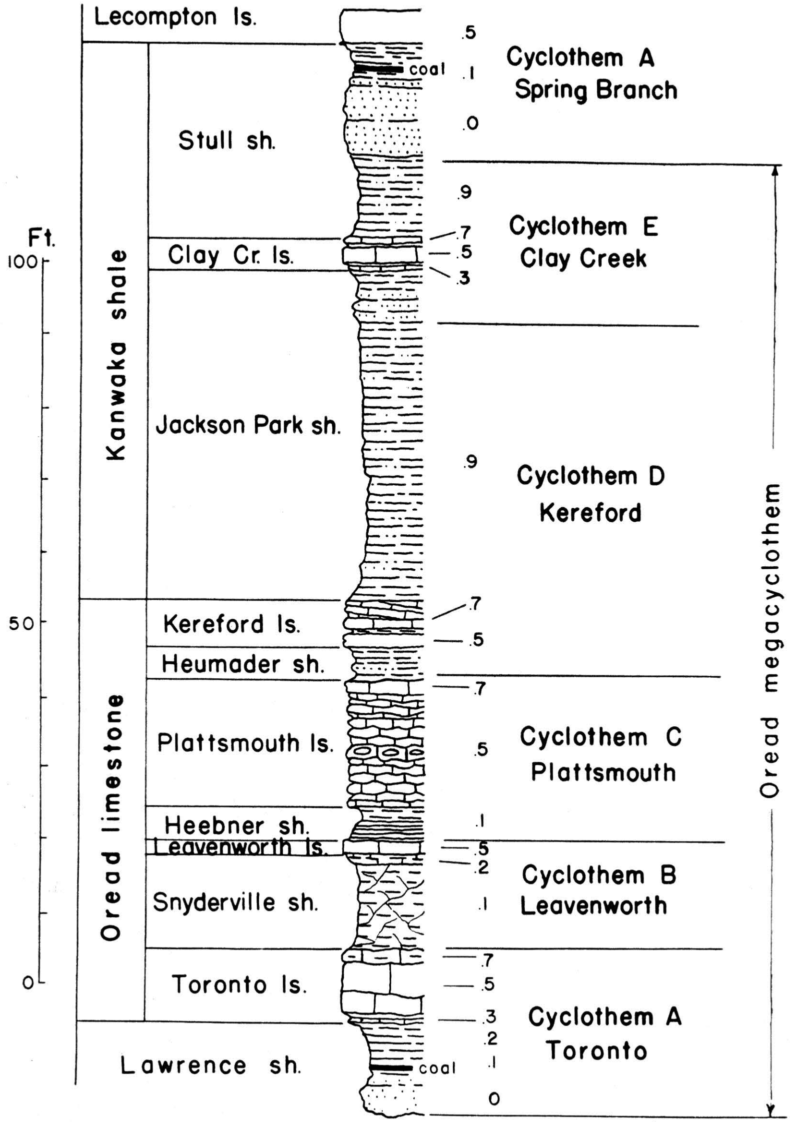

FIG. 3.—Diagram showing typical megacyclothem of the Shawnee group.

of distinctness and prominence of elements that are restricted to a single part of the ideal simple cyclothem. For example, it may be noted that oölitic limestone with a strongly molluscan fauna is a typical near-end member of the receding phase of the simple cyclothem (fig. 3). The occurrence of such rock (A.7) between the "lower" (A.5) and "middle" (B.5) limestones, both of which contain fusulinids, is expectable on the hypothesis of a group of related cyclothems, but is seemingly inexplicable otherwise. The same may be said of other members. The coal A.1*c* is definitely recognized in many places and occurs in its proper relationships as compared to the ideal simple cyclothem. The carbonaceous or coaly streak in B.1 fits properly in the cyclothem that contains the "middle" limestone (B.5) as its central member, but is anomalous otherwise. It is nevertheless true that in different parts of the megacyclothem certain members of the supposed simple cyclothems are characteristically suppressed and it is also true that certain members are strongly developed in a particular supposed simple cyclothem but little developed or absent in others. These facts, in conjunction with the difference in physical characters that distinguish the fusulinid-bearing members and their repetition in constant order, give definite basis for the grouping designated as a megacyclothem. Indeed, the cyclic character of the larger rhythm is much more evident and striking than that of the indicated lesser rhythm. The arrangement of megacyclothem members in five cyclothems, as shown in the second table, is tentatively accepted as more completely and naturally representing essential relationships than a grouping in two very unequal cyclothems, as indicated in the first table.

The formations of the Shawnee group, as previously noted, have been defined to consist of closely associated limestones and intervening thin shales on the one hand, and of thick shales and included thin limestone and sandstone on the other (see fig. 10). These two types of formations are arranged in alternating succession. In terms of megacyclothem members, as given above, the Oread limestone includes members A.5 to D.7, inclusive; the Kanwaka shale contains the remainder of this megacyclothem, D.8 to E.9, and in addition the basal part of the next following one, A.0 to A.4; the Lecompton limestone includes members A.5 to D.7 of this second megacyclothem, the Tecumseh shale members D.8 to E.9 and the following A.0 to A.4, and so on. This stratigraphic classification which is based essentially on lithologic features is the most natural and practical, but does not coincide with the limits of either the cyclothems or of the megacyclothems. Arguments in favor of defining formation boundaries so as to coincide with the limits of megacyclothems have some merit but are open to the objections that a complete revision of stratigraphic nomenclature would be required, that boundaries would be difficult to map, and that in order to be logical the group boundaries would have to be modified. Furthermore, if adopted for one part of the system, the cyclic basis of classification should be applied to the remainder, and such action seems definitely inexpedient. Finally, it is certain that although some features of the cyclic development are very definitely known, others remain to be worked out.

Members of formations and cyclothems of the Douglas group. The Douglas group consists mainly of clastic deposits in which only one or two cyclothems with persistent limestones are developed, but there are alternations of sandstone, shale and coal beds that indicate the existence of other partially complete cyclothems (see fig. 9). Much study of the Douglas beds remains to be done.

Members of formations and cyclothems of the Missouri series. The cyclothems of the Missouri series are generally similar to those of the Shawnee group, but the succession of different members is less complete. There is seemingly greater irregularity than in the Shawnee group, which makes classification of some parts of the Missouri series doubtful as yet. Equivalents of cyclothems B and C as listed under the Shawnee megacyclothem are definitely recognized again and again in the Missouri series, but cyclothems corresponding to A, D, and perhaps E are either absent or not clearly identified. Therefore, we may tentatively distinguish megacyclothems in the Missouri series with the differentiation and grouping of members as shown in the following table. The most prominent and characteristic members are designated by an asterisk (*).

Subdivisions of a typical Missouri series megacyclothem

Cyclothem C

C.9. Shale, unfossiliferous or with plant fossils.

C.8. Shale, molluscan fossils.

*C.7. Limestone, oölitic, or very siliceous, cherty, or fragmental, molluscan fossils or algae ("super" limestone).

C.6. Shale, molluscan and molluscoid fossils, well developed in some cases but typically absent in others.

*C.5. Limestone, light-gray, wavy-bedded, locally chert-bearing, in general thick, may contain fusulinids ("upper" limestone).

C.4–C.2. Shale, molluscan and molluscoid fossils.

*C.1. Shale, black fissile, contains conodonts, scanty brackish water molluscan fauna and abundant macerated plant fragments.

C.0. Sandstone, mostly lacking or unrecognized.

Cyclothem B

B.9–B.8. Absent or not recognized.

B.7. May be represented in "middle" limestone by abundant *Osagia*, pelecypods and worm borings, brecciated limestone.

B.6. Absent or not recognized.

*B.5. Limestone, dark-blue, dense, a single massive bed with vertical joints, may contain fusulinids but commonly molluscoids and mollusks are dominant ("middle" limestone).

B.4–B.2. Shale, molluscan and molluscoid fossils.

B.1. Coal, thin but persistent in some cases, absent in others, underlain by nonmarine shale, locally bearing plant fossils.

B.0. Sandstone or red clay shale, may be absent.

Next below the cyclothem B, as listed above, mainly distinguished by the "middle" limestone (B. 5), is a cyclothem of the C type with prominent "super" and "upper" limestones. The peculiarities of the Missouri series cyclothems may be related to the more dominantly marine character of these deposits in the northern Mid-Continent region. Southward tracing of the beds shows that in general the limestones become thin and eventually disappear, the shales become thicker and more sandy, beds of sandstone and coal appear. Clastic sediments were evidently borne mainly from the south, and in Oklahoma sandstone and shale far outweigh limestone. The deposits are mostly marine, however. Careful study of southern Kansas and Oklahoma beds belonging in the Missouri series, with special attention given to cyclic sequences, has not been undertaken, but no indication has yet been seen that members characteristic of the A cyclothem make appearance in this region. In the case of the Stanton limestone, at least, there are three distinct cyclothems, each containing fusulinid members and other typical elements of the ideal cyclothem, but the lowest of these three cyclothems is typically representative of the "B cyclothem," characterized by presence of a "middle" (dense blue, vertically jointed) limestone.

Formations and members of the Missouri series have been defined wholly on the basis of lithologic characters. Some formations embrace most of the beds in a megacyclothem, as defined above, but others include relatively small parts of two adjacent cyclothems or megacyclothems and a few comprise the limestone or shale portion of a single cyclothem. The recognition and definition of cyclic elements has value in indicating the relationship of beds, but it has not been applied uniformly to stratigraphic classification of the Missouri series (see figs. 7 and 8).

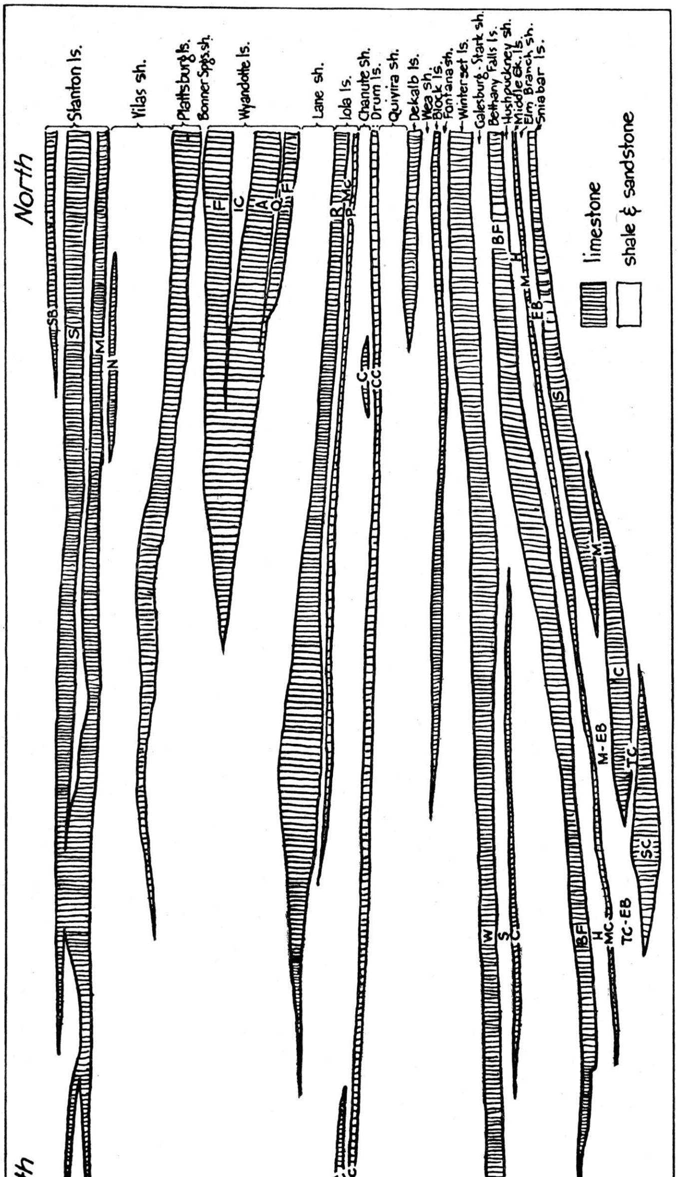

FIG. 4A.—Diagrammatic representation of stratigraphic units in the Missouri series along the strike of outcrops in eastern Kansas. (For DeKalb read Westerville; for Elm Branch read Ladore; for Sniabar read Hertha.)

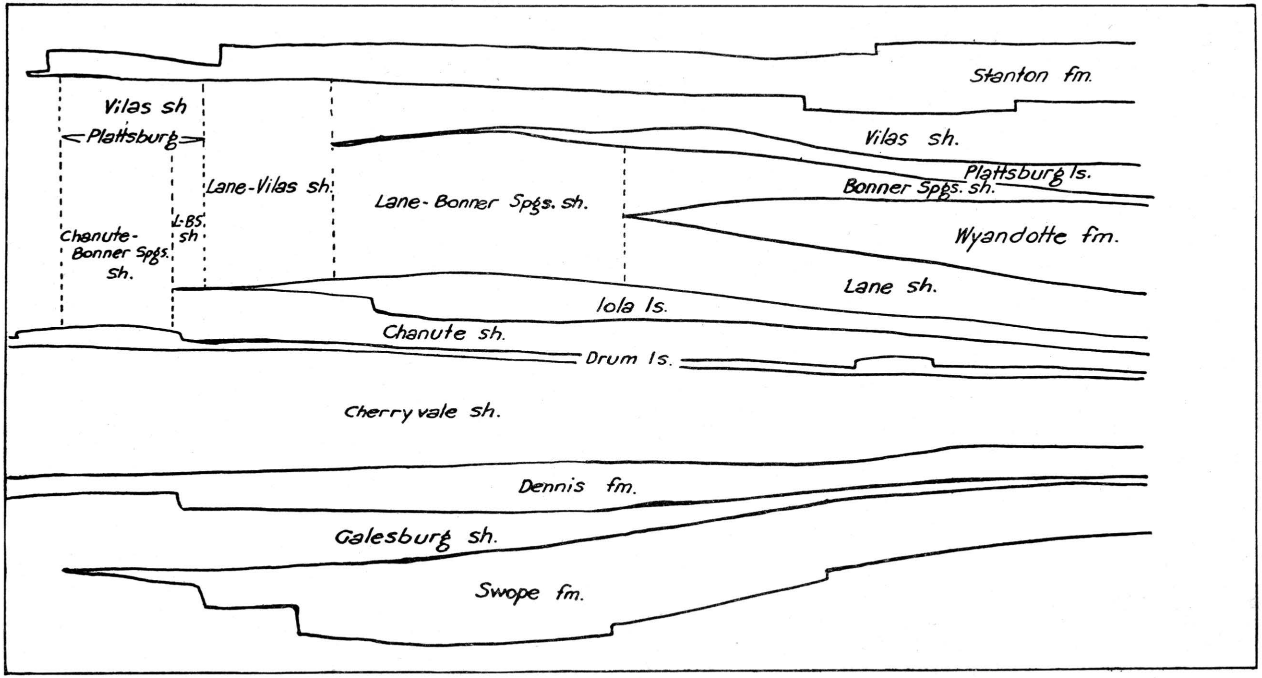

FIG. 4B.—Same as Fig. 4A, showing stratigraphic nomenclature. (Definition of the Swope formation is modified to exclude beds below Middle Creek limestone. (See page 83.)

Members of formations and cyclothems of the Des Moines series. In the Des Moines series, the existence of a number of cyclothems is definitely determined, but detailed stratigraphic investigation of this part of the section remains to be undertaken. The Marmaton-group cyclothems closely resemble those of the Missouri series. Persistent limestones are well developed. The Cherokee cyclothems, as yet little known in Oklahoma, Kansas and Missouri, appear to be very similar to those described by Weller and Wanless in Illinois. Here the sandstone, shale and coal of the nonmarine part of the cycle are approximately equal in importance to the marine, or the nonmarine may be better developed than the marine (see fig. 6).

Some Problems of Stratigraphic Nomenclature

The application of names to the stratigraphic units recognized in the Pennsylvanian of the Mid-Continent states offers a number of vexing problems. In the first place, it is necessary to determine as accurately as possible the prior use of stratigraphic names, and in several cases difficulty and confusion are encountered here. The availability or suitability of names, in a number of cases, depends on the accuracy of correlation between outcrops at distant points.

A problem encountered in regional stratigraphic study of any system is that concerning the use of names in relation to lateral changes in the character of the beds. No stratum or group of strata is laterally continuous indefinitely. Ultimately, a limestone grades into sandstone or shale, or it pinches out. Thus, a sharply defined stratigraphic boundary between limestone and shale in one section may be lost entirely where the limestone disappears. Some of the difficulties and complexities in the application of names as encountered in eastern Kansas are represented diagrammatically in the accompanying sketches (figs. 4A, 4B). Ideally, contemporaneous deposits of different lithologic character may be recognized by continuous faunal horizons. A horizon in the midst of thick shale may carry a distinctive group of fossils that represents exact equivalence in age wherever the faunal horizon is identified. The shale may grade laterally into limestone or sandstone, but if the faunal horizon persists in the latter, fairly exact correlation of beds in the shale and limestone or sandstone is possible (fig. 5). Examples of this type of faunal and lithologic relationships are encountered in the

Mesaverde sandstone-Mancos shale sections of the Cretaceous in the Rocky Mountains region, in the Elmdale shale-Foraker limestone of the Kansas-Oklahoma region, in the Ordovician and Devonian of New York, and many other cases. Such occurrences are of much stratigraphic value and interest, but it is generally quite impossible to map the line defined by fossils. The beds are divided, rather, on lithologic bases. Stratigraphic names must have practical application.

It appears from our study that the only practical basis for differentiation of beds such as those of the Kansas Pennsylvanian, that are to be named and mapped, is a lithologic one. Thus, a limestone formation is considered to end where the limestone disappears. In the case of a formation name which applies to a group of beds, upper and lower limits of the formation may vary in different localities. The exact upper and lower limits may be indicated by reference to the names of the subordinate units that are recognizable in these particular places. In order to avoid numberless additions of stratigraphic names where the boundaries of formational units vary, usage adopted by the Kansas Geological Survey calls for expansion and in many cases hyphenation of the boundary units. For example, the Howard formation in part of central Kansas includes three limestone members (Bachelor Creek, Church and Utopia) and two shale members (Aarde and Winzeler), the lower one containing the widely persistent Nodaway coal bed. The formation may be defined stratigraphically in this region by writing "Howard limestone (Bachelor Creek-Utopia)." Near Howard, Kansas, where the Utopia member is lacking, the exact designation becomes "Howard limestone (Bachelor Creek-Church)." In northern Kansas and southern Nebraska we find numerous sections which show the Utopia limestone and Nodaway coal but lack the Bachelor Creek member. The Howard limestone may be defined here by writing the names of the lower and upper members, as "Nodaway-Utopia." This usage of terms means that in places where the upper or lower members of a formation are absent or unrecognizable, the adjacent formation units are expanded actually a slight amount. For instance, the Severy shale in Greenwood county, Kansas, includes the strata between the top of the Topeka limestone, below, and the base of the Bachelor Creek member of the Howard limestone, above. Farther north, the top of the Severy may be defined at the base of the Church member of the Howard. It is recognized that equivalent shale deposits may thus be classed as belonging in the Howard limestone in some sections and as included in the upper Severy shale in other sections. The only alternative to this seems to be a departure from definition of formation and member units on lithologic bases and the drawing of arbitrary unrecognizable boundaries within shale bodies. These latter can be mapped only approximately and cannot be defined in sections.

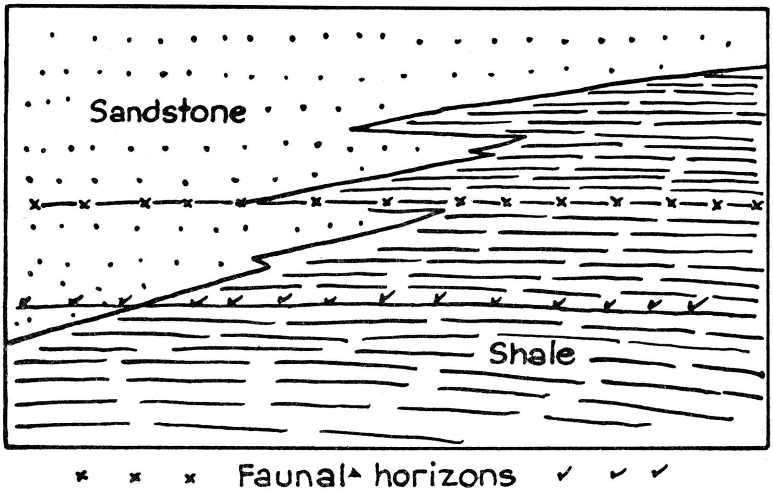

FIG. 5.—Diagram showing gradation of shale into sandstone, with faunal horizons persisting through both types of rock.

South of the point where the Wyandotte limestone disappears, the Lane shale and the Bonner Springs shale, which occur below and above the Wyandotte, respectively, come together and no mappable horizon is found between the Iola limestone and Plattsburg limestone. The thick shale extending from the top of the Iola to the base of the Plattsburg may be designated as Lane-Bonner Springs shale. This usage seems preferable to introduction of a new name for this shale, (1) because the hyphenated name automatically defines the span of the shale body, (2) because adoption of the latter practice would require almost numberless additions to the existing long list of Pennsylvanian stratigraphic units, and (3) because the method of nomenclature is flexibly adapted to various types of changes along the strike of the beds. It is recognized that the middle part of the Lane-Bonner Springs shale may be stratigraphically equivalent to the Wyandotte limestone (see fig. 5).

Summary of the Revised Stratigraphic Classification of the Pennsylvanian Rocks of Kansas

Three divisions of series rank, separated one from another by unconformities, are now recognized in the Pennsylvanian section of Kansas. These are named, in upward order, the Des Moines series, the Missouri series, and the Virgil series. The Virgil beds are separated from the overlying Big Blue series, classed as "Permian," by an unconformity (see fig. 12). Because the boundaries of these series are defined by unconformities rather than by arbitrarily selected conformable contacts, there is necessary revision of the line between Des Moines and Missouri beds. The Missouri series is restricted to include only the lower part of deposits formerly designated by this name, and the boundary between Missouri and Virgil beds is an unconformity in the lower part of the Douglas group of previous usage (fig. 9). The upper boundary of the Virgil series is located at the break that occurs near the horizon of the Brownville limestone, and within the group of beds formerly known as Admire shale.

The Des Moines series in Kansas contains two groups, the Cherokee beds below, and the Marmaton group above. These groups are defined as previously, except that some rocks formerly classed as upper Marmaton are transferred to the Missouri series (fig. 6).

The rocks of the Missouri series are divided into five major segments which are clearly differentiated in east-central Kansas and western Missouri, but are not so definite in southern Kansas. At the base of the series is the Bourbon formation, including the deposits, chiefly shale and sandstone, that occur between the post-Des Moines unconformity and the base of the Hertha limestone. Conformably above the Bourbon beds comes the Bronson group, consisting chiefly of limestone and including the beds from the base of the Hertha limestone to the top of the Dennis limestone. This corresponds to the lower part of the Kansas City group as previously defined. The Bronson group is a compact assemblage of limestones that readily stand apart from the contiguous strata (fig. 7). The Kansas City group is redefined to include the middle and upper part of the old "Kansas City formation" as proposed by Hinds and Greene, and in addition it includes shale in the lower part of the previously defined

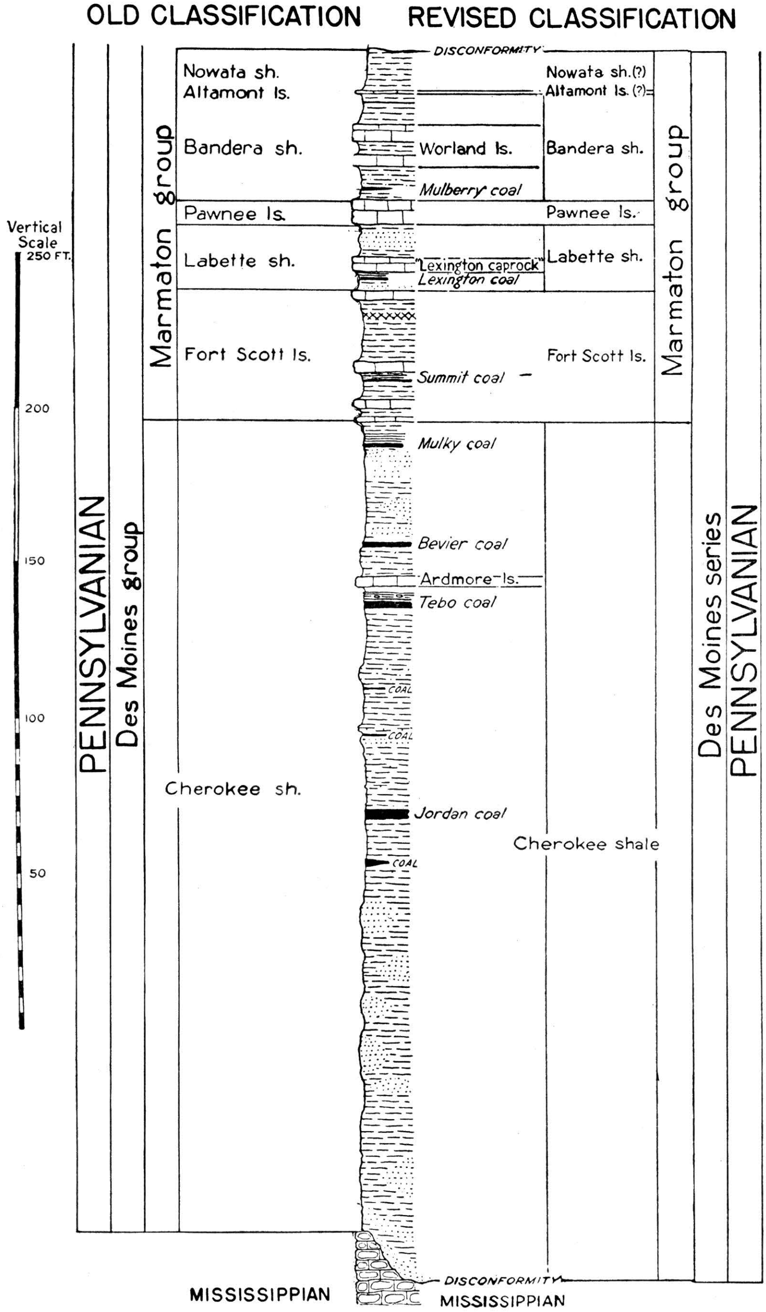

FIG. 6.—Diagram showing comparison of old and revised classification of Des Moines beds. This section, representing conditions in the latitude of the Kansas river, does not show the most typical development of the Marmaton beds. In southeastern Kansas the Lenapah limestone appears above the Altamont and beneath the disconformity that marks the base of the Missouri series, as redefined.

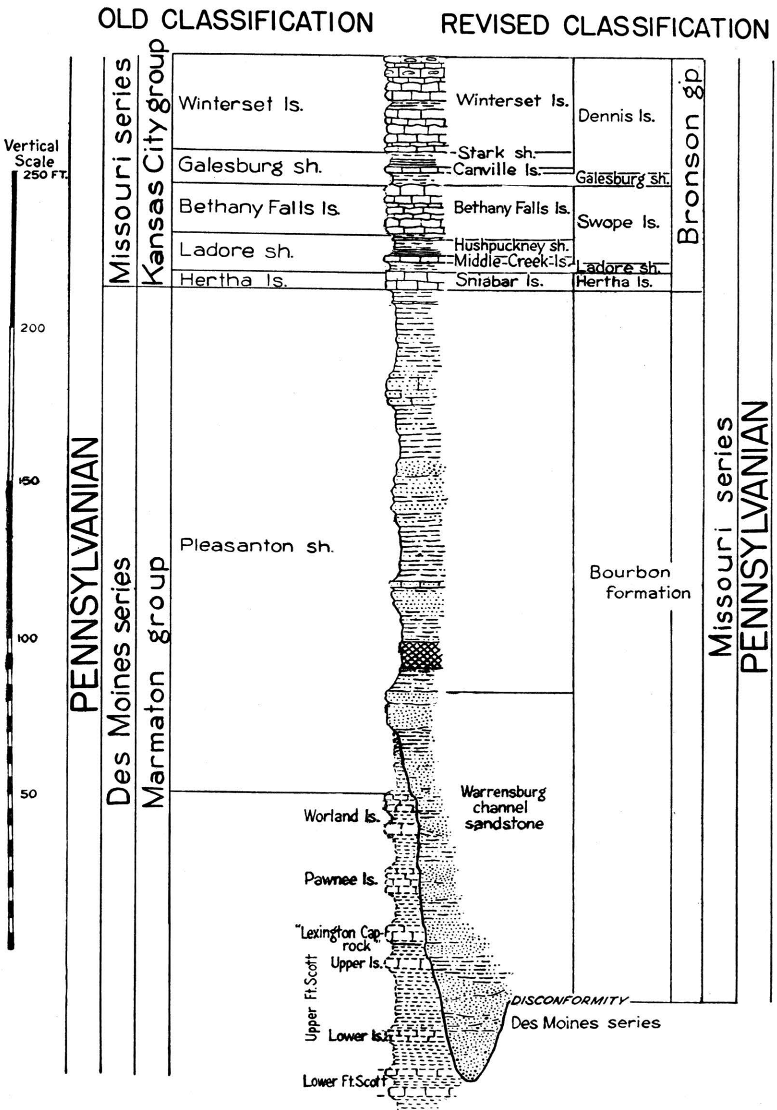

Fig. 7.—Diagram showing comparison of old and revised classification of lower Missouri beds (redefined).

"Lansing formation." It extends from the base of the Fontana shale to the top of the Bonner Springs shale. Thus the revised Kansas City group comprises the shale and included limestones, mostly thin or lenticular hard-rock bodies, that lie between the persistent and prominent Bronson and Lansing limestones. The Kansas City group contains much more shale than the next lower or higher groups. The Lansing group contains the Plattsburg and Stanton limestones, together with the mostly rather thin Vilas shale that lies between them. It is thus a limestone group that is persistent. Finally, a variable thickness of beds, chiefly shale, that occur between the top of the Lansing and the unconformity at the base of the Virgil series, is classed as the Pedee group. These rocks were formerly included in the "Douglas formation" (fig. 8).

The Virgil series contains three groups as now classified in Kansas. Beneath the Oread limestone there is thick shale and sandstone, and rather unimportant thin limestone, that comprise the Douglas group. The Douglas beds are very dominantly clastic (fig. 9). The Shawnee group is defined to include the beds from the base of the Oread limestone to the top of the Topeka limestone, and thus is made up of alternating limestone and shale formations, each about 40 to 80 feet in thickness. These beds show best the characteristic features of the cycle of cyclothems which has been designated as a megacyclothem (fig. 10). The Wabaunsee group comprises the remainder of the Virgil series, in which there are numerous thin limestones and moderately thick shale bodies. Here is found a good development of simple cyclothems which, unlike those of the Shawnee group, are not evidently to be grouped in megacyclothems (fig. 11). There is possibly some ground for subdivision of the Wabaunsee group into two parts, as proposed (in manuscript) by G. E. Condra. If this is done, the line of separation belongs near the horizon of the Tarkio limestone, for in northern Kansas and in Nebraska the Tarkio and adjacent formations are well developed and fairly thick, whereas south of Emporia, Kan., the Tarkio disappears and the contiguous shales become markedly thin.

The accompanying figures 6 to 12 show the revised classification of the Pennsylvanian rocks of Kansas, and for comparison, indicate its relation to older usage.

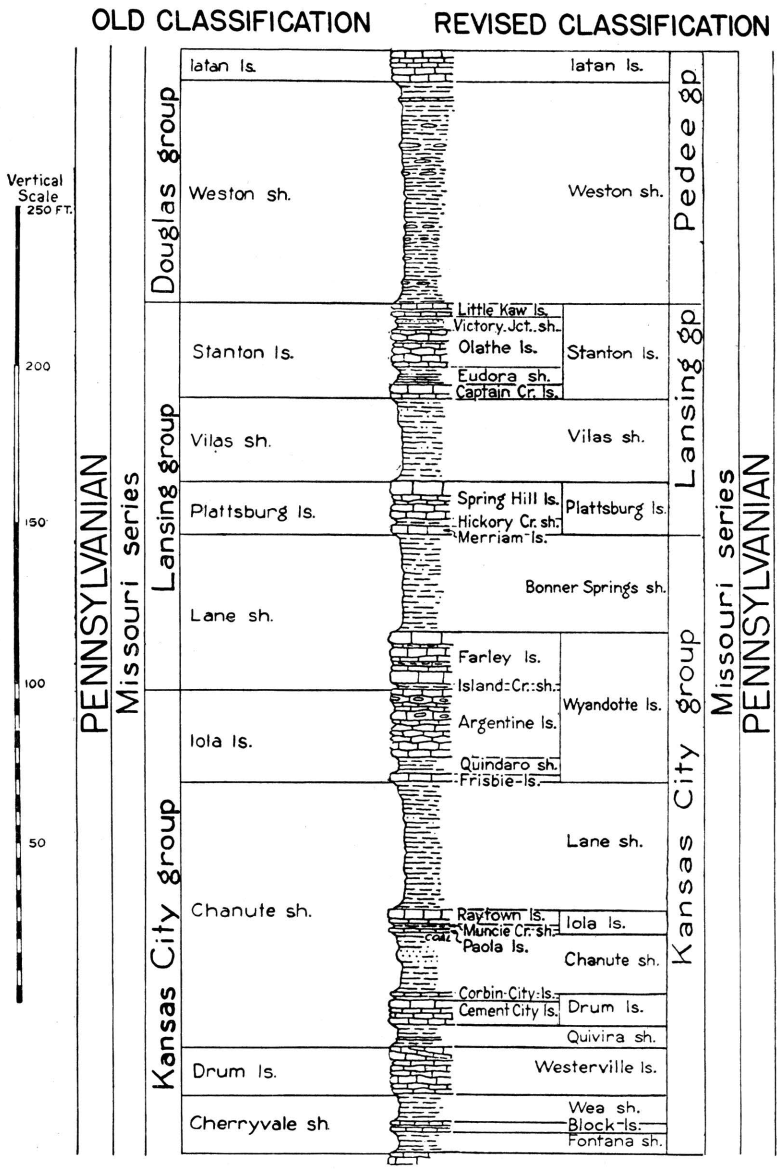

FIG. 8.—Diagram showing comparison of old and revised classification of upper Missouri beds (redefined).

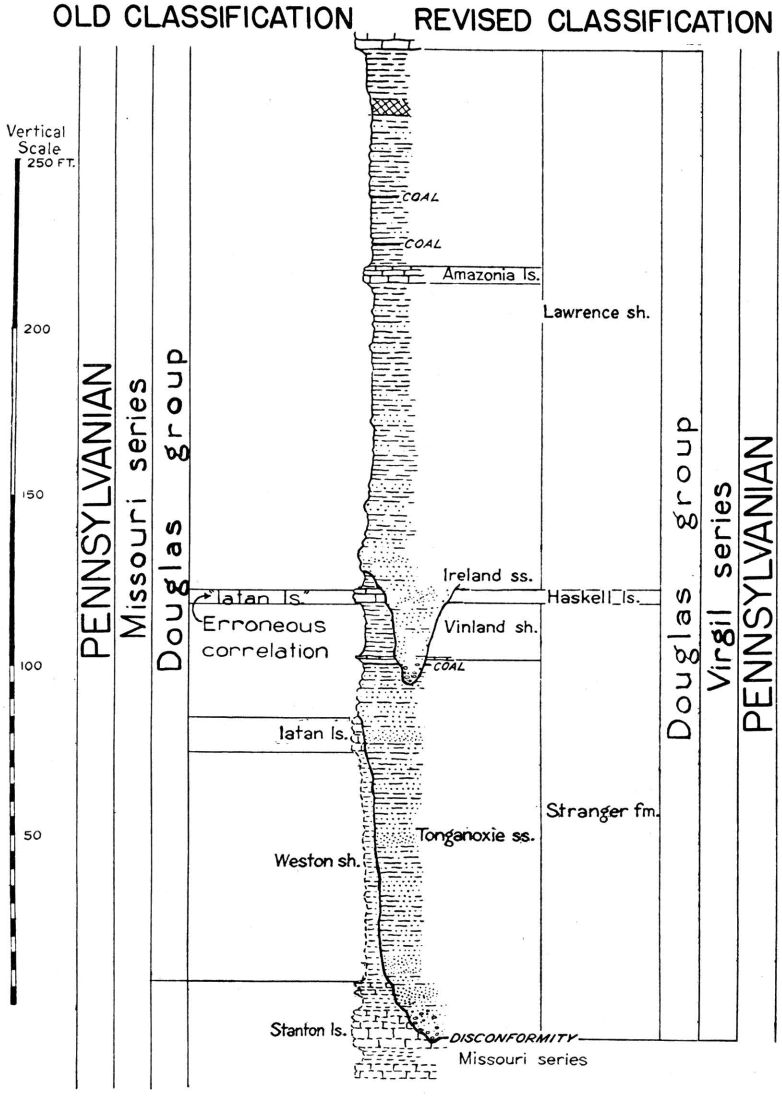

FIG. 9.—Diagram showing comparison of old and revised classification of lower Virgil beds. The unconformity that separates the Stranger formation from the Iatan, Weston, or Stanton beds was not recognized in earlier work.

STRATIGRAPHIC DIVISIONS OF THE PENNSYLVANIAN ROCKS OF KANSAS

The following pages are devoted to a delineation of the major and minor stratigraphic divisions of the Pennsylvanian rocks of Kansas as these are now recognized by the State Geological Survey. Treatment is arranged according to the order of succession, from lowest or oldest to highest or youngest. References to previously published usages are given in the manner that is commonly employed in the synonymies accompanying descriptions of fossils, because this shows most completely and concisely the history of nomenclature. There are many cases in which the use of terms by older writers is mistaken or misleading, and the relation of these varying stratigraphic definitions to present classification cannot be understood without these annotations. The references are arranged in chronologic order under the head of each different stratigraphic term or usage.

The name of the author of each stratigraphic term and the date when it was proposed are indicated following the stratigraphic term. In case of revised definition of terms, the name of the original author and the date of proposal are enclosed in parentheses, and the following unenclosed name and date refer to the revised definition of the term that is currently accepted. Thus, the term "Des Moines" was first applied to certain Pennsylvanian strata in the northern Mid-Continent region by Keyes in 1893, but the stratigraphic application of this term was modified by Moore in 1932.

The oldest valid use of a stratigraphic term—that is, the oldest use that coincides with present definition—is designated in the synonymies by an asterisk (*). Stratigraphic terms that are abandoned or not recognized are indicated by a dagger (†).

The discussion of each stratigraphic unit is generally limited to a brief statement of definition and a short description of chief lithologic and other characters. The object of the report is to consider classification and nomenclature of the rocks rather than to portray their stratigraphic development in any detail.

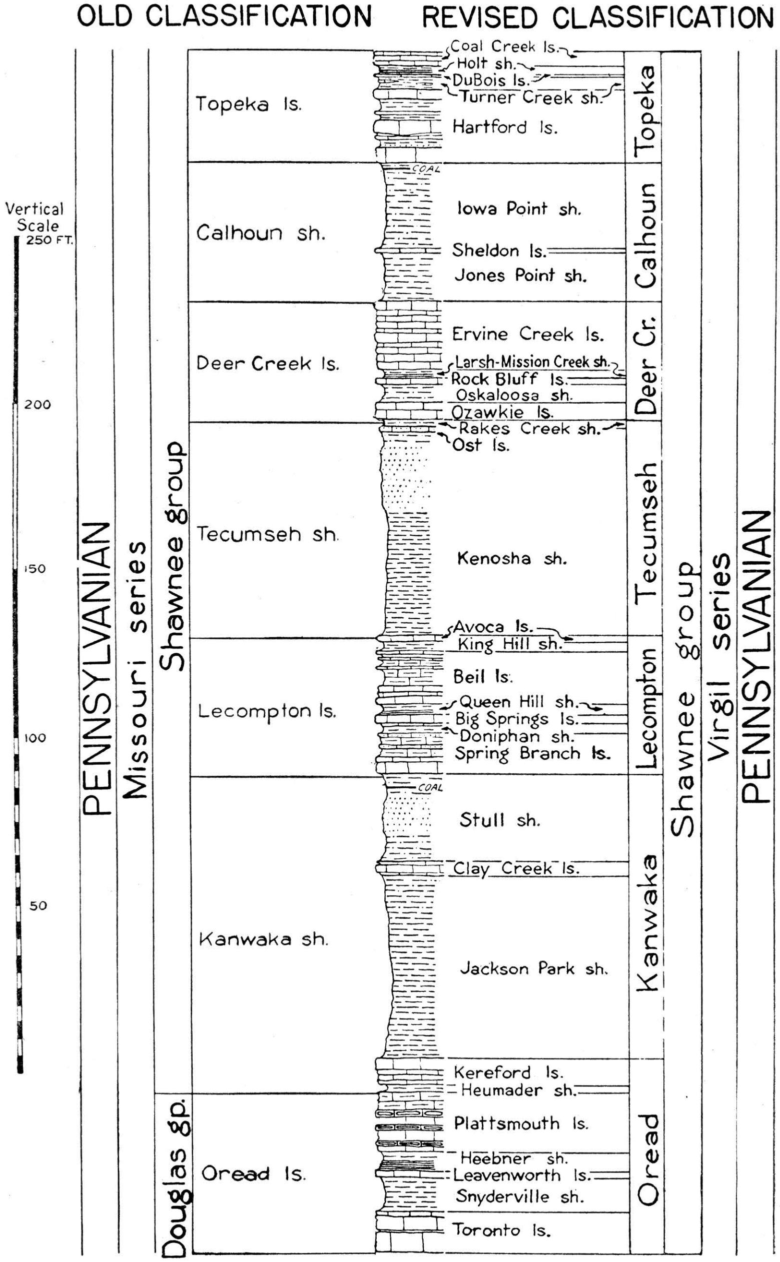

FIG. 10.—Diagram showing comparison of old and revised classification of middle Virgil beds.

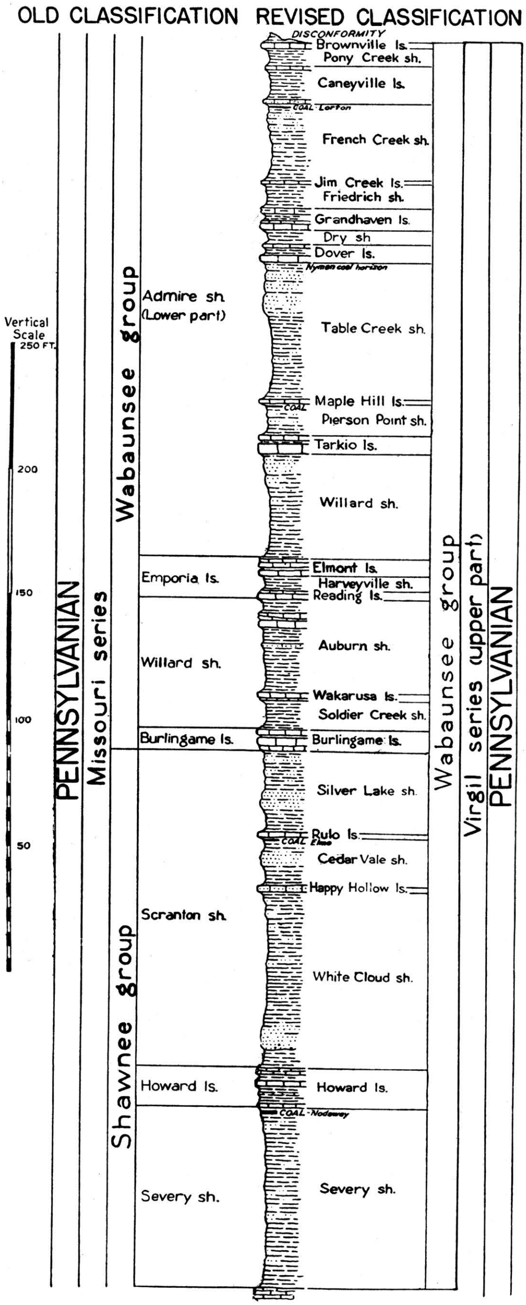

Fig. 11.—Diagram showing comparison of old and revised classification of upper Virgil beds.

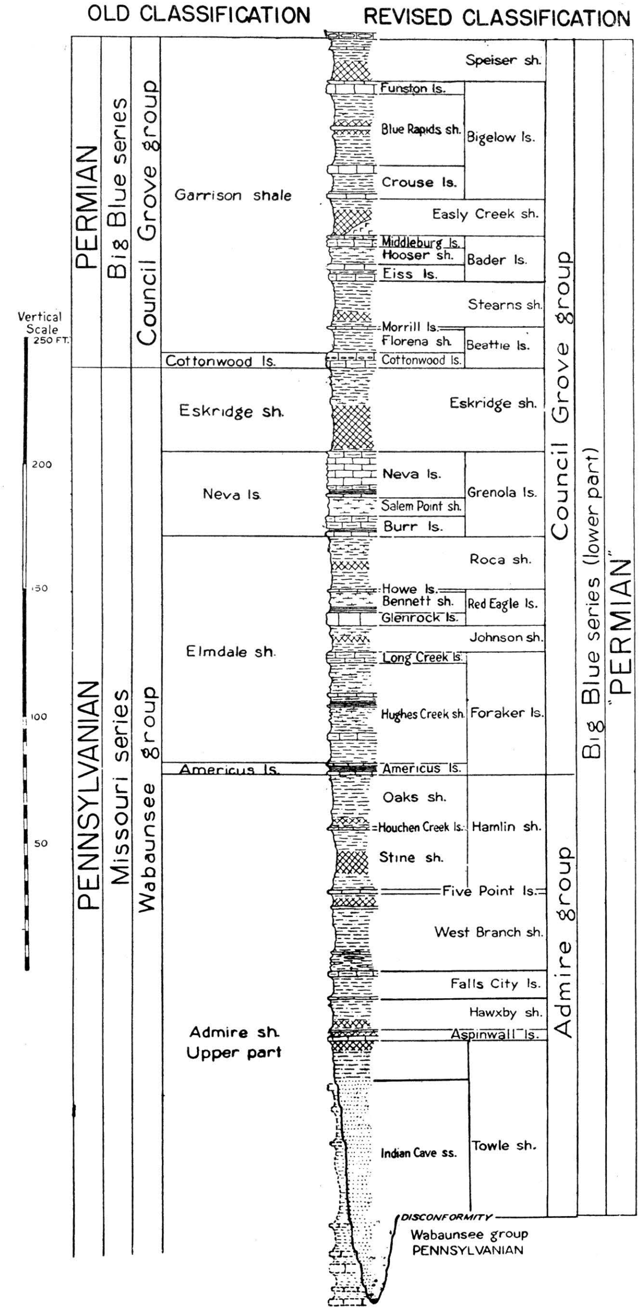

FIG. 12.—Diagram showing comparison of old and revised classification of beds now referred to the lower part of the Big Blue series of "Permian" age. This shows especially the revision of the boundary between the Pennsylvanian and "Permian" rocks.

DES MOINES SERIES

DES MOINES SERIES (Keyes, 1893), Moore, 1932

1893, *Des Moines formation*, KEYES, C. R., Iowa Geol. Survey, vol. 1, p. 100. "Represents the lower Coal Measures." The original use of this term is not accompanied by precise stratigraphic definition.

1896, *Des Moines series*, KEYES, C. R., Iowa Acad. Sci., Proc., vol. 4, p. 22. Indicates that the term Des Moines applies to beds between the top of the Mississippian and the base of the †Bethany [Bronson] limestone. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 18. Includes beds from base of Cherokee shale to base of Hertha limestone.

1915, *Des Moines group*, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 16, 36. Includes beds from the base of the Cherokee to the base of the Hertha limestone. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 89. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 20. Same.

1932, **Des Moines series*, MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 89. Restricts definition to include beds from the base of the Cherokee shale to the widespread unconformity reported as occurring in or at the base of the Pleasanton shale as previously generally defined. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, p. 20. Same.

Type locality, along Des Moines river, in central Iowa.

The Des Moines series in Kansas, Missouri, Iowa and Nebraska includes the lower part of the Pennsylvanian system, from the unconformity at its base to an unconformity that occurs at the base or within what has generally been called the Pleasanton shale.

The lower boundary of the Des Moines series is sharply defined. North of the Kansas-Oklahoma line strata of Morrow age, which represent a part of Pennsylvanian time that is older than Des Moines, are absent. Except locally, beds of Late Mississippian (Chester) age are lacking also, and therefore the basal Des Moines rests on Middle Mississippian limestones or it overlaps the Mississippian and is found on older Paleozoic rocks of the Ozark uplift. There are many places in Missouri where the Des Moines beds lie on various formations of Ordovician age. Subsurface studies in Kansas reveal the importance of the break at the base of the Des Moines series, for the rocks below the Cherokee are in places folded and faulted and they were beveled by erosion before deposition of the Des Moines beds. Along parts of the axis of the Nemaha uplift and elsewhere, the Des Moines series unconformably overlies pre-Cambrian granite. It is also found resting unconformably on Cambrian, Ordovician, Silurian, Devonian and Mississippian rocks. Locally there are thick deposits of conglomerate at the base of the Des Moines series, and there is overlap of younger Des Moines beds on pre-Pennsylvanian rocks.

Previous definitions have placed the upper boundary of the Des Moines beds at the base of the widespread, topographically prominent Bronson limestones (termed †Bethany by Keyes). This nearly coincides with the line of division between Des Moines and Missouri that is drawn here, but it is clear that the Bronson rests conformably on the next underlying strata and that the change in type of sediments from dominant shale and sandstone in the †Pleasanton to dominant limestone in the Bronson group is not a satisfactory basis for designation of a series boundary. The important change in faunas which distinguishes the Missouri from the Des Moines beds is one of the most strongly defined of any in the Late Paleozoic succession, but it does not coincide with the boundary at the base of the Bronson strata. Although the upper part of the †Pleasanton—that is, the beds between the unconformity at the base of the Warrensburg or equivalent sandstones and the base of the Bronson, which in this paper are termed the Bourbon formation—is not very fossiliferous, no fossils indicative of the Des Moines series have been found in any part of it. The known faunas of the Bourbon formation contain common Missouri series species.

The grounds in geologic theory for establishment of major stratigraphic boundaries at widespread unconformities have already been discussed. It may be deemed sufficient, therefore, to call attention to the existence of such an unconformity near the top of the Des Moines series as previously defined and to revise the upper boundary of this series to coincide with the unconformity. There are many places along the outcrop where the exact location of the break cannot be ascertained, but this is due to lack of good exposures or to lithologic similarity of beds locally occurring below and above the unconformity and to lack of abundant fossils. There are many other places in Iowa, Missouri, Kansas, and Oklahoma where the position of the unconformity, and accordingly of the Des Moines-Missouri boundary, can be accurately placed.

The Des Moines series appears at the surface in a wide belt extending across south-central Iowa, north-central, western and southwestern Missouri and southeastern Kansas into eastern Oklahoma. Strata belonging to this series are recognized in innumerable deep wells located in areas west of the Des Moines outcrop, and it appears that under cover of younger formations the Des Moines extends throughout most of the plains region east of the Rockies, reaching northward to South Dakota and southward to Texas. Beds of this age, which, however, are not physically continuous with the Des Moines deposits of the northern Mid-Continent region, have wide distribution in the eastern and western parts of the continent.

The thickness of the Des Moines series in the neighborhood of the outcrop in Kansas ranges from about 400 to 600 feet. In the Forest City Basin, which includes parts of northeastern Kansas, northwestern Missouri and southeastern Nebraska, the total thickness of the Des Moines beds reaches 900 feet. Well records in central and western Kansas indicate that the Des Moines series gradually decreases in thickness westward and that in some places it disappears.

Shale and sandstone are the most important kinds of rocks in the Des Moines series, but in the upper part there are several persistent limestones and a number of coal beds are present.

Correlation.—The Des Moines series is represented in Oklahoma and Arkansas by a great thickness of shale and sandstone beds and locally by some limestone. The base of the Atoka appears to mark the lower limit of the Des Moines and the base of the Seminole conglomerate the top of the series. Evidence derived from plants and invertebrates obtained at many horizons in this part of the Pennsylvanian section clearly indicate this correlation and it is possible to trace some beds of the Des Moines in Kansas and northeastern Oklahoma to the north flank of the Arbuckle and Ouachita mountains. Sandstone and locally conglomerate occur at the base of the Des Moines and also at the base of the Missouri series, and the basal beds of both series show overlap relations to older strata. The exact position of the boundary between Morrow and Des Moines beds is not certainly determined along the north flank of the Arbuckles, but it appears to lie above the base of rocks called Atoka in parts of this region.

Fossils of Des Moines age occur in the rocks of the Ardmore basin south of the Arbuckles, beginning a short distance above the Lester limestone of Tomlinson's Dornick Hills formation. The Deese beds, several thousands of feet thick, are of Des Moines age.

The Strawn group of north-central Texas, excepting possibly a small part of the topmost beds as now classified, may be correlated with the Des Moines series. These beds are lithologically and faunally similar to the Des Moines strata in Oklahoma and Arkansas. In west Texas the Des Moines is regarded as equivalent to an upper part of the Haymond formation and the lower part of the Gaptank beds.

Subdivisions of the Cherokee shale and of the Marmaton group have been traced eastward across northern Missouri and have been identified in the Pennsylvanian outlier at St. Louis. All of the rocks of the latter, excepting possibly a few feet of sandstone at the top, belong to the Des Moines series. From here it is a very short distance to the west edge of the Illinois Pennsylvanian area. Detailed studies by Knight, Weller and Wanless furnish the basis for correlation of numerous stratigraphic units in the Missouri and Illinois Des Moines section. In the latter state the Des Moines includes beds from near the base of the Carbondale to a short distance above the base of the McLeansboro formation, as classified in earlier studies. The recent work of Weller and Wanless has led to definition of numerous "cyclical formations" or cyclothems in the Illinois Pennsylvanian. The top of the Des Moines is tentatively drawn at the base of the Trivoli cyclothem.

According to evidence of fossil plants, the Des Moines series may be identified in the Appalachian region as correlative to the upper Pottsville (probably all of the Kanawha group), all of the Allegheny and the lowermost part of the Conemaugh beds, but the precise lower and upper limits are not definitely determined.

Beds of Des Moines age are widespread in the western United States. The lower part of the Minnelusa formation in the Black Hills, the McCoy formation, most of the Weber and lower Hermosa beds of Colorado, the Magdalena limestone of New Mexico and others are included here.

Subdivisions.—The Des Moines series is divided in Kansas into the Cherokee shale below, and the Marmaton group above. The boundary between these has long been placed at the base of the Fort Scott limestone, but there is much to recommend a revision of classification so as to restrict application of Cherokee to beds below the Ardmore limestone and to expand the Marmaton (or introduce a new term) to include the beds between the base of the Ardmore and the top of the series. This suggested change is not now made because studies of the Des Moines beds in Kansas are not yet sufficiently detailed. F. C. Greene, who has done very extensive work on the Des Moines and other Pennsylvanian rocks of Missouri, believes that the classification of the Des Moines beds should be revised approximately as indicated here.

CHEROKEE SHALE, Haworth and Kirk, 1894

1894, **Cherokee shale,* HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 105. Name applied to beds, reported to be about 500 feet thick, lying between the Mississippian †Galena [Boone] limestone and the †Oswego [Fort Scott] limestones. —— 1895, HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 455. Same. —— 1896, ADAMS, G. I., Kan. Univ. Geol. Survey, vol. 1, p. 18. Same. —— 1896, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 1, pp. 37, 150. Same. —— 1896, KIRK, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 72. Same. —— 1897, KEYES, C. R., Iowa Acad. Sci., Proc., vol. 4, p. 22. Same. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 27. Same. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 16. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, pp. 74, 77. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 16, 38. Same. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 90. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 20. Same. —— 1933, GREENE, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 15. Same. Notes horizons of chief coals, limestone (Ardmore, Rich Hill or Verdigris) and sandstones ("Squirrel," "Clear Creek" or Bartlesville, Burgess). —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 11. Same. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, pp. 21-25. Same.

Type locality, named from Cherokee county, Kansas.

As currently defined, the Cherokee shale includes the strata from the base of the Pennsylvanian, north of the Kansas-Oklahoma line, upward to the base of the Fort Scott limestone. It is possible that ultimately the Cherokee will be defined as a group, for there are within it a number of persistent stratigraphic units and there appear to be cyclic successions of sandstone, shale, coal and in some cases thin limestone beds that correspond to the cyclic formations, or cyclothems, as defined in Illinois.

Shale is the strongly predominant kind of rock in this formation, and accordingly the outcrop area is a lowland plain in which there are few exposures. Gray or bluish-gray clayey and silty micaceous shale is most common, but there is also much sandy shale. Very dark or black carbonaceous shale occurs at several horizons. Fossils are rare or lacking in parts of the Cherokee shale deposits. Some beds, however, especially certain calcareous horizons, contain numerous marine invertebrates. Other beds, which in most cases are associated with a coal bed, yield remains of land plants. Sandstone occurs in different parts of the Cherokee, but most of the beds appear to lack persistence. Some of the sandstones are highly lenticular bodies. In this group the so-called "shoestring sands" belong. They are elongate channel-fillings or in some cases probably sand bar deposits. Many of them are important reservoirs of oil and gas. Some of the sandstones are thick and massive, others thin and platy or shaly. They are all quartzose and most of them contain fairly abundant mica. In parts of Missouri there is a prominent basal sandstone and conglomerate at the bottom of the Cherokee shale. Limestone beds are not prominent, but there are a number of thin, rather dense, generally rather dark-blue beds. Some of these are local in distribution, whereas others are persistent for scores of miles. The most important limestone occurs in the upper middle part of the Cherokee. The name *Ardmore limestone** appears to have priority, as applied to this bed, but the Oklahoma term Verdigris limestone has been more used. The Cherokee is the chief coal-bearing formation in the Pennsylvanian of the northern Mid-Continent region. There are several beds which in different places are of workable thickness.

The Cherokee shale attains maximum thickness, insofar as the area north of Oklahoma is concerned, in the Forest City Basin of northwestern Missouri and northeastern Kansas. The core of a well at Forest City, Mo., shows 712 feet of Cherokee. The overlap of the formation on the Ozarks gives rise to much smaller thicknesses of Cherokee in various counties of Missouri where the lower Cherokee beds are lacking. The average thickness in southeastern Kansas is about 400 feet.

The outcrop of the Cherokee extends in a broad belt from south-central Iowa across Missouri and southeastern Kansas into Oklahoma. In Oklahoma and Arkansas equivalents of the Cherokee occur at the surface over a very large territory.

A number of subdivisions of the Cherokee shale have been named. Because the stratigraphy of this part of the Pennsylvanian is as yet insufficiently studied, no description or discussion of these smaller units will be undertaken in this paper.

* Gordon, C. H., Mo. Geol. Survey, vol. 9, p. 20, 1893.

MARMATON GROUP (Haworth, 1898), Moore, 1932

1897, Not *Marmaton formation,* KEYES, C. R., Iowa Acad. Sci., Proc., vol. 4, p. 24. Name applied to shale between the Fort Scott and Pawnee limestones. Although Marmaton as here used has priority over Labette shale, introduced by Haworth in 1898, the latter term has come to be recognized for the shale next above the Fort Scott limestone. Keyes' use of Marmaton also is older than that proposed by Haworth, but Haworth's definition has become established by usage.

1898, *Marmaton formation,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 92. Includes beds from base of †Oswego [Fort Scott] limestone to top of †Pleasanton shale, which is equivalent to the top of the Bourbon formation of present classification. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 74. Same as preceding, but term it "Marmaton stage." —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 91. Same as Haworth, 1898. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 23. Same.

1932, **Marmaton group,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 89. Restricts application of term to beds below the unconformity that separates the Des Moines and Missouri series as redefined in this paper. Includes Henrietta formation and part of Pleasanton formation as classified in Missouri. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, p. 20. Same.

Type locality, along Marmaton river in Bourbon county, Kansas.

The Marmaton group, as previously defined in reports of the Kansas Geological Survey, included the beds from the base of the Fort Scott limestone to the base of the Hertha limestone. The upper boundary has been revised by me to coincide with the upper limit of the Des Moines series, which is at the unconformity below the Warrensburg channel sandstone or within the †Pleasanton shale of earlier terminology. The group consists chiefly of alternating layers of shale and limestone. There are some persistent thin coal beds and some sandstone. Definite indications of cyclic sequence of beds are observed in the Marmaton group, but this part of the section has been insufficiently studied as yet to determine satisfactorily the number and character of cyclothems.

The Marmaton group includes strata that in Missouri have been called the Henrietta formation and lower Pleasanton shale. Recent work by F. C. Greene[10] shows the widespread occurrence in Missouri of two limestones (called *Worland limestone*) in the lower part of the so-called Pleasanton, and at present there seems to be little good

10. Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 18, 1933.

reason to continue use of the term Henrietta. Greene is in accord with restriction of Des Moines and of Marmaton to beds below the unconformity that has been mentioned.

The thickness of the Marmaton group in Kansas ranges from a little over 100 feet to about 200 feet. The outcrop of these beds extends across southeastern Kansas from Linn county to Labette and Montgomery counties.

Subdivisions of the Marmaton group, named in upward order, are Fort Scott limestone, Labette shale, Pawnee limestone, Bandera shale, Altamont limestone, Nowata shale, Lenapah limestone, and Memorial shale. The upper units have not been traced definitely northward from exposures in southern Kansas. The limestone beds in western Missouri that Greene has called lower and upper Worland may prove to be equivalent to already named beds in Kansas, including the Altamont, but this is not certain. Greene believes that the Worland is definitely below the horizon of the Altamont limestone, and reconnaissance study by N. D. Newell indicates that the so-called Worland limestone belongs to the Pawnee limestone.

FORT SCOTT LIMESTONE (Swallow, 1866), Bennett, 1896

1866, *Fort Scott limestone,* SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 25. Applies name to an irregularly bedded limestone, equivalent to the upper Fort Scott of later writers, exposed at Fort Scott, Kan.

1866, Not *Fort Scott coal series,* SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 25. Includes about 100 feet of beds with the Fort Scott limestone at the top.

1866, Not *Fort Scott marble,* SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 25. Name applied to a thin dark veined limestone in what is now called Cherokee shale.

1866, Not *Fort Scott marble series,* SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 25. A group of beds that includes the "Fort Scott marble."

1874, *Fort Scott group,* BROADHEAD, G. C., Mo. Geol. Survey, Rept. 1873-1874, pp. 101, 126, 158.

1894, †*Oswego limestone,* HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, pp. 105, 107, 116. Apply this name to two limestone beds separated by black shale. Equivalent to the Fort Scott limestone of later general usage. The name Oswego is preoccupied by a Silurian formation in New York. —— 1895, HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 456. Same. —— 1896, ADAMS, G. I., HAWORTH, E., KIRK, M. Z., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, pp. 21, 40, 73, 88. Same. —— 1898, HAWORTH, E., Kan. Univ. Geol.

Survey, vol. 3, p. 30. Same. Designates the lower limestone bed as the "Fort Scott cement rock" (p. 31).

1896, Not *Fort Scott limestone,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 1, p. 42. Suggests that the name Fort Scott is suitable as an alternative designation for Oswego limestone, but "one should be careful not to include the upper limestone, a heavy system which is well developed around Fort Scott." It is difficult to understand this, because it was the upper limestone that was specifically designated by Swallow as the Fort Scott limestone. Haworth's usage, as here reported, would restrict the name to the lower limestone or "cement rock."

1896, **Fort Scott limestone,* BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, p. 91. Includes the "cement rock" and overlying limestone [Swallow's Fort Scott limestone] as the "Oswego, or Fort Scott limestone." —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 29. Notes that the term Oswego is preoccupied and applies Fort Scott to the two limestones and included black shale at Fort Scott. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 16. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 81. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines (2), vol. 13, p. 20. Same. Classes as member of the Henrietta formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 92. Same as Haworth and Bennett. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 25. Same as Haworth and Bennett. —— 1933, GREENE, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 16. Same. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, pp. 20, 21. Same.

1897, †*Henrietta formation* (part), KEYES, C. R., Iowa Acad. Sci., Proc., vol. 4, p. 22. Includes Fort Scott limestone, Marmaton [Labette] shale, and Pawnee limestone. —— 1900, KEYES, C. R., Iowa Acad. Sci., Proc., vol. 7, p. 84. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 19, 61. Same. —— 1933, GREENE, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 16. Same. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 13. Same.

Type locality, Fort Scott, Kan.

The name Fort Scott has been used in such varied ways by Swallow, who introduced it as a stratigraphic term, and by later writers, that there is reason to question its value. There is no confusion, however, in tracing the various usages or in understanding just what beds different writers have designated as Fort Scott limestone. For a long time the geological surveys of Kansas and Missouri have accepted the definition of the Fort Scott at its type locality as including a lower massive somewhat siliceous and magnesian limestone member, the "cement rock" at Fort Scott, black fissile shale and locally coal above this bed, and a thick, irregularly bedded limestone (Swallow's original Fort Scott limestone) that overlies the black shale. The lower limestone is about 6 feet thick, the shale 6 feet, and the upper limestone 18 feet, making a total of 30 feet. These members are fairly persistent southward along the outcrop but there appears to be an additional bed or beds below the lower limestone. Study of sections in western Missouri by F. C. Greene shows that a number of changes in the character and sequence of beds belonging at this horizon may be recognized. These bear importantly on recognition of cyclothem phases and on proper understanding of the different sections. It is possible that revision of stratigraphic definitions will be required.

The Fort Scott limestone is traceable across Missouri to Iowa, although the character and thickness of various subdivisions changes a good deal, and it is recognized in the Pennsylvanian outlier at St. Louis, Mo. Southwestward the Fort Scott can be followed without difficulty to the valley of the Arkansas river southeast of Tulsa, Okla., but it has not been identified definitely south of this river. The horizon belongs in the Wetumka shale of southern Oklahoma.

LABETTE SHALE, Haworth, 1898

1866, *Pawnee limestone series* (part), SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 24. Includes beds from top of Fort Scott limestone to top of Pawnee limestone.

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 108. The name Laneville was applied to beds between the †Oswego [Fort Scott] limestone and †Erie [Bronson] limestone.

1896, †*Pleasanton shale* (part), ADAMS, G. I., Kan. Univ. Geol. Survey, vol. 1, p. 22. Applies this name to beds between the †Oswego [Fort Scott] and Altamont limestones.

1897, †*Henrietta formation* (part), KEYES, C. R. (See under Fort Scott limestone.)

1897, *Marmaton formation,* KEYES, C. R., Iowa Acad. Sci., Proc., vol. 4, p. 24. Name proposed for beds between Fort Scott and Pawnee limestones. It has priority over Labette, but usage has established the latter term, and Marmaton is used in a different sense as subsequently proposed by Haworth.

1898, **Labette shale,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 36. Includes strata between the †Oswego [Fort Scott] and Pawnee limestones. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 31. Same. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 17. Same. ——1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 82. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 21. Same. Classed as member of the Henrietta formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 92. Same. Classed as a member of the Marmaton formation. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 26. Same as Moore and Haynes. —— 1933, GREENE, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 16. Same. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, pp. 20, 21. Same.

Type locality, village of Labette, Labette county, Kansas.

The Labette shale includes the beds between the Fort Scott and Pawnee limestones. The formation consists mainly of clayey and sandy shale. In the middle upper part there is a rather persistent zone of platy to shaly sandstone. Near the base is the Lexington coal which recent work in Missouri shows is equivalent to the Mystic coal of Iowa. This coal is overlain by a thin limestone, the so-called Lexington cap-rock, in Missouri and Iowa, but the bed is not definitely recognized in Kansas. Another coal bed occurs in the upper part of the Labette shale in parts of southeastern Kansas. The thickness of the Labette shale ranges from about 20 feet to 60 feet in Kansas, and it thickens southward in Oklahoma.

LABETTE SHALE,
ENGLEVALE SANDSTONE MEMBER, Pierce and Courtier, 1935

1935, **Englevale channel sandstone,* PIERCE, W. G., AND COURTIER, W. H., Am. Assoc. Petroleum Geologists, Bull., vol. 19, pp. 1061-1064. Designates channel sandstone in lower part of the Labette shale.

Type locality, vicinity of Englevale, sec. 24, T. 28 S., R. 24 E., Crawford county, Kansas.

A channel sandstone, with maximum observed thickness of about 50 feet, occurs in the lower Labette shale in northeastern Crawford county, Kansas. The sandstone body has an average width of 0.4 mile and has been traced for a distance of 9 miles in a direction trending north-northwest from the town of Arma. The sandstone rests disconformably on Fort Scott limestone or Cherokee shale, filling an erosion channel that was cut partly or entirely through the Fort Scott limestone. The sandstone appears to grade upward into shale of the lower part of the Labette shale.

PAWNEE LIMESTONE, Swallow, 1866

1866, *Pawnee limestone series* (part), SWALLOW, G. C. (See under Labette shale.)

1866, **Pawnee limestone,* SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 24. Name applied to "heavy-bedded, porous and compact, coarse and fine, drab, brown and bluish gray, cherty, concretionary and mottled [limestone], 20 to 25 feet thick" occurring next above the Fort Scott limestone. —— 1895, HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 457. Same. —— 1896, HAWORTH, E., KIRK, M. Z., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, pp. 43, 74, 92, 153. Same. —— 1898, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, pp. 37, 85, 92, 94. Same. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 32. Same. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 17. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 83. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 21. Same. Class as member of the Henrietta formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 93. Same. Class as member of the Marmaton formation. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 26. Same as Moore and Haynes. —— 1933, GREENE, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 17. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, pp. 20, 21. Same as Moore.

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z. (See under Labette shale.)

1896, †*Pleasanton shale* (part), ADAMS, G. I. (See under Labette shale.)

1897, †*Henrietta formation* (part), KEYES, C. R. (See under Fort Scott limestone.)

1897, Not †*Pawnee limestone,* DRAKE, N. F., Am. Philos. Soc., Proc., vol. 36, p. 386. Refers to limestone at Pawnee, Okla., that probably corresponds to Foraker of present classification. The name Pawnee is not applicable to this higher limestone because of Swallow's prior usage.

Type locality, on Pawnee Creek near village of Pawnee, southwest of Fort Scott, Kan.

The Pawnee limestone lies between the Labette and Bandera shales. The main part of the formation consists of massive, light-gray, rather fine-grained limestone that in places attains a thickness of nearly 50 feet. In some places there is a thin bed of blue dense limestone with vertical joints at the base of the Pawnee, separated from the upper limestone beds by two feet or more of black slaty shale. This blue bed has the characteristics of the "middle" limestone member of various higher Pennsylvanian formations in Kansas, and like them is overlain by black shale. The Pawnee limestone is somewhat less fossiliferous than the Fort Scott limestone, in general. The formation extends across much of north-central Missouri and is present in the St. Louis area. It persists southward for some distance into Oklahoma but is not differentiated south of the latitude of Tulsa.

BANDERA SHALE, Adams, 1903

1866, †*Marais des Cygnes coal series* (part), SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 22. Includes beds between top of Pawnee limestone and base of †"Well rock series" [Bronson?].

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z. (See under Labette shale.)

1895, †*Pleasanton shale* (part), HAWORTH, E., Kan. Univ. Quart., vol. 3, p. 274. Includes beds between top of the Pawnee limestone and base of the †Erie [Bronson] limestone. —— 1895, HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 457. Same. —— 1896, ADAMS, G. I. (See under Labette shale.) —— 1896, HAWORTH, E., KIRK, M. Z., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, pp. 44, 74, 93, 153. Same as Haworth, 1895. ——1898, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 39. Same. Designates the beds between the Pawnee and Altamont limestones as "Lower Pleasanton shale." —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 21, 75. Same as Haworth, 1895. —— 1933, GREENE, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 17. Same. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 14. Same.

1900, †*Marais des Cygnes shale* (part), KEYES, C. R., Iowa Acad. Sci., Proc., vol. 7, p. 84. Includes beds between top of Pawnee limestone and base of †Bethany [Bronson] limestone. —— 1928, KEYES, C. R., Pan-Am. Geologist, vol. 50, p. 67.

1903, **Bandera shale*, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 32. Name applied to strata between the Pawnee and Altamont limestones. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 17. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 84. Same. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 93. Same. Class as member of the Marmaton formation. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 26. Same. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, pp. 20, 21. Same.

Type locality, Bandera, Bourbon county, Kansas.

The Bandera shale includes clayey and sandy strata lying between the Pawnee limestone and Altamont limestone. Most of the shale is dark-colored. Shaly sandstone, sandstone flags and massive sandstone occur in places in the Bandera shale. One or more beds of coal also belong in this formation.

The thickness of the Bandera shale is reported to be 60 to 120 feet in Kansas, but thinner in Oklahoma. The outcrop belt of the shale can be followed across Kansas from Missouri to Oklahoma, but its extent as a distinct unit is not definitely determined. F. C. Greene * recognizes in western Missouri two fairly prominent and persistent limestone beds that he terms the lower and upper *Worland limestones,* and places them in the Bandera shale.

ALTAMONT LIMESTONE, Adams, 1896

1866, †*Marais des Cygnes coal series* (part), SWALLOW, G. C. (See under Bandera shale.)

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z. (See under Labette shale.)

1895, †*Pleasanton shale* (part), HAWORTH, E. (See under Bandera shale.)

1896, **Altamont limestone,* ADAMS, G. I., Kan. Univ. Geol. Survey, vol. 1, p. 22. Name applied to limestone "at summit of the ridge at Altamont," Labette county, Kansas. —— 1898, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, pp. 39, 92, 94, 100. Same. Classed as a subdivision of the †Pleasanton shale and recognized as the first persistent limestone above the Pawnee. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 85. Same. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 93. Same. Class as member of the Marmaton formation. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 27. Same. —— (1935) 1936, OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, pp. 20, 21. Same.

1900, †*Marais des Cygnes shale* (part), KEYES, C. R. (See under Bandera shale.)

1903, †*Parsons limestone* (part), ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 33. Notes that the Altamont limestone occurs next above the Bandera shale. The †Parsons formation includes the Altamont, overlying shale and a higher limestone [Lenapah]. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 17. Same. —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 16. Same. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, Independence quadrangle, p. 1. Same.

Type locality, Altamont, Labette county, Kansas.

The Altamont limestone occurs between the Bandera and Nowata shales. It has been classed with the next higher limestone and shale under the name †Parsons limestone, but the thickness of the Nowata

* Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 18, 1933.

shale in most places and the clear evidence that the Altamont and Lenapah limestones represent different cyclothems are reasons for regarding them as independent units.

The Altamont is a massive, light-colored limestone, about 4 to 10 feet thick, that in parts of southeastern Kansas makes an easily traceable escarpment. Fossils are mostly rather uncommon.

Because of southward thinning of the Bandera shale, the Altamont limestone occurs only a little above the Pawnee limestone in part of northern Oklahoma, and northeast of Tulsa these two limestones are combined under the name Oologah limestone.

NOWATA SHALE, Ohern, 1910

1866, †*Marais des Cygnes coal series* (part), SWALLOW, G. C. (See under Bandera shale.)

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z. (See under Labette shale.)

1895, †*Pleasanton shale* (part), HAWORTH, E. (See under Bandera shale.)

1900, †*Marais des Cygnes shale* (part), KEYES, C. R. (See under Bandera shale.)

1903, †*Parsons limestone* (part), ADAMS, G. I. (See under Altamont limestone.)

1908, †*Walnut shale*, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 86. Includes beds between Altamont and Coffeyville [Lenapah] limestones. The name Walnut is preoccupied by a Cretaceous formation in Texas and therefore is not available for this shale in Kansas. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 93. Same.

1910, **Nowata shale*, OHERN, D. W., Okla. Univ., Bull. 4, p. 23. Name applied to beds between the Altamont and Lenapah limestones. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 27. Same. Classed as member of the Marmaton formation.

Type locality, Nowata, Nowata county, Oklahoma.

The Nowata shale comprises 30 to 50 feet or more of bluish-gray or yellowish clayey and sandy shale that occurs between the Altamont and Lenapah limestones. This shale unit is clearly differentiated in southeastern Kansas east of Coffeyville and in northeastern Oklahoma, but because the Lenapah disappears a few miles northeast of Tulsa and is not now known far north of the Kansas-Oklahoma line, the stratigraphic definition and relations of the Nowata to the south and north of the area where the Lenapah occurs are in doubt. There are few fossils in most outcrops of the Nowata shale.

LENAPAH LIMESTONE, Ohern, 1910

1866, †*Marais des Cygnes coal series* (part), SWALLOW, G. C. (See under Bandera shale.)

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z. (See under Labette shale.)

1895, †*Pleasanton shale* (part), HAWORTH, E. (See under Bandera shale.)

1900, †*Marais des Cygnes shale* (part), KEYES, C. R. (See under Bandera shale.)

1903, †*Parsons limestone* (part), ADAMS, G. I. (See under Altamont limestone.)

1908, †*Coffeyville limestone,* HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 87. Name applied to thin but persistent limestone that is prominently exposed along banks of the Verdigris river at Coffeyville, Kan. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 94. Same.

1910, **Lenapah limestone,* OHERN, D. W., Okla. Univ., Bull. 4, p. 23. Refers to limestone typically exposed at Lenapah, Okla., next above the Nowata shale. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 27. Same. Classed as member of the Marmaton formation.

Type locality, Lenapah, Nowata county, Oklahoma.

The Lenapah limestone conformably overlies the Nowata shale and in a number of exposures appears to be overlain conformably by shale. The limestone is about 20 feet thick at the type locality in northeastern Oklahoma but thins to 7 feet or less near Coffeyville, Kan., and becomes discontinuous southward or grades into thin limestone and shale beds. As typically developed, the limestone is light bluish-gray, fairly pure, hard and massive. The main body of the formation near Lenapah is very fine-grained and can be identified as corresponding to the "upper" limestone (the main part of Cyclothem C of the Shawnee type of megacyclothem) of other Pennsylvanian limestone formations. This part of the Lenapah becomes nodular and shaly in southern Kansas. The top part of the formation is a fairly persistent, single massive ledge 2 to 7 feet thick that appears strongly mottled or brecciated and contains rather common algal remains. Fossils of Des Moines type, including *Mesolobus* and *Prismopora,* have been collected from the Lenapah.

MEMORIAL SHALE, Dott, 1936

1866, †*Marais des Cygnes coal series* (part), SWALLOW, G. C. (See under Bandera shale.)

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z. (See under Labette shale.)

1895, †*Pleasanton shale* (part), HAWORTH, E. (See under Bandera shale. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 88. Include beds between top of †Coffeyville [Lenapah] limestone and base of "Bethany Falls" [Hertha] limestone. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 94. Same as Haworth and Bennett.

1900, †*Marais des Cygnes shale* (part), KEYES, C. R. (See under Bandera shale.)

1903, †*Dudley shale* (part), ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 34. Name applied to beds between the top of the †Parsons [Altamont-Lenapah] and Hertha limestones. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 17. Same. —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Describe the "Ladore-Dudley shale" as the lowest member of the Coffeyville formation, the Hertha limestone being absent. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, Independence quadrangle, p. 2. Same.

1906, *Coffeyville formation* (part), SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Include beds between top of †Parsons [Altamont-Lenapah] limestone and base of Drum [miscorrelated with Winterset at Coffeyville] limestone. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 2. Same.

1920, †*La Cygne shale*, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 28. Includes beds between Lenapah and Hertha limestones. Classed as a member of the Marmaton formation.

1936, *Memorial shale*, DOTT, R. S., Mss. Name applied to beds between top of "Eleventh Street" limestone [Lenapah] and unconformity at top of Des Moines series.

An undetermined thickness of shale that overlies the Lenapah limestone appears to belong to the top part of the Des Moines series, and it should be differentiated from basal beds of the Missouri series even though in mapping some areas it is impracticable to trace the series boundary. The term Dudley shale, as proposed, presumably includes upper Des Moines beds and also lower Missouri shale and sandstone equivalent to the Bourbon formation. The Coffeyville formation is still more inclusive. Shale between the Lenapah limestone, below, and the unconformity at the top of the Des Moines series has recently been named the Memorial shale.

MISSOURI SERIES

MISSOURI SERIES (Keyes, 1893), Moore, 1932

1893, *Missouri terrane,* KEYES, C. R., Ia. Geol. Survey, vol. 1, pp. 85, 114-116. Proposed name without definite indication of stratigraphic boundaries, to replace the nongeographic term "Upper Coal Measures," and to include the beds typically developed in northwestern Missouri.

1894, *Missouri formation,* KEYES, C. R., Ia. Geol. Survey, vol. 2, pp. 137-139, 155-159.

1894, *Missouri stage,* KEYES, C. R., Mo. Geol. Survey, vol. 4, pp. 30, 82. Same as "Missouri terrane." —— 1895, LONSDALE, E. H., Ia. Geol. Survey, vol. 4, pp. 391-411.

1896, *Missourian series,* WHEELER, H. A., Mo. Geol. Survey, vol. 11, p. 46. —— 1897, PROSSER, C. S., Jour. Geol., vol. 5, p. 3. Proposes to include unnamed beds from the base of the series to the base of the Wabaunsee, the Wabaunsee formation and the Cottonwood formation. The upper boundary of the series is thus placed at the base of the Florena shale of present classification. —— 1899, KEYES, C. R., Am. Geologist, vol. 23, pp. 302-303. Defines the series as including strata from the base of the †Bethany limestone [corresponds to base of Hertha limestone] to top of Cottonwood limestone. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, pp. 83, 86. Definition same as in Keyes, 1899. —— 1902, PROSSER, C. S., Jour. Geol., vol. 10, p. 704. Places upper boundary of series at base of Wreford limestone.

1897, *Missourian formation,* BAIN, H. F., Ia. Geol. Survey, vol. 7, pp. 446-451. —— 1897, TILTON, J. L., AND BAIN, H. F., Ia. Geol. Survey, vol. 7, pp. 509-520. —— 1898, LEONARD, A. G., Ia. Geol. Survey, vol. 8, pp. 82-83. —— 1898, MARBUT, C. F., Mo. Geol. Survey, vol. 12, pt. 2, pp. 31, 210, 268.

1901, *Missourian stage,* CALVIN, S., Ia. Geol. Survey, vol. 11, pp. 400-460. —— 1901, UDDEN, J. A., Ia. Geol. Survey, vol. 11, pp. 202-277. —— 1903, UDDEN, J. A., Ia. Geol. Survey, vol. 13, pp. 123-183.

1902, *Missourian division,* BAIN, H. F., U. S. Geol. Survey, 22d Ann. Rept., pt. 3, pp. 333-366.

1915, *Missouri group,* HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 22-35. Define base at bottom of Hertha limestone. Include Wabaunsee formation at top but upper limit of the group is not definitely stated. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, pp. 94-107. Include beds from base of Hertha limestone to top of Eskridge shale. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 29. Same.

1927, *Missouri series,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 24. Includes beds from base of Hertha limestone to top of Eskridge shale.

1932, **Missouri series*, MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 90. Defines lower boundary at disconformity that occurs between Altamont or Lenapah limestone below and Hertha limestone above, and places upper boundary at disconformity that occurs immediately above the Stanton limestone, Weston shale, or Iatan limestone. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 19-79, 168-184. Same.

Type locality, northwestern Missouri.

The name Missouri or Missourian was introduced by Keyes as a geographic term to designate the "Upper Coal Measures" essentially as defined by Broadhead (1872) and Winslow (1891). The base of Broadhead's "Upper Coal Measures" was drawn at the bottom of sandstone in what has subsequently been called †Pleasanton shale, whereas the lower boundary of the Missouri "stage" was placed at the base of the "great limestone at Winterset" Iowa, which is the base of the later defined Kansas City formation. The top of the Missourian was set by Keyes at the base of the Cottonwood limestone, a horizon long established in an arbitrary manner as the boundary of strata classed respectively as Pennsylvanian (or Coal Measures) and Permian (see fig. 12). Using the same lower limit as employed in Keyes' Missouri stage, but extending the upper boundary to the base of the Wreford limestone, Haworth[11] preferred the designation "Upper Coal Measures," but Adams[12] concluded that neither lithologic nor paleontologic characters were sufficiently well defined to afford basis for satisfactory major subdivision of the Pennsylvanian rocks in the northern Mid-Continent area. As a matter of fact, there is ample paleontologic basis for separation of the beds at a horizon near the base of the Missouri as defined by Keyes, and there are lithologic and stratigraphic differences in the beds below and above this line. Accordingly, Hinds and Greene, Moore, Condra and others have adopted this division.

Hinds and Greene[13] note that "there are strong indications of a widespread unconformity within the Pleasanton formation, and it may be that the faunal break . . . is due to this feature. If this is so, the boundary between the two groups [Des Moines and Missouri] should be drawn at the unconformity." This boundary within the Pleasanton, as commonly defined, is apparently that which Broadhead used in dividing the "Upper Coal Measures"

11. Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, pp. 73-76, 1908.
12. Adams, G. I., U. S. Geol. Survey, Bull. 211, pp. 69-72, 1903.
13. Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 6, 1915.

from the lower beds, and it is the line of separation which I suggest shall be used in redefining the base of the Missouri beds. It is true that it is difficult to map this boundary accurately, but there is little doubt that it is really the significant line of stratigraphic partition, rather than the base of a nearby limestone bed that rests conformably on underlying shale. The widespread channel sandstones and sheet sand bodies at this horizon, the generally clastic character of the †Pleasanton beds which is in contrast to the calcareous deposits of adjacent lower and higher parts of the section, and the change in the faunas that occurs at this horizon, are all features associated with interruption of sedimentation. The beds above and below the break are mostly parallel and physical evidence of the existence of an unconformity is generally not striking, but the interruption of sedimentation in a stable platform area of the earth crust, such as includes the northern Mid-Continent region, is probably equivalent in time to crustal deformation in certain geosynclinal regions, although no such disturbance is known in North American geosynclines. It should not be inferred that evidence of the unconformity at the base of the Missouri series is in any degree a matter of doubt, even though in some sections where basal sandstone or conglomerate is lacking the precise position of the boundary may not be determinable. On the contrary, the break can be recognized on the basis of physical features and stratigraphic relations at very many places from Oklahoma to Iowa, and wherever fossils are found above and below the boundary they are accordant with the division that is made on the basis of the unconformity. An interesting account of the disconformity and associated channel sandstone deposits at the base of the Missouri series in the vicinity of Kansas City has recently been published by Bartle.[13a]

The upper boundary of the Missouri beds is here redefined to coincide with the widespread unconformity that has been recognized recently between the Stanton limestone, Weston shale or Iatan limestone, below, and clastic Douglas deposits of the Stranger formation (new) or possibly in places of the Lawrence shale. This break marks the base of the Virgil series as defined in this report. There is well marked physical evidence of this boundary that is traceable southward into Oklahoma, and it is believed that the Missouri-Virgil break corresponds to the large hiatus in the Ar-

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13a. Bartle, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, pp. 16-18, pl. 2, 1933.

buckle Mountains area between the Belle City limestone of Kansas City age, below, and the Vamoosa and succeeding coarse clastic deposits that are clearly of Late Pennsylvanian age. There are paleontologic characters that distinguish the Missouri beds from those classed as Virgil, but the faunal change at the boundary of these divisions is less strongly marked than that at the lower boundary of the Missouri series.

The Missouri beds are designated as a series because they are defined by physical and faunal breaks from contiguous strata that are similar in character but of lesser magnitude than the break that separates Pennsylvanian from Mississippian. The unconformities below and above the Missouri series are not obviously different in character or time value, however, from the break that is regarded as marking the Pennsylvanian-"Permian" boundary in the northern Mid-Continent region.

Correlation.—The Missouri series is a clearly defined unit in Kansas, Nebraska, Missouri and Iowa, characterized on the whole by prominence of limestones. Correlation of Des Moines beds from Missouri to Illinois, which in the main is believed to be fairly accurate, indicates that equivalents of the Missouri series form most of the McLeansboro formation, extending from slightly above the base nearly to the top (probably from base of Trivoli cyclothem to base of Merom sandstone). In Ohio the equivalents of the Missouri beds are tentatively identified as including strata from the Brush Creek limestone to some distance above the Ames limestone. In terms of the Appalachian stratigraphic units, this means that the Missouri series corresponds to most of the Conemaugh beds, but the boundaries of the major divisions of the Appalachian district do not exactly coincide in position with the breaks recognized as series boundaries in the Mid-Continent region.

In northern Oklahoma the "Cleveland sand," which rests unconformably on different upper Des Moines strata, marks the base of the Missouri series, and the contact between the Ochelata and Nelagoney formations, as defined in most places, marks the top of the Missouri. In southern Oklahoma the base of the Missouri series is marked by sandstone and grit at the base of the Seminole formation (shown by Dott to be equivalent to the base of the "Cleveland sand"; and the youngest Missouri beds remaining on the northern flank of the Arbuckle Mountains is the Belle City limestone. The Hoxbar formation in the Ardmore Basin south of the Arbuckles appears to contain beds of Missouri age and the

Hoxbar-Pontotoc angular unconformity is interpreted as corresponding to the Missouri-Virgil break, although the hiatus in the southern Oklahoma area is much greater. Faunal and lithologic evidence indicates that equivalents of the Missouri series occur in the lower Canyon strata of north-central Texas and in the Gaptank formation of west Texas. An unconformity below the Home Creek limestone, near the top of the Canyon group, is believed to mark the boundary between the Missouri and Virgil series in north-central Texas. There are unconformities also in West Texas, the classificatory significance of which has not yet been sufficiently studied. It is not now possible to correlate the Kansas and Texas beds as precisely as will surely be possible in future.

Subdivision.—No satisfactory subdivision of the Missouri series into groups that are well differentiated throughout the entire northern Mid-Continent region can be made. This is due to marked changes in the character of stratigraphic units along the strike, especially from central Kansas southward. It is desirable, however, to recognize the groups that appear natural in the Kansas and Missouri river valleys and to drop this classification in areas to the south where it is inappropriate. Reference may be made conveniently to combinations of groups by using two or more group terms joined by a hyphen where, as at the outcrop in southern Kansas or in subsurface studies of central and western Kansas, the boundaries between strata belonging to different groups cannot be recognized.

The main subdivisions that are here defined in the Missouri series of northeastern Kansas are called, in upward order, Bourbon formation, Bronson group, Kansas City group, Lansing group, and Pedee group. The stratigraphic limits and content of these groups will be described in following sections.

BOURBON FORMATION, Moore, 1932

1866, †*Marais des Cygnes coal series* (part), SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., pp. 22-24. Includes beds between Pawnee limestone below and †"Well rock series" [Bronson?] above. —— 1867, SWALLOW, G. C., Am. Assoc. Adv. Sci., Proc., vol. 15, p. 69. Same.

1894, †*Laneville shale* (part), HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 108. Includes beds between †Oswego [Ft. Scott] limestone and †Erie [Hertha-Winterset] limestone. Use of term in different places indeterminate because of confusion in identification of Erie.

1895, †*Pleasanton shale* (part), HAWORTH, E. (See under Bandera shale.)

1900, †*Marais des Cygnes shale* (part), KEYES, C. R. (See under Bandera shale.)

1903, *Dudley shale* (part), ADAMS, G. I. (See under Memorial shale.)

1920, †*La Cygne shale* (part), MOORE, R. C. (See under Memorial shale.)

1932, **Bourbon group,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 90. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 99. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36. p. 136.

(1935) 1936, *Bourbon shale,* OCKERMAN, J. W., Kan. Geol. Survey, Bull. 20, p. 20. Same as Moore, 1932.

(1935) 1936, *Bourbon formation,* NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 21. Same as Moore, 1932.

Type locality, Bourbon county, Kansas. Most of the formation is exposed on Kansas highway No. 3 where the road ascends the bluffs of Marmaton river about one mile south of Uniontown.

The Bourbon formation includes the beds between the disconformity that marks the base of the Missouri series and the base of the Hertha limestone. As seen in Bourbon and Linn counties the outcrop of the formation comprises most of the slope of the prominent escarpment that is capped by beds of the Bronson group, and the same is probably true northeastward to Kansas City and southwestward beyond Erie. Because the lower boundary of the formation is difficult to trace, except where fairly prominent sandstone occurs at the base, it may be necessary in geologic mapping to combine the Bourbon with the disconformably underlying upper Des Moines shale, but this does not invalidate the stratigraphic definition of the Bourbon formation. Much detailed work remains to be done on this part of the section.

Most of the Bourbon formation consists of bluish-gray and yellowish-brown silty to sandy shale. Locally at the base there is thick, irregularly bedded or massive yellow-brown sandstone and in places there are extensive sandstones in the middle and upper parts of the formation. The latter sandstone beds are apparently distinguished by their more even bedding and by lateral gradation into shaly sandstone or sandy shale. The presence of prominent channel sandstones belonging to the Bourbon in the Kansas City region is shown by Bartle[14] and throughout much of western Missouri is reported by F. C. Greene.[15] Bartle has shown that locally near Kansas City the channel sandstones cut out all of the limestone and shale beds of the upper Des Moines series, reaching downward into the Chero-

14. Bartle, G. G., Mo. Bur. Geol. and Mines, Bien. Rept., App. 3, pp. 16-18, 1933.
15. Personal communication.

kee shale. The Warrensburg and Moberly sandstones in central Missouri and several other channel sandstone occurrences in that state[16] are in part certainly and in part questionably classed as representing basal deposits of the Missouri series and belonging to the Bourbon formation. Locally there are deposits of conglomerate that are to be placed in the same category. An interesting occurrence described by Hinds and Greene[17] is found in Putnam and Schuyler counties, northern Missouri, where conglomerate containing rounded fragments of *Chaetetes* derived from Marmaton limestones rests on successively lower beds of the "Henrietta formation" going eastward. The conglomerate which attains a thickness of 20 feet is classed by Hinds and Greene as "basal Pleasanton." It appears to correspond to the Chariton conglomerate of Bain[18] in Appanoose county, Iowa. These conglomerates that overlap successive units of the upper Des Moines section are to be classed as basal Missouri series deposits belonging to the Bourbon formation as here defined.

Much variation in the lithologic character of the formation from place to place is indicated by field studies. For example, in part of southwestern Linn county 30 feet or more of dense blue flaggy and concretionary limestones alternating with dark shale grade laterally in a short distance into shale that lacks limestone. Fossiliferous dark-blue limestones and black fissile shale occur in the lower part of the formation toward the south. One of the limestone beds in this part of the section is tentatively identified as equivalent to the *Checkerboard limestone* of Oklahoma.

Near the top of the Bourbon formation is a fairly persistent, but lenticular sandy impure limestone that, as seen in most places, is distinctly nodular or apparently composed of irregularly shaped limestone fragments. The rock is gray to brown and weathers with an uneven surface. This bed has been named the "Critizer limestone" (corrected spelling is "Critzer") by Jewett,[19] who classed it, however, as a member of the Swope formation and, according to conclusions of F. C. Greene, N. D. Newell, and me based on field examination in 1934, assigned this bed to an erroneous position above the Schubert Creek limestone. Further discussion of the stratigraphy of these beds is given under description of the Hertha

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16. See Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 91-106, 1915.

17. *Op. cit.*, p. 105.

18. Bain, H. F., Ia. Geol. Survey, vol. 5, pp. 394-398, 1895.

19. Jewett, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 99, 1932; Kan. Acad. Sci., Trans., vol. 36, p. 136, 1933.

limestone. The "Critzer limestone" of Jewett is believed by Greene and me to be equivalent to the "Fragmental limestone"[20] of Iowa geologists. We have seen this rock above the Ovid coal in northern Missouri and southern Iowa. The "Critzer" is apparently a "super" limestone, representing the receding algal, molluscan phase of the sedimentation cycle that includes the Ovid coal, and it is probable that somewhere along the strike other typical members of this cyclothem will be observed. For the present, recognition of the "Critzer" as a named member of the Bourbon formation and of other stratigraphic units in this part of the section that may come to be differentiated is withheld, for it is clear that much additional study is desirable.

The thickness of the Bourbon formation is not definitely known in most of the area of its outcrop, but it probably exceeds 100 feet in most places. In parts of the Kansas City region the thickness of beds assignable to the Bourbon appears to exceed 150 feet. Beds equivalent to this formation have been traced across northwestern Missouri and into southern Iowa. Southward in Oklahoma there is apparently a rapid expansion in thickness of the beds between the Checkerboard, which belongs below the top of the Bourbon, and the post-Des Moines unconformity. In east-central Oklahoma, therefore, it appears that beds stratigraphically equivalent to the Bourbon formation measure several hundreds of feet in thickness.

BRONSON GROUP, Adams, 1904

1894, †*Erie limestone,* Haworth, E., and Kirk, M. Z., Kan. Univ. Quart., vol. 2, p. 108. Name applied to limestones above †Laneville [Bourbon in part] shale. Not clearly defined. This name is preoccupied by the Erie beds of Devonian age in New York (1842). —— 1894, Haworth, E., and Piatt, W. H. H., Kan. Univ. Quart., vol. 2, p. 116. —— 1894, Haworth, E., Kan. Univ. Quart., vol. 2, p. 118. —— 1895, Haworth, E., Am. Jour. Sci. (3), vol. 50, p. 458. States that the †Erie consists of three main limestone "systems," occupying interval between †Pleasanton [Bourbon in part] and †Thayer [Fontana-Chanute] shales. —— 1896, Haworth, E., Kan. Univ. Geol. Survey, vol. 1, p. 45. —— 1896, Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 76. "Triple system near Uniontown." —— 1896, Bennett, J., Kan. Univ. Geol. Survey, vol. 1, p. 95. Same. —— 1898, Haworth, E., Kan. Univ. Geol. Survey, vol. 3, pp. 44, 88, 94, 101.

1896, †*Bethany limestone,* Keyes, C. R., Am. Jour. Sci., (4), vol. 2, pp. 221-225. Extends usage as given by Broadhead, and states that the †Bethany is synonymous with the "Erie" or "Triple limestone" of Haworth.

20. Tilton, J. L., and Bain, H. F., Ia. Geol. Survey, vol. 7, pp. 511-514, 1897.

1898, †*Pottawatomie formation* (part), Haworth, E., Kan. Univ. Geol. Survey, vol. 3, p. 92. Includes "†Erie limestones, †Thayer shales, Iola limestone, Lane shale, †Garnett limestone. This division is limited stratigraphically by the †Pleasanton shale below and the Lawrence [Weston-Lawrence] shales above." This corresponds to beds from the base of the Bronson group to the top of the Lansing group of present classification.

1904, **Bronson formation,* Adams, G. I., U. S. Geol. Survey, Bull. 238, pp. 17-19. Applies name to include Haworth's "triple limestone system" and designates members, in upward order, Hertha limestone, Ladore shale, †Mound Valley limestone, Galesburg shale, and Dennis limestone. These subdivisions are erroneously indicated in the bulletin but corrected in an errata sheet.

1905, *Bronson beds,* Wooster, L. C., Kan. Acad. Sci., Trans., vol. 19, pp. 118-121.

1908, †*Pottawatomie stage,* Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 75. Includes beds from base of "Bethany Falls [Hertha] limestone to top of Stanton limestone."

1915, *Kansas City formation* (part), Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 23, 116. Includes strata from base of Hertha to top of "Iola [Argentine] limestone." —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 95. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 29. —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 26. —— 1933, Greene, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 19. —— 1933, Bartle, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 18.

1932, *Bronson group,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., pp. 90-91. —— 1932, Jewett, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 99. —— 1933, Jewett, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 136. —— (1935) 1936, Ockerman, J. W., Kan. Geol. Survey, Bull. 20, pp. 18-20. —— (1935) 1936, Newell, N. D., and Jewett, J. M., Kan. Geol. Survey, Bull. 21, pp. 24-34, 168-171.

Type locality, vicinity of Bronson, Bourbon county, Kansas.

That the grouping of beds which are called Bronson is convenient and desirable is shown by the recognition of the so-called "triple limestone system" named † Erie by early Kansas stratigraphers. Keyes regarded these limestones as belonging together and extended Broadhead's † "Bethany Limestone" to include them. Adams introduced the term Bronson to replace the inappropriate names previously used. The Bronson group is here defined as by Adams to include the strata from the base of the Hertha limestone to the top of the Dennis limestone.

The Bronson beds are defined as a group because the constituent major limestone and shale units are each more or less complex, representing individual sedimentation cycles or important lithologic elements of cycles. In other words, the group contains at least three cyclothems, or rather, megacyclothems. Each limestone formation at least, as will be noted, contains a number of distinctive members.

The chief distinguishing feature of the Bronson group is the prominence of limestone. From east-central Kansas to central Iowa the three limestone formations of the group are separated by thin shale so that in general they form a single escarpment. The thickness of the different formations and members changes somewhat along the outcrop but except in southern Kansas, where thickening of the shales and thinning of the limestones causes divergence and weakening of some of the escarpment-forming units, the group is a compact, readily defined stratigraphic assemblage.

The thickness of the Bronson group in the type region is about 100 feet. In the Kansas City area it comprises about 85 feet of beds. In southern Kansas 150 to 175 feet of strata belong to the Bronson.

The Bronson group contains strata that are continuous with the upper part of the Coffeyville formation (above the Checkerboard limestone) and the Hogshooter limestone of the northern Oklahoma section.

According to the classification that has been developed by our studies, the Bronson group contains the following formations, named in upward order: Hertha limestone, Ladore shale, Swope limestone, Galesburg shale, and Dennis limestone.

HERTHA LIMESTONE, Adams, 1903

1894, †*Erie limestone* (part), HAWORTH, E., AND KIRK, M. Z. The Hertha is the lowermost of the limestones in the "triple system" called †Erie. For references see under Bronson group.

1903, **Hertha limestone*, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 35. Applies name to "limestones succeeding the upper Pleasanton shale as exposed in the vicinity of Hertha, . . . equivalent to the lower member of the Erie formation." —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 18. Same as above but classed as lowermost member of the Bronson formation. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 23. Class as lowermost member of Kansas City formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 96. Same as Hinds and Greene. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 31. Same as Hinds and Greene. —— 1933, BARTLE,

G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 19. Same. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, pp. 24-26. Same as Adams, 1904.

1898, *Bethany Falls limestone,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, pp. 45, 100. Erroneously regards lowermost division of the †Erie limestone as Bethany Falls. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 89. Applies the name Bethany Falls to the limestone between †Pleasanton and Ladore shales, because of erroneous conclusion that Adams' Hertha is equivalent to the Bethany Falls limestone at Kansas City.

1932, *Swope limestone* (part), MOORE, R. C., AND NEWELL, N. D., cited in Moore, R. C. Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 90. Includes beds classed in this paper as Hertha limestone, Ladore shale, and Bethany Falls limestone. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 100. Same, proposing names for limestone and shale members. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 132. Same.

Type locality, Hertha, Neosho county, Kansas. The limestone is exposed just east of the town, but the best outcrops are in northeast corner sec. 20, T. 29 S., R. 20 E. and in roadcut 2 miles north and 1 mile west of Hertha. Adams' description of type locality is indefinite, but his map shows clearly the limestone to which he intended to apply the name Hertha.

As noted in the discussion of the Bronson group, early workers on the stratigraphy of southeastern Kansas observed the three-fold character of the succession of limestones exposed in central Neosho and Bourbon counties. Adams applied the name Hertha to the lowermost of these limestones, and referring to his description and maps of the Iola quadrangle, there is no difficulty or uncertainty in identifying the beds called Hertha in the type region. In tracing the Hertha and associated limestones northeastward, however, various difficulties and some confusion have been encountered. These are due partly to the thinning of the shales between the limestones so that the outcrop of individual limestones is not clearly reflected in the topography, partly to variations in the thickness and lithologic characters of each of the limestones along the strike, and partly to the lithologic and faunal similarity of portions of each limestone to the others. It is necessary to measure and study sections at short intervals in order to determine the nature of the variations and to establish definitely the stratigraphic relations of exposures in distant places. The difficulties are somewhat greater in the lower part of this limestone section than the upper, because of the more lenticular nature of some of the lower limestone units. It is hardly surprising to find that Haworth and Bennett miscorrelated the Hertha with the Bethany Falls limestone. Correction of this was made by Hinds and Greene, who showed that the Bethany Falls was equivalent to the middle rather than the lower of the three main limestones.

Working under my general direction, J. M. Jewett, now of the University of Wichita, studied the Bronson beds during parts of 1931 and 1932, and concluded that Haworth and Bennett were right in regarding the Hertha as synonymous with Bethany Falls. It appears that Jewett's identification of type Hertha was based on Adams' original description and map (1903) rather than his revised map (1904) in which the designation of the Hertha was changed. Adams states that the Hertha limestone at the type locality is about 10 feet thick. This is in fair agreement with the thickness of the limestone designated as Hertha in 1903, but is nearly twice the thickness of the limestone indicated as Hertha in 1904. Haworth, Bennett, and Jewett are right in concluding that the Hertha as mapped in 1903 is Bethany Falls, but the definition and description given by Adams in 1903 and his generalized stratigraphic section in the 1904 paper agree in indicating that the rock which it was intended to name Hertha is the one exposed just east of Hertha. This latter limestone is not the Bethany Falls but occurs some 50 feet lower in the section at this place. The confusion in determining the relations of Hertha to Bethany Falls is due chiefly to Adams' carelessness.

Returning to consideration of Jewett's work, it is to be noted that because he regarded the Hertha as synonymous with Bethany Falls this name was dropped in favor of the latter term and new names were introduced for limestones that are found beneath the Bethany Falls. In the Kansas City area the prominent brown limestone that was called Hertha by Hinds and Greene was named Sniabar by Newell. Traced southward this was found to occur above another limestone which Jewett named "Critzer." Jewett's studies indicated that these limestones disappear southward and a third limestone of different character, which he named Schubert Creek, makes appearance. This limestone in turn was thought to pinch out before the latitude of Hertha is reached and the limestone at the east edge of Hertha (Adams' Hertha limestone, 1904) was interpreted to belong still lower in the section. Under urgency of preparing information for the field conference of the Kansas Geological Society in September, 1932, I made a reconnaissance in the field with Jewett and the results of his work were released somewhat prematurely. The stratigraphic sequence of the limestones and shales below the

Bethany Falls determined by Jewett is as follows, in upward order: Hertha limestone (at Hertha), unnamed shale included in the Bourbon, Schubert Creek limestone, Tennison Creek shale, Critzer limestone, Mound City shale, Sniabar limestone, Elm Branch shale, Middle Creek limestone, and Hushpuckney shale.

Because the sequence of beds indicated did not agree satisfactorily with evidence of the cyclic succession of strata in other parts of the Missouri series and because of doubts as to some of Jewett's correlation of beds, the section between Kansas City and Oklahoma was reëxamined by me in June, 1934, and in company with F. C. Greene and N. D. Newell in July, 1934. Additional field studies by Jewett during the summer of 1935 have settled some points, but not all. It is agreed that the beds called Hertha by Hinds and Greene at Kansas City are the same as the Hertha limestone at the type locality. The names, Elm Branch, Sniabar, Tennison Creek and Schubert Creek, are applicable to lithologic elements of the cyclothem in which the Hertha limestone is the dominant element, but these names are not required in order to delineate the features of stratigraphy. They will not be recognized, therefore. It may be useful to employ the term Critzer limestone, but it is not now included in the list of recognized units.

The Hertha limestone is considered to comprise the first important limestone unit, locally divided by shale into two or more beds, below the Middle Creek limestone member of the Swope limestone. The Middle Creek is an excellent, very persistent marker bed that occurs next below the Bethany Falls limestone. The thickness of the shale interval between the top of the Hertha and the base of the Middle Creek, or in the south where the Middle Creek disappears, the base of the Bethany Falls, ranges from 2 to 50 feet or more. The Hertha rests conformably on the Bourbon formation. A marker bed near the top of the Bourbon from Linn county, Kansas, northeastward is the fragmental limestone called "Critzer." Black fissile shale immediately underlies the Hertha near Hertha and to the south.

The thickness of the Hertha limestone ranges from about 4 feet to as much as 30 feet locally in northern Bourbon county where the upper and lower members are separated by some 15 feet of shale. About 20 feet of solid limestone belonging to the Hertha is observed also in Bourbon county. The Hertha formation is known to extend from south-central Iowa to Labette county, Kansas, but it is not known to reach the Oklahoma line.

The lower limestone of the Hertha formation is a light bluish-gray rock when fresh. It is typically very massive and weathers to a strong yellowish- or reddish-brown color. The texture is fine and dense, and the rock resists weathering. Fine sandy impurities appear to be present as seen at most places, and toward the south there is a rather characteristic irregular lamination of silty or sandy layers alternating with purer limestone. This rudely laminated rock appears somewhat mottled blue and brownish. Fossils are mostly not abundant in this limestone, but fragments of crinoid stems and a variety of brachiopods, some bryozoans, and in places bellerophontid gastropods appear weathered in relief on the exposed rock surface.

The upper part of the Hertha limestone in many places is a light-gray rock that weathers creamy-white or gray. In places the color is distinctly bluish-gray in fresh exposures. The texture is very fine and dense, some portions of the member being almost lithographic limestone, but in most places the rock appears roughly porous or brecciated with irregular solution of the matrix around angular and nodular dense limestone fragments. Thin veins of calcite in irregular forms are distributed through the limestone, also. It is identified as a "super" limestone, for it has many of the peculiarities of this unit (algal-molluscan bed) of the typical cyclothem. Fossils are rare at most places. In the Hertha limestone at Hertha and southward there are numerous specimens of *Marginifera*. The thickness of this light-gray, apparently fragmented limestone ranges from a feather edge to about 20 feet. In Bourbon county it is fairly uniform but farther north it is developed only locally. The thickness of the member near Kansas City varies in a few miles along the outcrop from less than an inch to about 12 feet.

LADORE SHALE, Adams, 1904

1894, †*Erie limestone* (part), HAWORTH, E., AND KIRK, M. Z. (See under Bronson group.)

1896, †*Bethany limestone* (part), KEYES, C. R. (See under Bronson group.)

1904, **Ladore shale*, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 18. Includes beds between Hertha and †Mound Valley [Bethany Falls] limestones. Called Galesburg in text but name changed to Ladore on errata sheet. Classed as member of the Bronson formation. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 91. Name applied to shale between "Bethany Falls [Hertha] limestone" below and †Mound Valley [Bethany Falls] limestone above. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and

Mines, (2), vol. 13, p. 25. Shale between Hertha and Bethany Falls limestones. Classed as member of Kansas City formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 96. Same as last. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 33. Same as last. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 19. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 26. Includes beds between Hertha limestone, below, and Middle Creek limestone member of the Swope limestone, above.

1906, *Ladore-Dudley shale* (part), SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Describe as lowermost member of Coffeyville formation in the Independence quadrangle where Hertha is not found. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Folio 159, p. 2. Same as last.

1932, †*Elm Branch shale,* NEWELL, N. D., Mss. cited in Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 90. Defined to include beds between Sniabar and Middle Creek limestones. Classed as member of the Swope formation. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 101. Same. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 134. Same.

Type locality, Ladore, southern Neosho county, Kansas. The town, located in sec. 27, T. 30 S., R. 19 E., is built on Hertha. The Swope scarp crosses NW. cor. of same section, so that the thick shale between the two in sec. 27 may be regarded as the type of this unit.

The Ladore shale includes the beds between the top of the Hertha limestone and the base of the Swope limestone. Throughout the region north of Erie, Kan., the top of the Ladore is at the base of the Middle Creek member of the Swope, but south of Erie, where the Middle Creek limestone is absent, the top of the Ladore is considered to extend to the base of the Bethany Falls limestone. The latter condition obtains at the type locality of the Ladore. This definition recognizes the probable inclusion at the top of the Ladore in southern Kansas of shale that is equivalent to the Hushpuckney and Middle Creek members of the Swope formation, but it is certainly undesirable to extend an imaginary boundary at some guessed position beneath the Bethany Falls, and it seems likewise undesirable in this case to employ a cumbersome hyphenation of stratigraphic terms, such as Ladore-Hushpuckney, in order to indicate the shale between Hertha and Bethany Falls.

As interpreted by previous authors, in parts of eastern Kansas and western Missouri, where the dense blue limestone that is now called Middle Creek is present, the Ladore shale includes this limestone and the overlying shale, the top of the Ladore being thus uniformly drawn at the base of the Bethany Falls limestone. This seems on casual consideration to be much simpler and more natural. It is apparent, however, that the dense blue limestone is definitely a part of the cyclothem that includes the Bethany Falls. It is the "middle" limestone and the Bethany Falls comprises the "upper" and "super" limestones. As already defined in many other cases the blue "middle" limestone is regarded as an integral part of limestone formations of which the succeeding "upper" and "super," if the latter is present, make up the main thickness. Consistency in classification and recognition of the cyclic relationship of the various beds thus demands that the Middle Creek limestone be pigeonholed with the Bethany Falls rather than left as a parting in the Ladore shale.

The Ladore shale includes blue-gray or brownish-clayey and sandy beds that attain a thickness of 50 feet or more to the south but in places to the north are only 2 feet thick. Shaly sandstone appears in part of the Ladore section in Neosho county and southward.

SWOPE LIMESTONE (Moore and Newell, 1932), Moore and Newell, 1936

1894, †*Erie limestone* (part), HAWORTH, E., AND KIRK, M. Z. (See under Bronson group.)

1896, †*Bethany limestone* (part), KEYES, C. R. (See under Bronson group.)

1904, *Bronson formation* (part), ADAMS, G. I. (See under Bronson group.)

1932, *Swope limestone,* MOORE, R. C., AND NEWELL, N. D., cited in Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 90. Used to include beds from the Schubert Creek limestone to Bethany Falls limestone inclusive. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 100. Same. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, pp. 132-133. Same.

(1935) 1936, **Swope limestone,* MOORE, R. C., AND NEWELL, N. D., cited by Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 26. Restricted to include three members, named in upward order, Middle Creek limestone, Hushpuckney shale, and Bethany Falls limestone. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 168-169.

Type locality, Swope park, Kansas City, Mo. Typically shown in quarry at 49th street and Swope Parkway in Kansas City, Missouri, also in road cut on U. S. 50, one-half mile northwest of Knobtown, Jackson county, Missouri.

The Swope limestone is here defined to include the beds from the base of the Middle Creek limestone to the top of the Bethany Falls limestone. The reasons for placing the Middle Creek with the Bethany Falls as part of a limestone formation, rather than leaving it as a more or less unnoticed bed in the Ladore shale, have been given in the discussion of Ladore. The typical expression of cyclothem units that appears in the Middle Creek, Hushpuckney and Bethany Falls was recognized clearly by me in 1930 or before. Study of beds in the Shawnee group had led to observation of the repetition in constant sequence of "lower," "middle," and "upper" limestones with black slaty shale between the "middle" and "upper" beds. The Middle Creek is obviously a "middle" limestone, in terms of homology with the Shawnee cycles, the Hushpuckney contains black slaty shale, and the Bethany Falls (at least in part) is identifiable as an "upper" limestone. The massive brown somewhat impure Hertha limestone in the Kansas City district closely resembles in many features the "lower" limestone members of the Shawnee limestone formations. The conclusion was reached that the Hertha, Ladore and Bethany Falls units, as previously defined, when joined together represent a limestone formation corresponding to those in the Shawnee group. The Swope formation was thus defined in 1932. Subsequently the proper classificatory status of the Hertha limestone has appeared more and more doubtful. Since nowhere else in the Missouri series has a well defined "lower" limestone (in terms of the Shawnee cycle) been found, it seems best to withdraw the Hertha and Ladore from the Swope as first proposed, restricting it to the beds already indicated. The Swope limestone thus becomes comparable to other limestone formations of the Missouri series which begin with "middles," contain "uppers," and locally have "supers" at the top.

The thickness of the Swope limestone at the type locality in the southeast part of Kansas City, Mo., is 28 to 30 feet. Excepting some local variation this is about the thickness of the formation northeastward into Iowa and southwestward to southern Bourbon county, Kansas. Farther south the limestone becomes gradually thinner and disappears a few miles south of Mound Valley in Labette county. Strata equivalent to the Swope formation belong in the upper middle part of the Coffeyville formation as defined in northern Oklahoma.

Swope Limestone,
MIDDLE CREEK LIMESTONE MEMBER, Newell, 1932

1904, *Ladore shale* (part), Adams, G. I. (See under Ladore shale.)

1932, **Middle Creek limestone,* Newell, N. D., Mss., cited in Jewett, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 101. Consists of dense blue limestone evenly bedded, 1 to 2 feet thick, between Ladore shale below and Hushpuckney shale above. Classed as member of the Swope formation. —— 1933, Jewett, J. M., Kan.

Acad. Sci., Trans., vol. 36, p. 134. Same. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, pp. 26, 27. Same.

Type locality, SW sec. 22, T. 18 S., R. 24 E., on Middle Creek at crossing of main highway 3 miles east of La Cygne, northern Linn county.

The Middle Creek limestone member of the Swope formation conformably overlies the Ladore shale and is overlain by black fissile shale of the Hushpuckney shale member of the Swope. It is a dark bluish, dense, hard, brittle, even-textured limestone that in most outcrops shows vertical joints. The thickness of the member ranges from a few inches to about 4 feet, the maximum being observed in parts of Bourbon county. The thickness in any one region shows very slight change. There are one or two beds normally, but only locally are the two beds separated by a few inches of shale. Batostomellid bryozoans are common in the upper part, especially at the base of the upper layer where two beds are present, and on the upper surface of the lower layer there are common fucoid markings.

SWOPE LIMESTONE, HUSHPUCKNEY SHALE MEMBER, Newell, 1932

1904, *Ladore shale* (part), ADAMS, G. I. (See under Ladore shale.)

1932, **Hushpuckney shale,* NEWELL, N. D., in Jewett, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 101. For the black and gray shale between the Middle Creek limestone below and Bethany Falls limestone above. Classed as a member of the Swope formation. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 134. Same. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 27. Same.

Type locality, on Hushpuckney Creek. Typically exposed at railroad cut center north line sec. 13, T. 19, R. 23; also center south line sec. 22, T. 18, R. 24, in creek bed.

The Hushpuckney shale member of the Swope formation includes the beds between the top of the Middle Creek limestone and the base of the Bethany Falls limestone. The upper half to two thirds of the member consist of bluish or bluish-gray clay shale, and the remaining lower part of the shale is black and fissile. Excepting microscopic forms fossils are rare or lacking. The thickness of the Hushpuckney shale member ranges from about 3 to 6 feet, the average being 4 feet. The member is distinguishable in northwestern Missouri and across eastern Kansas as far as Erie where the Middle Creek limestone disappears.

SWOPE LIMESTONE,

BETHANY FALLS LIMESTONE MEMBER, Broadhead, 1865

1865, **Bethany Falls limestone,* BROADHEAD, G. C., St. Louis Acad. Sci., Trans., vol. 2, p. 320, 1868. (First issued July, 1865.) —— 1873-'74, BROADHEAD, G. C., Mo. Geol. Survey Rept., pp. 97, 317. Used †"Bethany limestone" and various authors have since used this term. The original name Bethany Falls, however, is preferred. —— 1900, GALLAGHER, JOHN A., Mo. Geol. Survey, vol. 13, Prel. Rept., pp. 189, 198. —— 1915, HINDS, HENRY, AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 25. Classes as a member of the Kansas City formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 96. Same as Hinds and Greene. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 33. Same. —— 1932, MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 90. Classed as uppermost member of the Swope formation. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 101. Same as Moore, 1932. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 134. Same. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 20. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 27-29, 168-169. Same.

1896, †*Mound Valley limestone,* ADAMS, G. I., Kan. Univ. Geol. Survey, vol. 1, p. 23. Refers to limestone 10 to 15 feet thick that makes bold escarpment a short distance northwest of Mound Valley, Kan. Erroneously correlating this limestone with beds belonging to the Dennis formation, Adams states that it passes under the surface at Cherryvale and has 5 inches of coal under it on Drum Creek. As shown in the accompanying section this limestone is the first above the Altamont and occurs between unnamed shales. The Dennis limestone is not recognized as distinct from the †Mound Valley [Bethany Falls] and accordingly the next higher limestone is said to be the †Independence [Drum] limestone. —— 1898, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, pp. 47, 102. Same, but regards the †Mound Valley as equivalent to the middle limestone of the †Erie or "triple system" [Bronson]. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 18. Reports that the †Mound Valley limestone occurs between Ladore shale (called Galesburg in text but changed on errata sheet) and Galesburg shale (called Cherryvale in text). Classes it as the middle member of the Bronson formation. —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Describe the †"Mound Valley limestone lentil" as a division of the "Coffeyville formation" in the Independence quadrangle. Overlies "Ladore-Dudley" shale and occurs below Galesburg shale. ——1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 92. Apply the name to limestone immediately northwest of Mound Valley, between Ladore and Galesburg shales. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 2. Same as Schrader and Haworth.

1896, Not †*Bethany limestone,* KEYES, C. R., Am. Jour. Sci., (4), vol. 2, pp. 221-225. Applies the name †Bethany limestone to the lower limestone of the Missourian series. Synonymous with †"Erie" or "triple limestone" of Haworth, and to Bronson group as now defined.

1903, *Hertha limestone,* ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 35, map, pl. 3. This original application of the term Hertha clearly refers to limestone that is Bethany Falls. Adams later (1904) shifted application of Hertha to the limestone next below the Bethany Falls.

1908, Not *Bethany Falls limestone,* HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 89. This name is erroneously applied to the lower limestone [Hertha] of the "triple system" called Bronson by Adams, "because field study shows that this is the same as the Bethany Falls (Broadhead's bed No. 78) at Kansas City."

Type locality, falls on Big Creek at Bethany, Mo.

The Bethany Falls limestone is classed as the uppermost member of the Swope formation and it is the main limestone unit in the formation. It occurs above the Hushpuckney shale and beneath the Galesburg shale. The Bethany Falls limestone is somewhat variable from place to place, but on the other hand can be identified at most outcrops very readily and definitely. There are two chief elements in the member, a lower part consisting of light-gray, dense, thin-bedded limestone that occurs in uneven, somewhat wavy layers with shale partings and fairly abundant fossils, and an upper part consisting of bluish-gray, massive, mottled or nodular limestone that is believed to be of algal origin, and locally of gray-white oölitic limestone. The lower subdivision ranges in thickness from less than one foot in a few places to a maximum of about 20 feet, the average being about 12 feet. This part of the Bethany Falls limestone is a typical "upper limestone" in lithologic and faunal characters and in stratigraphic position, as compared to limestone formations in the Shawnee group. The upper subdivision is a typical "super limestone" in lithologic characters and in abundance of algal deposits, but mollusks and other fossils that are very abundant in some "super" beds are lacking here. The massive mottled or nodular limestone ranges in thickness up to about 7 feet, and the oölitic limestone to about 13 feet. At many places the oölitic part of the Bethany Falls is weathered so that the oölitic granules are removed by solution leaving the material between the oölites behind, and accordingly the rock appears very porous. The oölitic phase of the upper Bethany Falls limestone is widely developed in Kansas south of the Kansas river, but is not common to the northeast. The total thickness of the Bethany Falls limestone ranges from about 12 to 27 feet, the average in eastern Kansas being about 18 feet.

The outcrop of the Bethany Falls limestone is marked in many places by the occurrence of large blocks, 10 to 20 feet in diameter, that are separated from the formation along joint planes and moved various distances down hill sides on account of creep. No other formation of the Missouri series exhibits this feature so commonly as the Bethany Falls limestone.

The Bethany Falls is traced from south-central Iowa, where it was called the †Earlham limestone by the Iowa Geological Survey, to southern Kansas not far from the Oklahoma boundary. This limestone was called †Mound Valley by the early Kansas Geological Survey, but the name Bethany Falls has priority. A good deal of confusion was introduced in the classification and nomenclature of beds that are now referred to the Bronson group by reason of mistakes and carelessness on the part of Adams.

GALESBURG SHALE, Adams, 1903

1894, †*Erie limestone* (part), HAWORTH, E., AND KIRK, M. Z. (See under Bronson group.)

1896, †*Bethany limestone* (part), KEYES, C. R. (See under Bronson group.)

1903, **Galesburg shale,* ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 36. "This name is here applied to the rocks occupying the interval between the Hertha [Bethany Falls] limestone and the Dennis limestone." As used in this publication the new name Hertha limestone is synonymous with Bethany Falls. Adams later (1904) shifted application of Hertha to the limestone next below the Bethany Falls. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 18. Calls this the Cherryvale shale in text but on errata sheet changes name to Galesburg. Lies between †Mound Valley limestone (erroneously called Dennis in text) below and Dennis limestone (erroneously called Drum in text) above. —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Describes Galesburg shale as a member of the Coffeyville formation in the Independence quadrangle. It is reported to occur above the †Mound Valley [Bethany Falls] limestone lentil and below the Dennis limestone lentil. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 2. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 93. States that Adams applied the name Galesburg to shale between the Hertha and Dennis, overlooking the †Mound Valley [Bethany Falls] limestone. (Change in use of the term Hertha by Adams in 1903 and 1904 is overlooked by Haworth and Bennett.) The name is here restricted to shale above †Mound Valley and below Dennis. —— 1915, HINDS, HENRY, AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 26. Name applied to shale between Bethany Falls and Winterset limestones. Classed as a member of the Kansas City formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 96. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 33. Same. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 101. Restricts name to the shale between Bethany Falls limestone and Canville limestone, the latter being classed as the basal member of the Dennis limestone. Contains Cedar Bluff coal and Dodds Creek sandstone. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 133. Same as Jewett. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 20. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 30-31, 169. Same as Jewett.

1904, *Bronson formation* (part), ADAMS, G. I. (See under Bronson group.)

Type locality, Galesburg, Neosho county, Kansas. Galesburg is built largely on Winterset limestone. The Galesburg shale makes the slope south of town in sec. 5, T. 30 S., R. 19 E.

The Galesburg shale includes the beds that lie between the Swope and Dennis limestones. The member of the Swope that everywhere occurs next below the Galesburg is the Bethany Falls limestone. Throughout east-central Kansas the basal member of the Dennis is the Canville limestone, in northeastern Kansas and northwestern Missouri the basal Dennis is the Stark shale, and in southern Kansas and northern Oklahoma the only recognizable member of the Dennis is the Winterset limestone. The upper boundary of the Galesburg shale, therefore, shows more varied relationships than the lower. It should be pointed out that as previously defined in the Kansas City area, the Galesburg includes the Stark shale. Because the Stark shale is a member of the Dennis formation and because it is readily distinguishable from the Galesburg shale on the basis of lithologic characters, it should not be included with the Galesburg.

The Galesburg shale near Galesburg, Kan., comprises about 70 feet of gray and yellowish-brown clayey and sandy shale and near the top some sandstone. The shale is unfossiliferous. The sandstone becomes increasingly prominent southward. It has been designated as the *Dodds Creek sandstone* by Jewett. Below the sandstone is a fairly persistent thin coal named the *Cedar Bluff coal.* In western Bourbon county, near Uniontown, the Galesburg shale is about 10 feet thick. At Kansas City it consists of 2 to 3 feet of buff calcareous nodular shale. The lower part of the overlying Stark shale is black and fissile.

Although very thin in northeastern Kansas and northwestern Missouri, the Galesburg shale is traceable into Iowa. The southern limit of the Galesburg as a distinct stratigraphic unit is in Labette county, Kansas, for the Swope limestone disappears in this region and except for thin apparently discontinuous limestone that probably represents the Checkerboard limestone of Oklahoma there is a continuous shale section extending downward from the base of the Winterset limestone to the base of the Missouri series.

DENNIS LIMESTONE, Adams, 1903

1894, †*Erie limestone* (part), HAWORTH, E., AND KIRK, M. Z. (See under Bronson group.)

1896, †*Bethany limestone* (part), KEYES, C. R. (See under Bronson group.)

1903, **Dennis limestone,* ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 36. Adams states: "The name Mound Valley limestone was proposed in 1896 for the limestone exposed in the hills northwest of Mound Valley (Adams, Kan. Univ. Geol. Survey, vol. 1, p. 23, 1896), and the bed was correlated with the middle member of the Erie (same, p. 25). The formation as exposed at Cherryvale had been previously described but not named, and had been incorrectly correlated with the Oswego of Haworth (Kan. Univ. Quart., vol. 2, p. 118, 1894). The name Dennis, from the town of that name in Labette county, Kansas, near which it is conspicuously exposed, is now proposed for this limestone. This formation has a thickness of from 10 to 15 feet and varies from a heavy-bedded limestone to a thin-bedded limestone with shale partings. It has been traced from Mound Valley southwestward to the Verdigris river near Liberty where it thins out." —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 19. Erroneously calls this the Drum limestone, but the name is changed to Dennis on an accompanying errata sheet. It is classed as the uppermost member of the Bronson formation. —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Describe Dennis limestone lentil as a division of the Coffeyville formation in the Independence quadrangle. The Dennis lies between Galesburg and Cherryvale shales. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 2. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 93. Notes outcrops of upper of two limestones to which Adams applied the term "Dennis" at the station of Dennis, and restricts use of the name to this upper limestone which overlies the Galesburg shale. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 26. Regards the Dennis formation as the exact equivalent of the Winterset limestone. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 102. Dennis limestone contains Winterset limestone member at the top, with Stark shale and Canville limestone below. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 132. Shows that the Winterset limestone is the uppermost limestone of the typical Dennis formation, and names the two lower members of the Dennis the Stark shale and Canville limestone. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 32-34, 170-171. Same as Jewett.

1904, *Bronson formation* (part), ADAMS, G. I. (See under Bronson group.)

Type locality, Dennis, Labette county, Kansas. Typical outcrops are located near the northwest corner of sec. 14, T. 31 S., R. 18 E.

The Dennis limestone is the uppermost formation of the Bronson group. It overlies the Galesburg shale and is succeeded conformably by the Fontana shale. Near Dennis and for a considerable distance northward, the formation contains three members, the thin blue dense blocky Canville limestone at the base, the black fissile and gray or buff Stark shale in the middle, and the thick gray or blue thin-bedded or in part massive oölitic Winterset limestone at the top. The Canville is a typical "middle" limestone, as compared to the members of Shawnee limestone formation. The Stark is typical of the shale members that occur between "middle" and "upper" limestones. The Winterset contains parts that are typical of both "upper" and "super" limestones, as seen in other formations. There is no question, therefore, as to the genetic relationships of the beds that are included in the Dennis formation. The lithologic and faunal characters of the formation will be described under headings devoted to the respective members. The thickness of the Dennis limestone ranges from 5 or 6 feet, in an area a few miles southwest of Coffeyville, to more than 70 feet. The Winterset and Stark members are continuous to south-central Iowa, and the Winterset extends to southern Oklahoma. The Oklahoma name Hogshooter limestone is an exact synonym of Winterset and accordingly should be dropped.

Dennis Formation

CANVILLE LIMESTONE MEMBER, Jewett, 1932

1932, **Canville limestone,* Jewett, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 102. Consists of 2 feet or less of dense blue limestone, classed as lowermost member of Dennis limestone. —— 1933, Jewett, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 133. Same. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 32. Same.

Type locality, Canville Creek, Neosho county. Typical exposures about 3 miles west of Stark in roadcuts at the NE. cor. sec. 26, T. 27 S., R. 20 E., and in the SE¼ sec. 20, T. 27 S., R. 19 E.

The Canville limestone is the lowermost member of the Dennis limestone. It overlies the Galesburg shale and is overlain by the Stark shale member of the Dennis. The Canville limestone is dense, fine-grained, hard, and shows prominent vertical joints. As seen at some outcrops it is a single layer about a foot thick, but where the thickness is greater there may be two or three beds. The maximum observed thickness is about 3 feet. The member becomes thin and disappears in southern Neosho county and in northern Linn county, the area of typical development, therefore, being confined to Neosho, Bourbon and Linn counties.

DENNIS FORMATION
STARK SHALE MEMBER, Jewett, 1932

1932, **Stark shale*, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 102. Middle member of the Dennis limestone. —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 133. Same. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 32, 170. Same.

Type locality, near Stark, Neosho county, Kansas. Typical exposures are found in the SE¼ sec. 18, T. 27 S., R. 21 E., and NW¼ sec. 28, T. 27 S., R. 20 E.

The Stark shale is the middle member of the Dennis limestone, occurring normally above the Canville limestone and below the Winterset limestone. North of the point in Linn county where the Canville limestone disappears, the Stark shale rests directly on the Galesburg shale, but because the lower part of the Stark member consists of black fissile shale that is unlike the Galesburg, it is readily possible to differentiate the two shales. Where the Canville limestone is missing in southern Kansas, absence of black platy shale at the horizon of the Stark member makes it impossible to recognize the Stark shale. The upper boundary of the Galesburg shale is here extended to the base of the Winterset limestone.

The Stark shale consists typically of two parts, a lower subdivision of black fissile shale, 1 to 3 feet thick, and an upper subdivision of gray or buff, more or less calcareous clay shale, 2 to 5 feet thick. At Kansas City the total thickness of the Stark member amounts to about 4 feet. The black shale contains conodonts and macerated plant remains. Small phosphatic concretions occur here rather commonly. The upper shale contains a mixed brachiopod and pelecypod fauna in many places. The most common fossils are *Derbya crassa* and *Aviculopectens*. *Liorhynchus rockymontanum* has been observed in this shale at Kansas City.

DENNIS FORMATION
WINTERSET LIMESTONE MEMBER, Tilton and Bain, 1897

1897, **Winterset limestone*, TILTON, J. L., AND BAIN, H. F., Ia. Geol. Survey, vol. 7, pp. 517-519. The "Missourian formation" in Madison county is reported to be represented only by the †"Bethany limestone." They propose to restrict the term Winterset, "heretofore used loosely as the equivalent of Bethany," to beds 6 and 7 of section exposed at

Winterset (pp. 509-510 for stratigraphic section in sec. 22, T. 75 N., R. 28 W., Iowa). The Winterset limestone is here 17 feet thick. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 26. Apply the name to a limestone above the Bethany Falls. Classed as a member of the Kansas City formation. The Winterset is regarded as synonymous with Dennis limestone. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 97. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 34. Same. —— 1932, JEWETT, J. M., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 102. Classed as upper member of Dennis formation. Notes that the limestone at Coffeyville was called lower Drum by Schrader (Independence folio, 1908). —— 1933, JEWETT, J. M., Kan. Acad. Sci., Trans., vol. 36, p. 132. Same. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 20. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 32-34, 170-171. Same as Jewett.

1898, †*DeKalb limestone,* BAIN, H. F., Ia. Geol. Survey, vol. 8, pp. 277-278. Proposes the name DeKalb to replace the inappropriate term, "*Fusulina* limestone" previously used. The typical section is just east of DeKalb station, sec. 28, T. 28 N., R. 26 W. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 29. Condra believes this is the same as the Drum limestone described by G. I. Adams at a later date. In October, 1932, G. E. Condra, F. C. Greene, and R. C. Moore traced the so-called Drum limestone of the Kansas City area to Winterset, Iowa. They determined that the type DeKalb limestone is the same as the Winterset limestone. The latter name being the oldest, the term DeKalb must be dropped.

Type locality, vicinity of Winterset, Iowa (sec. 22, T. 75 N., R. 28 W.).

The Winterset limestone is here classed as the uppermost member of the Dennis limestone. From Neosho county northward the Winterset rests on shale that is called Stark, but to the south the underlying shale is included in the Galesburg. In east-central Kansas, northwestern Missouri, and southern Iowa, the shale next above the Winterset is called the Fontana shale. In southern Kansas the shale overlying the Winterset has been termed Cherryvale. As will be noted in later discussion devoted to the Cherryvale, there are unsolved problems in connection with the detailed correlation of the southern and northern Kansas sections between the Winterset and Drum limestones.

The Winterset limestone is typically a light bluish-gray to bluish fine-grained limestone that occurs in somewhat uneven to distinctly wavy thin beds separated by thin shale partings. In places the lower part is thick-bedded, dark-gray limestone with abundant fine calcite veins. Beds of shale, including black platy shale, a foot or more in thickness, occur in a number of sections of the Winterset limestone. Near the top there is commonly a prominent zone of very dark-gray to black chert concretions and in places this type of chert occurs in the middle part of the member. The associated limestone beds may be distintlcy siliceous. Light-gray oölitic limestone is present at the top or in the upper half of the member locally, especially in east-central Kansas. Farther south there is a prominent development of irregularly bedded, pseudo-brecciated and veined light-gray limestone in the upper part of the member that is regarded as probably algal in origin. This type of limestone has a thickness of more than 50 feet locally. Near Cherryvale and Coffeyville the typical Winterset limestone is succeeded by a zone of very dense dark-blue, fine-grained siliceous to sandy limestone beds interbedded with shale. These beds are unfossiliferous flagstones. They are tentatively regarded as forming one type of the "super" limestone deposits that occur in the Dennis formation, because the same sort of beds are known elsewhere in such relations.

The Winterset limestone yields abundant fossils in many places. The thin wavy-bedded strata commonly contain numerous brachiopods, including especially representatives of the genus *Marginifera,* bryozoans, and in the siliceous and oölitic beds abundant pelecypods and gastropods. Large nautiloid cephalopods and some ammonoids have been collected in the Winterset of the Kansas City area. Fusulinds of the *Triticites irregularis* type are numerous in some of the brachiopod-bearing beds.

The variety of deposits and their succession in the Winterset limestone, as here recognized, indicate somewhat greater complexity of cyclic phases than in other members of formations in the Missouri series. Some of these variations, especially the recurrence in vertical sequence of phases that normally are confined to a single part of a cyclothem, suggest rudimentary cycles or minor oscillations within the main one. For the present it can be said that no doubt is attached to the correlation or tracing of the limestone that is called Winterset, from its type locality in Iowa to southern Kansas, and there is no difficulty in recognizing typical elements of the sedimentary cycle in various exposures of the Winterset (that is, "upper" and "super" types of limestone, both as regards lithologic and faunal characters), but there are uncertainties as to the interpretation of the cyclic phases. Detailed studies of the Winterset limestone will probably furnish information that will permit answers to a number of present questions concerning the member.

The equivalence of the Winterset limestone to the Hogshooter limestone of Oklahoma has been determined by tracing outcrops and by comparison of sections at frequent intervals along the outcrops.

A part of this tracing that calls for special care is in the vicinity of Coffeyville, Kansas, where the limestone formations in this part of the Pennsylvanian section are much thinner than to the north or south, and where there are local variations in lithologic characters. Structural irregularities further complicate field study of the stratigraphy. Ohern in 1910 traced the limestone that caps the bluffs west of the Verdigris at Coffeyville into limestone that is definitely identified as Hogshooter, and this was checked later by Condra and Moore in 1930 and again by Moore in 1933. In the course of studying the lower Missouri series beds in northeastern Kansas, R. H. Dott, Joseph Borden, and Ronald J. Cullen, were in doubt as to relationships of the Hogshooter and Winterset, but a field conference of those geologists and R. C. Moore in May, 1934, led to agreement that the limestone called Winterset at Coffeyville and that called Hogshooter in northern Oklahoma are the same.

KANSAS CITY GROUP (Hinds and Greene, 1915), Moore, 1936

1886, Not *Kansas City oölite,* BROADHEAD, G. C., St. Louis Acad. Sci., Trans., vol. 4, p. 483. Refers to beds now classed as Westerville limestone.

1898, Not *Kansas City limestone,* GALLAHER, J. A., Mo. Geol. Survey, Bien. Rept., p. 51. —— 1900, GALLAHER, J. A., Mo. Geol. Survey, vol. 13, p. 203. Refers to three different limestones that were miscorrelated.

1898, †*Pottawatomie formation* (part), HAWORTH, E. (See under Bronson group.)

1915, *Kansas City formation,* HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 23, 116. Proposed name to include beds from the base of the Hertha limestone to the top of the "Iola" (Argentine) limestone. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 95. Same. ——1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 29. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 27. Name applied to beds identified as Hertha to Iola, inclusive. —— 1932, MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conference, p. 91. Application of name modified to include beds from the top of the Winterset limestone to the base of the Wyandotte limestone. —— 1933, GREENE, F. C., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 2, p. 19. Same as Hinds and Greene, 1915. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 18. Same as Hinds and Greene. *—— (1935) 1936, MOORE, R. C., cited by Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 34. Name applied to beds between the top of the Winterset limestone and the base of the Plattsburg limestone. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 34-69, 171-181. Same as Moore, 1936.

Type locality, Kansas City, Mo.

As originally proposed, the Kansas City group or "formation" was designed to include the lower portion of the prominent limestones and interbedded shales that formed the †Pottawatomie formation of Haworth. The "Pottawatomie" beds are separated from the Marmaton limestones below by thick shale and sandstone that was formerly called Pleasanton shale, and they are separated from the relatively thick Shawnee limestones above by a considerable thickness of shale and sandstone that was formerly classed as the Douglas formation. Thus, the "Pottawatomie" is a well characterized group that is distinguished by prominence of limestones. It corresponds exactly to the widely used "Kansas City-Lansing" limestones of workers in the subsurface geology of Kansas, for in many places it is not possible to differentiate the subdivisions of this group of beds in study of materials from deep drilling even though the bottom and top are clearly determinable. The two-fold division of the "Pottawatomie" beds was made because the escarpments made by the lower group of limestones (here termed Bronson group) and the upper group of limestones (Lansing group) were distinct, and perhaps more importantly because it was believed that there was a significant paleontologic distinction, marked mainly by the appearance of the brachiopod *Enteletes* in the Lansing beds. It is now known that *Enteletes* appears locally in the limestone called Iola by Hinds and Greene (Argentine limestone of present classification), and in Oklahoma this fossil is found in the Holdenville formation which is considerably lower than the Argentine in stratigraphic position. Cogent practical reasons can be advanced for reviving the term Pottawatomie, but objection might be raised that this lumping of beds includes all of the Missouri series, as restricted, except the lower and upper clastic deposits. If the Missouri series is to be divided into smaller group units, it appears that the Bronson beds are readily and clearly differentiated as a lithologically distinct, stratigraphically useful element. Similarly, the limestones of the Lansing "formation," as defined by Hinds and Greene, are a compact unit of persistent and prominent hard strata. There is then left the middle portion of Haworth's "Pottawatomie" beds, which is composed mostly of shale and thin limestones. There is possible question as to the advisability of retaining the name Kansas City for this stratigraphic division, but the term is so familiar to geologists in the northern Mid-Continent region that it has been thought best to continue its use. The splendid sections in the river bluffs at Kansas City show the entire group, and except in a few places all of the rocks in these sections belong to the group as here revised.

The Kansas City group is now defined to include the strata from the top of the Winterset member of the Dennis limestone to the base of the Plattsburg limestone. Named in upward order, the following formations are recognized: Fontana shale, Block limestone, Wea shale, Westerville limestone, Quivira shale, Drum limestone, Chanute shale, Iola limestone, Lane shale, Wyandotte limestone, and Bonner Springs shale. Recent observations by Newell in southern Kansas suggest the possibility that the Fontana shale and Block limestone are really to be recognized as upper elements of the Dennis formation, and if this proves to be indicated by further detailed studies, the boundary between the Bronson and Kansas City groups should be placed at the top of the Block limestone.

FONTANA SHALE, Newell, 1932

1908, *Cherryvale shale* (part), Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 95. The beds between the Dennis and Drum limestones in eastern Kansas are here called Cherryvale shale. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 26. Strata between the Winterset and Drum [Westerville] limestones are called Cherryvale shale and classed as a member of the Kansas City formation. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 97. Same as Hinds and Greene except that in southeastern Kansas the limestone called Drum is correctly defined. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 34. Same as Moore and Haynes. —— 1933, Bartle, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 21. Same as Hinds and Greene.

1932, **Fontana shale,* Newell, N. D., Mss. cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 91. This name applies to a 15-foot argillaceous shale immediately above the Winterset limestone in the vicinity of Fontana, Miami county, and elsewhere in eastern Kansas. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 36. First formal definition.

Type locality, village of Fontana, Miami county, Kansas, typical exposures near NE. cor. sec. 11, T. 18 S., R. 23 E., and near middle west side NW. 1/4 sec. 36, T. 18 S., R. 23 E.

The Fontana shale overlies the Winterset member of the Dennis limestone and underlies the Block limestone. It is a fairly uniform clay shale of greenish-gray to buff color that contains scattered calcareous nodules. Locally there is ferruginous calcareous shale at the base. The formation is mostly barren of fossils but near the top there are commonly abundant specimens of the small brachiopod *Chonetina flemingi* var. *plebeia*. The Fontana shale is 15 feet thick near Fontana and about 5 feet thick in the vicinity of Kansas City. Southward the shale thickens to 25 feet in Linn county. Since the Winterset and Block limestones are found at various places in northwestern Missouri and southern Iowa, it appears that the Fontana shale can be recognized from Linn county, Kansas, to Iowa. The southern Kansas equivalent of the Fontana shale is not satisfactorily determined at the present time. It may be found in the Cherryvale shale but this is not certain. The Cherryvale shale, defined from outcrops in the vicinity of Cherryvale, northeastern Montgomery county, lies between the Winterset limestone, below, and the Drum limestone, above. As very well shown in brick pits about two miles south of Cherryvale, this shale is a uniform blue silty sedimentary deposit about 60 feet in thickness and it is practically devoid of fossils. Near the top of the shale are a few layers of blue dense limestone flags which persist northward and southward for several miles. In the vicinity of Coffeyville, these flaggy blue limestones lie considerably below the horizon of the Drum limestone and only a few feet above the Winterset limestone. Similar but less clearly defined relations are observed to the north. It thus appears that the Cherryvale shale of the type region is a decidedly lenticular stratigraphic unit and that it is lower than other fairly thick shale and sandstone locally occurring above the flaggy limestones and beneath the Drum limestone. The correlation of the Cherryvale shale with Fontana and other formations that are recognized between the Winterset and Drum limestones of the Kansas City area is very uncertain. It is not advisable at present to use the term Cherryvale shale except in the vicinity of Cherryvale.

BLOCK LIMESTONE, Newell, 1932

1908, *Cherryvale shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Fontana shale.)

1932, **Block limestone*, NEWELL, N. D., Mss. cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 91. Term applied to a dense, bluish, evenly-bedded limestone about 15 feet above the Winterset limestone; 3 to 5 feet thick in the type region. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 37. First formal description.

Type locality, near the hamlet of Block in eastern Miami county. Typical exposures are found in roadcuts near center S. line sec. 6, T. 18 S., R. 24 E., and near center W. line sec. 18, T. 19 S., R. 23 E.

The Block limestone occurs between the Fontana shale, below, and the Wea shale, above. As developed in the type area of eastern Miami county, it is a blue-gray, fine-grained, hard limestone that occurs in moderately thick even beds with common vertical joints. The rock breaks into angular fragments on weathering and in some respects resembles a "middle" limestone of the thicker, more complex limestone formations. The Block limestone is not definitely classifiable in this maner, however, for in some outcrops the beds are thin and wavy or nodular, a character that is foreign to "middle" limestones. Near Kansas City there are several thin dense blue limestones separated by a few inches to a foot or two of shale at the horizon of the Block limestone. The lithologic and faunal characters of these limestones are typical of the Block limestone, but the occurrence of the interbedded shale is not normal. Fusulinids are common in various outcrops of this limestone and the brachiopod *Marginifera wabashensis* is abundant at many places. The thickness of the Block limestone ranges from about 3 to 8 feet, the average being about 4 feet. The unit has been identified at exposures from Linn county, Kansas, northward to Iowa.

WEA SHALE, Newell, 1932

1908, *Cherryvale shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Fontana shale.)

1932, **Wea shale,* NEWELL, N. D., Mss. cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 91. The term is applied to shale, 15 to 20 feet thick, between the Block and Westerville limestones. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 38. First formal description.

Type locality, Wea Creek in northeastern Miami county, Kansas. The best exposures occur near the SE. cor. sec. 31, T. 16 S., R. 24 E., and near the center of the east side of sec. 12, T. 18 S., R. 22 E.

The Wea shale occurs next above the Block limestone and is overlain by the Westerville limestone. The shale is mostly olive-green in color and clayey, but there is a persistent thin zone of maroon silty to clayey shale near the top. The Wea shale is more calcareous to the north. The thickness of this shale in eastern Kansas ranges from about 10 to 30 feet, the greatest thickness being observed in eastern Johnson county, a few miles southwest of Kansas City. The Wea shale is traceable across northwestern Missouri into Iowa, but south of the type region the Westerville limestone is mostly missing so that the shales that belong below and above this limestone are in contact. The stratigraphic relationships of the shales can be determined in well exposed sections because of lithologic distinctions between the Wea shale and the Quivira shale. It is not practicable, however, to draw a boundary at the top of the Wea shale where the Westerville limestone is absent, and the shale between the Block and Drum limestones is designated as Wea-Quivira shale.

WESTERVILLE LIMESTONE, Bain, 1898

1886, *Kansas City oölite,* BROADHEAD, G. C., St. Louis Acad. Sci., Trans., vol. 4, p. 483.

1898, **Westerville limestone,* BAIN, H. F., Iowa Geol. Survey, vol. 8, pp. 276-277. "In Union county there is an important bed of limestone, which, from the fact that it is well shown on Sand creek near Westerville, may be called the Westerville limestone. It lies some little distance above the De Kalb horizon." —— 1898, BAIN, H. F., Am. Jour. Sci., (4), vol. 5, pp. 337, 339. —— 1933, CONDRA, G. E., AND UPP, J. E., Neb. Geol. Survey, (2), Paper 4, pp. 5, 8, 10. Note that in October, 1932, G. E. Condra, F. C. Greene, and R. C. Moore traced the so-called Drum limestone of the Kansas City area to Winterset, Iowa, and found it to be the same as the type Westerville limestone. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 40-43, 172-173. Shows that Westerville is not the same as Drum.

1908, *Drum limestone* (part), HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 96. The oölite [Westerville limestone] at Kansas City is regarded as equivalent to the Drum limestone of southern Kansas. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 26. Indicate doubt as to the identification of Drum at Kansas City but accept correlation with the "Kansas City oölite" [Westerville] largely on basis of faunal similarity noted by Beede. Classed as a member of the Kansas City formation. —— 1930, SAYRE, A. N., Kan. Univ. Sci. Bull., vol. 19, pp. 75-80. Describes type Drum in southeastern Kansas but erroneously includes the oölite of the Bethany Falls near Elsmore and the Westerville limestone at Kansas City as equivalents of the Drum. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 22. Same as Hinds and Greene.

1915, †*Cullom limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Pub., vol. 9, p. 20. Name applied to limestone in Cass county, Neb., thought to belong in the Lecompton limestone, but subsequently (Condra, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 11, 1930) recognized as equivalent to †DeKalb. Studies by Condra, Greene, and Moore in October, 1932, indicate that the †Cullom is equivalent to the lower part of the Westerville limestone.

1927, †*DeKalb limestone,* Condra, G. E., Neb. Geol. Survey, Bull. 1, (2), p. 29. Correlates the so-called Drum limestone at Kansas City and the true Drum limestone of Kansas with the †DeKalb limestone of Iowa, and because of priority of †DeKalb adopts this instead of Drum. —— 1932, Dunbar, C. O., and Condra, G. E., Neb. Geol. Survey, (2), Bull. 5, pp. 15, 18, table C. Note that the "Drum limestone" of Kansas City is not the same as the type Drum but is probably equivalent to the †DeKalb limestone of Iowa.

Type locality, on Sand creek near Westerville, Union county, Iowa.

The Westerville limestone is a persistent and distinctive stratigraphic unit in the vicinity of Kansas City and northward to Iowa, but it appears to be absent south of Miami county, Kansas. The Westerville occurs next above the Wea shale and underlies the Quivira shale. There has been a good deal of confusion in the classification and correlation of beds in this part of the section, but it is now determined that the formation called Westerville limestone by Bain in Iowa is a valid unit, that the †De Kalb limestone which has been misidentified in Missouri and Nebraska is a synonym of Winterset, and that the beds previously called Drum limestone at Kansas City really belong to the Westerville limestone.

The lithologic characters shown by Westerville beds in northeastern Kansas and northwestern Missouri are much more variable than in adjacent limestones. There is commonly a lower and an upper division, however, the former distinguished by its fine texture, moderately thin, somewhat uneven bedding and the latter by prominence of massive or cross-bedded oölite. Both parts of the formation are light bluish-gray to nearly white, and weather gray or buff, but their appearance is yet quite different one from the other. In places the upper beds of the Westerville are not oölitic but are dense, siliceous, chert-bearing rock that weathers light brown. Fossils are not common except in the oölite which yields a rich fauna of mollusks, brachiopods, bryozoans and various other invertebrates. In northern Missouri and in Iowa and Nebraska, oölite is not common in the upper Westerville limestone, and the fine-grained light blue-gray rock which generally occurs contains very abundant small fusulinids.

The thickness of the Westerville limestone averages about 8 feet.

QUIVIRA SHALE, Newell, 1932

1908, *Chanute shale* (part), Beede, J. W., and Rogers, A. F., Kan. Univ. Geol. Survey, vol. 9, p. 340. Class beds at Kansas City between "Drum" [Westerville] and "Iola" [Argentine] as "Chanute." The basal shale of this so-called Chanute is now called Quivira. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 27. Same. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 98. Interprets Kansas City section as by Beede and Rogers. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 35. Same. —— 1933, Bartle, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 22. Same as Hinds and Greene.

1932, **Quivira shale,* Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 91. Comprises shale with a carbonaceous layer between Westerville limestone and Cement City limestone. —— 1932-'34, name adopted in publications of the Neb. Geol. Survey. —— (1935) 1936, Newell, N. D., and Jewett, J. M., Kan. Geol. Survey, Bull. 21, pp. 43, 173. First formal description.

Type locality, Quivira Lake, east of Holliday, in sec. 32, T. 11 S., R. 24 E., Johnson county, Kansas. Also well shown behind school building at east edge of Holliday.

The Quivira shale comprises strata between the Westerville limestone below and the Drum limestone above. It is the shale formerly called "lower Chanute" at Kansas City. Where the Westerville limestone is absent, as in Miami county and to the south, the Quivira shale is in contact with the Wea shale, but because of distinguishing lithologic characters the two may be differentiated in many outcrops. Where it is not feasible or convenient to separate the shales, the combined units may be designated as the Wea-Quivira shale.

The Quivira shale consists mostly of olive-green clay shale but in most sections about 1 foot of black carbonaceous shale with corneous brachiopods, or in some sections about the same thickness of maroon clay occurs at the base. In Johnson county the carbonaceous layer is observed near the middle of the shale. The greenish shale is unfossiliferous.

The thickness of the Quivira shale in northeastern Kansas ranges from 4 to 11 feet. In the Kansas City section the thickness of this shale averages 7.5 feet. The Quivira is at present differentiated only in the region from Miami county northward across Johnson and Wyandotte counties, Kansas, and in Jackson and Platte counties, Missouri.

DRUM LIMESTONE, Adams, 1903

1894, †*Independence limestone*, HAWORTH, E., AND PIATT, W. H. H., Kan. Univ. Quart., vol. 2, p. 117. Name preoccupied by Independence shale (Calvin, 1878), Devonian of Iowa. —— 1896, ADAMS, G. I., Kan. Univ. Geol. Survey, vol. 1, pp. 23-24. —— 1898, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, pp. 48-49.

1903, **Drum limestone*, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 37. "The name Independence limestone was first used provisionally by Haworth and Piatt (1894) for the limestone exposed at Independence, Kan., which at that time was erroneously correlated with the Oswego limestone. Exposures of the formation at Cherryvale were also described and correlated with the whole of the Erie (same). Subsequently, the name Independence was used by Adams (1896) for the limestone which is exposed at the original locality and the formation was correlated with the upper member of the Erie. The name has been used in this sense, but is preoccupied by the Independence shale in the Devonian of Iowa, and the name Drum limestone, from Drum Creek, Kansas, where it is conspicuously exposed, is adopted." —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Near Independence the Drum is a single bed of limestone about 20 feet thick, but to the south it includes heavy-bedded limestone in the lower part, 12 feet, shale, 10 to 25 feet, and thin-bedded blue flaggy limestone in the upper part, 2 to 10 feet. Except as referring to the vicinity of Independence, this statement is erroneous, the heavy-bedded limestone indicated being Winterset. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 96. The typical outcrops on Drum Creek near Independence are probably equivalent to the oölite [Westerville] of Kansas City. This correlation is erroneous. —— 1908, BEEDE, J. W., AND ROGERS, A. F., Kan. Univ. Geol. Survey, vol. 9, p. 340. Same. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 2. Describes Drum limestone in the Independence quadrangle as resting on "Coffeyville formation" and overlain by "Wilson formation." Northwest of Coffeyville Schrader miscorrelates Winterset and overlying flaggy limestone with the Drum. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 98. Classes the Drum limestone as a member of the Kansas City formation. The type Drum is miscorrelated with oölitic limestone at Kansas City that is now called Westerville. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 35. "Drum limestone member of Kansas City formation" lies between Cherryvale shale and Chanute shale. —— 1930, SAYRE, A. N., Kan. Univ. Sci. Bull., vol. 19, pp. 75-80. Describes type Drum is southern Kansas, but erroneously includes the oölite of the Bethany Falls limestone near Elsmore (p. 80) and the Westerville limestone of Kansas City. —— 1932, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., pp. 91, 92. States that the Cement City limestone at Kansas City represents the lower part of the Drum limestone in southeastern

Kansas, as evidenced by field tracing. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull, 21, pp. 44, 174.

1915, Not *Drum limestone,* HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 26. Refers to Westerville limestone. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 22.

1915, *Chanute shale* (part), HINDS, H., AND GREENE, F. C. (op. cit.). The Cement City limestone, classed as a subdivision of the Chanute shale, is a member of the Drum limestone. —— 1917, MOORE, R. C., AND HAYNES, W. P., op. cit. Same. —— 1920, MOORE, R. C., op. cit. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 27-29. Same. ——1933, BARTLE, G. G., op cit.

1933, *Westerville limestone,* DUNBAR, C. O., AND CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 5.

Type locality, Drum Creek, Montgomery county, Kansas. Typical exposures along highway east of Independence, along south line sec. 28, T. 32 S., R. 16 E., and at cement plant quarry in NW¼ sec. 4, T. 33 S., R. 16 E.

In central Montgomery county, Kansas, where the type locality of the Drum limestone occurs, this formation rests conformably on shale called Cherryvale and is overlain by shale equivalent to the Chanute. In northeastern Kansas and northwestern Missouri the Drum limestone lies conformably on shale called Quivira and is overlain by the Chanute shale. Partly because of pronounced variation in lithologic characters and thickness of the Drum and to some extent also of the contiguous formations, and partly because of an absence of good exposures at frequent intervals or of a well defined escarpment at the Drum outcrop, there has been much confusion in the stratigraphic nomenclature of beds in this part of the section in northeastern Kansas and in Missouri. Early investigators of the geology of southeastern Kansas erroneously correlated the Drum with the Iola, the Winterset, the entire Bronson group and even the Fort Scott. These mistakes were due to very incomplete or careless field work and are only of historical interest. Correlation of the Drum limestone with the "Kansas City oölite" (Haworth and Bennett, Beede and Rogers, 1908; Hinds and Greene, 1915) is a different matter. This limestone which is prominent in the Kansas City region occurs in the approximate stratigraphic position of the Drum limestone and closely resembles it in the prominence of oölite, in the presence also of dense blue-gray limestone, in pronounced local variations of lithology and thickness, and in faunal characters. In 1927 Condra[21] concluded that the "Drum limestone" at Kansas City is the same as the †DeKalb limestone, defined by Bain in 1898 from

21. Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 29, 1927.

exposures in Iowa, and since the latter term has priority over Drum, †DeKalb was used replacing Drum both in the Kansas City area and southern Kansas. Field work by N. D. Newell in 1930 to 1932 showed that the "Drum limestone" at Kansas City is not the same as the type Drum, but a lower unit, the true Drum limestone being determined as equivalent to the so-called Cement City limestone of the Kansas City section. Also, as has been indicated, field study by Condra, Greene and Moore in 1932 showed that the "Drum limestone" of Kansas City is the same as the Westerville limestone of Iowa.

The Drum limestone is composed partly of fine-grained dense limestone, partly of granular more or less crystalline crinoidal limestone, and partly of oölite. Locally there are deposits of fine to very coarse limestone conglomerate. Fossils are very abundant in many places, the fauna being rich in the variety of species.

The thickness of the Drum limestone ranges from less than 2 feet to a known maximum of about 60 feet, found locally east of Independence. The average thickness is about 5 feet. The Drum has been traced from the Oklahoma line northward to Kansas City and has been identified at various places in northern Missouri, Iowa, and Nebraska.

Two subdivisions of the Drum limestone are at present recognized, the Cement City limestone member below, and the Corbin City limestone member above. At some exposures these are separated by a few inches of shale but elsewhere they are in contact.

Drum Limestone
CEMENT CITY LIMESTONE MEMBER,
Hinds and Greene, 1915

1898, †*Parkville limestone,* Gallaher, J. A., Mo. Geol. Survey, Bien. Rept., p. 51. Identifiable only by reference to localities cited. Appears to be erroneously placed in section or miscorrelated with other limestones. —— 1900, Gallaher, J. A., Mo. Geol. Survey, vol. 13, p. 205. Same.

1915, **Cement City limestone,* Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 27, 118. Apply the name to persistent limestone (Broadhead's No. 90) in the "Chanute shale." —— 1933, Bartle, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 23. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 45. Notes that this is the lower member of the Drum limestone.

Type locality, Cement City, northeastern Jackson county, Mo. Typical exposures in cement plant quarry.

The Cement City limestone member of the Drum formation, although less prominent in some exposures than the overlying Corbin

City member, is the most persistent and really most important of the two units. At most outcrops it is the only member present. The fresh limestone is blue-gray to pale-drab in color and on weathering the rock becomes light-gray somewhat mottled with brown or the member may become entirely brown. The texture of the rock is typically very fine and dense. Obscure thin wavy bedding may be observed, especially on weathered outcrops in many places, but the member tends to appear as a single massive ledge that breaks along widely spaced joint planes to make large blocks. In southern Kansas the wavy thin shale partings between the dense nodular limestone beds are somewhat more evident than in general to the north, and they yield a profusion of finely preserved bryozoans. A persistent zone of *Campophyllum torquium* is found near the top of the Cement City limestone in northeastern Kansas, and since this fossil is not observed in adjacent beds it is an aid in identifying the member. A variety of brachiopods, bryozoans and less commonly other invertebrates occurs in the Cement City limestone. At some places this member is unfossiliferous, or, as typically shown in parts of Johnson and Miami counties, there is an abundance of crinoid fragments evenly scattered through the rock but very few other fossil remains.

The thickness of the Cement City limestone ranges from about 2 feet to 10 feet.

Drum Limestone

CORBIN CITY LIMESTONE MEMBER, Moore, 1932

1932, **Corbin City limestone,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. This is the upper, oölitic part of the Drum formation. —— (1935) 1936, Newell, N. D., and Jewett, J. M., Kan. Geol. Survey, Bull. 21, pp. 45, 174.

Type locality, Corbin City, about 2 miles south of Cherryvale, Kansas.

The main part of the Drum limestone where it is locally some tens of feet in thickness near Independence consists of oölite that is here termed the Corbin City member. Lithologically and faunally this member is very sharply differentiated from the Cement City member, on which it rests disconformably in southern Kansas. Near Cherryvale the irregularities in the upper surface of the Cement City limestone are very abrupt and locally have a relief of nearly 5 feet. The oölitic limestone fills hollows and covers high parts of the underying dense blue-gray rock. To the southwest, west, and northwest of Coffeyville the Corbin City member is represented by limestone conglomerate in which pebbles, cobbles and locally rounded boulders of limestone 1 foot in diameter are embedded in a matrix of sandy, in part oölitic limestone. Despite the apparently unfavorable surroundings, there are well preserved fossils in parts of the matrix. The limestone pebbles appear to be in part identifiable as having come from the Cement City member and at least in part from dense dark-blue flaggy limestone beds that belong normally a few feet below the Cement City limestone in this region. The irregular surface carved in shale and sandstone beneath this conglomeratic limestone is well exposed in a highway cut about 3 miles west of Coffeyville. The oölitic limestone which is so prominent near Independence, is very light gray and weathers creamy-white. Much of this rock is prominently cross-bedded. It is highly fossiliferous, containing a large variety of brachiopods, bryozoans, and mollusks. Near Kansas City a limestone 1 foot or less in thickness, separated from the Cement City by a few inches of shale that contains abundant *Teguliferina*, is thought to represent the Corbin City member. This limestone is suboölitic to coquinoid and contains *Osagia*.

All of the observed characters suggest that the Cement City limestone is to be compared to the so-called "upper limestones" of the typical cyclic succession of beds in the Pennsylvanian limestone formations. The Corbin City limestone is very definitely a "super" limestone, as designated in this cycle.

The thickness of the Corbin City member ranges from a feather edge to approximately 50 feet, but the thickness is highly variable within even short distances.

CHANUTE SHALE (Haworth and Kirk, 1894), Haworth and Bennett, 1908

1894, *Chanute shale*, HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 109. Includes beds between the Winterset and Iola limestones. "Above the Erie limestone [Hertha to Winterset] there is another system of shales and sandstones, which in places reach a thickness of nearly 100 feet, but which along the Neosho river section possibly does not exceed 100 feet. It reaches maximum thickness in the vicinity of Thayer, where it is estimated to be 150 feet thick. It extends from below Osage Mission to above Chanute, which town may well give it a name, so that it may be called the Chanute shale. Here as elsewhere sandstone appears and disappears with great readiness. Around Thayer the sandstone occurs in heavy beds, some of which produce excellent building material. Below the sandstone at Thayer a seam of coal is found of sufficient thickness and quality to justify its being worked." —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 38. Includes beds between the "Drum [Dennis] and †Earlton [Iola] limestones." Since Adams in 1904 (see below) placed the lower boundary of the Chanute shale at the top of the Bronson limestone, which term he proposed to replace the invalid name †Erie, and since he erroneously called this limestone Drum in the southern part of the Iola quadrangle, it is clear that the intended definition of the boundaries of the Chanute by Adams in 1903 is the same as the original definition by Haworth and Kirk. —— 1904, ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 19. Applies name to shale between the Bronson and Iola limestones in the north part of the Iola quadrangle, and between the Dennis (called Drum limestone in text, name changed on errata sheet) and Iola limestones in the south part of the quadrangle. Notes "lenses of limestone at about the same horizon in the upper part," but regards them as local. These "lenses" are Drum limestone of present classification. —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14, pl. 3. Includes beds between Winterset and Iola limestones. Seventy-five feet of shale above the Drum limestone is classed as "Chanute shale in part" and placed as lowermost member of Wilson formation. One hundred feet of shale called Cherryvale, next below Drum, is classed as "part of Chanute" in plate but not mentioned in text. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 3. Describes formation in Independence quadrangle, using same classification as Schrader and Haworth, 1906. —— 1908, *HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 97. Applies Chanute to shale between Drum and Iola limestones. In one place correlate the Chanute with beds at Kansas City between "the oölite [Westerville] and base of number 98 [Argentine]" and in another place with "number 97 [Lane]" which is the shale between the Raytown and Argentine limestones. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 27. Beds between the "Drum" [Westerville] and "Iola" [Argentine] limestones are called Chanute shale. This follows one of the suggested correlations of Haworth and Bennett. Thus defined, the Chanute contains two persistent limestones which are here named Cement City and Raytown. The Chanute shale is classed as a member of the Kansas City formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 98. Includes beds between Drum and Iola limestones and classes the Chanute as a member of the Kansas City formation. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 35. Same as Moore and Haynes, 1917. —— 1932, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. States that owing to miscorrelation the so-called Chanute shale at Kansas City includes more than the typical Chanute shale. According to the revised classification the Chanute shale occupies the interval between the top of the Cement City limestone and a horizon a foot or so below the base of the Raytown limestone. —— 1933, BARTLE, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 23. Same as Hinds and Greene. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 48, 174.

1896, †*Thayer shale,* Adams, G. I., Kan. Univ. Geol. Survey, vol. 1, p. 24. Applies name to the shale, about 100 feet at Thayer, between †"Independence" [Dennis] and Iola limestones. Includes Thayer coal, coal mined south of Brooks and south of Independence. It is probable that Adams miscorrelated limestone now called Dennis near Thayer with the †Independence [Drum] limestone, for the true Drum is very inconspicuous in this region. This is indicated by the fact that he later abandoned Thayer as a synonym of the older name Chanute, which was applied to beds between the Dennis and Iola limestones. —— 1896, Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 76. Includes beds between the †Erie [Bronson] and Iola limestones. —— 1896, Bennett, J., Kan. Univ. Geol. Survey, vol. 1, p. 97. Same as Kirk. —— 1896, Haworth, E., Kan. Univ. Geol. Survey, vol. 1, p. 131. Includes shale between the †Independence [Dennis] and Iola limestones, without making any reference to the previously introduced term Chanute. —— 1895, Haworth, E., Am. Jour. Sci., (3), vol. 50, p. 459. Includes shale between †Erie [Bronson] and Iola limestones, but states that it forms main mass of bluffs along Verdigris and Fall rivers from Fredonia and Benedict southward [Lane-Bonner Springs shale in part]. —— 1900, Keyes, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 87. Includes beds between the †Bethany [Bronson] and Iola limestones. Credits introduction of the term Thayer to Broadhead (St. Louis Acad. Sci., Trans., vol. 4, p. 481, 1884), but it appears that Broadhead's use of the term was incidental and not formal.

Type locality, Chanute, Neosho county, Kansas. Typically exposed in SE¼ sec. 33, T. 26 S., R. 18 E., along highway and at several places in the central part of T. 28 S., R. 18 E.

Early usage of the term Chanute shale is somewhat confused because of miscorrelations of the limestones below and above. It is clear, however, that it was intended to designate by this name the shale and thin sandstone beds that form the plain extending eastward from Chanute to the prominent escarpment made by the Bronson limestones. The Iola limestone is well exposed in the vicinity of Chanute and it can be traced without difficulty to Iola, about 20 miles to the north. The term †Thayer shale is a subsequently introduced, synonymous unit. In 1908, Haworth and Bennett restricted application of Chanute shale to include only the upper part of the original Chanute, that is to the beds between the top of the Drum limestone and the base of the Iola limestone. This change may have been occasioned by recognition that the Cherryvale shale corresponds to the lower part of the Chanute as first defined and accordingly by decision to modify this overlap, but there is no discussion or explanation. Nevertheless, application of Chanute in the restricted sense has come to be accepted generally. There are difficulties in drawing the boundaries of the Chanute shale in some sections because of the thinning and local disappearance of the limestones below and above. These limestones have been miscorrelated, also, which leads to erroneous identification of beds classed as Chanute.

Recent field studies by Newell, moreover, have established that there is an important disconformity at the base of the Chanute beds in part of southeastern Kansas, including especially the region of the "Chautauqua arch," a structural uplift that affects Montgomery and Chautauqua counties, Kansas, and adjacent territory in northern Oklahoma. This disconformity is observed also in the vicinity of Chanute where the Drum limestone and underlying shale is eroded, so that sandstone of the basal Chanute rests directly on different beds of the upper Dennis limestone. This observation explains the original definition of Chanute shale as extending from the top of the †"Erie" [Bronson] limestone, of which the Dennis is the uppermost division, to the base of the Iola limestone. Since the shale and sandstone that, because of the disconformity, tends downward locally to stratigraphic horizons below the Drum, are of post-Drum pre-Iola age, corresponding to deposits that elsewhere lie between the Drum and Iola limestones, the Chanute shale may be recognized, as in later usage of the Kansas Geological Survey, to include beds above the Drum and below the Iola.

Careful tracing of outcrops accompanied by study of many sections shows that the supposed Drum limestone at Kansas City is the Westerville limestone, which is older than Drum, and that the supposed Iola limestone of this region is the Argentine limestone, which is younger than true Iola. Therefore, the so-called Chanute shale at Kansas City embraces beds that are stratigraphically lower and higher than the Chanute shale at the type locality.

The Chanute shale is mainly composed of yellowish-brown or buff sandy shale and dark-gray or greenish clay shale, but especially toward the south it contains much thin-bedded sandstone and there is at least one persistent coal bed. The sandy shale and sandstone occur chiefly in the upper part of the formation, above the coal bed mentioned. Where the sandstone above the coal becomes prominent it is differentiated under the name *Cottage Grove sandstone member*. The lower part of the Chanute shale is predominantly clayey but sandy shale and sandstone is found here also and locally there is very calcareous shale containing limestone nodules. A widespread deposit of maroon shale, 1 to 5 feet thick, averaging about 2 feet, occurs in northeastern Kansas and northwestern Missouri near the base of the Chanute. A coal bed, called the *Thayer coal,* extends almost uninterruptedly from the vicinity of Kansas City to Oklahoma. In the north it ranges in thickness from less than an inch to 3 or 4 inches and in some sections occurs very near the top of the formation. Farther south the coal is found at an increasing distance below the top of the Chanute up to 50 feet or more. The coal has a maximum thickness of about 2.5 feet and has been mined near Thayer and in the neighborhood of Independence. Marine fossils are not common in most parts of the Chanute shale but they occur in places. A fairly well preserved assemblage of land plants has been collected from the Chanute shale near Thayer.

The thickness of the Chanute shale ranges from about 10 feet at some places near Kansas City to 100 feet or more in southern Kansas. The average thickness in northeastern Kansas is about 25 feet and the thickness increases rather uniformly southward.

The Chanute is correlated with beds in the lower part of the Ochelata formation of northern Oklahoma.

CHANUTE SHALE
COTTAGE GROVE SANDSTONE MEMBER, Newell, 1932

1932, **Cottage Grove sandstone,* NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 49.

Type locality, Cottage Grove Township, in Allen county, Kansas.

The Cottage Grove sandstone member of the Chanute shale constitutes about the upper half or more of the formation in much of southeastern Kansas. The sandstone is yellowish-brown or tan and includes both thin-bedded and massive sandstone. Some parts of the member are soft and friable. Others consist of tightly cemented rock that resists weathering. According to reconnaissance studies it appears that the Cottage Grove sandstone is represented in northern Oklahoma by one of the prominent escarpment-forming sandstones west of the Hogshooter outcrop. The thickness of the Cottage Grove sandstone ranges from 2 or 3 feet in the northermost area where it is differentiated to about 50 feet in southern Kansas.

IOLA LIMESTONE, Haworth and Kirk, 1894

1894, **Iola limestone,* HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, pp. 109, 116, 119. The limestone underlying the town of Iola, Kan. —— 1895, HAWORTH, E., Kan. Univ. Quart., vol. 3, p. 276. —— 1895, HAWORTH, E., Am. Jour. Sci., (3), vol. 1, p. 459. —— 1896, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 1, p. 132, also pp. 47, 132, 158, 160. —— 1896, KIRK, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 77. —— 1896, BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, p. 97. —— 1903.

Adams, G. I., U. S. Geol. Survey, Bull. 211, p. 40. Formation "generally correctly correlated." Occurs between "Vilas [Chanute] shale" below and "Lane [Lane-Bonner Springs] shale" above. —— 1904, Adams, G. I., U. S. Geol. Survey, Bull. 238, p. 19. —— 1906, Schrader, F. C., and Haworth, E., U. S. Geol. Survey, Bull. 296, p. 14. Limestone 2 to 3 feet in Independence quadrangle below the †Concreto [Lane] shale and above the Chanute shale. Classed as a member of the †Wilson formation. —— 1908, Schrader, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 3. Same as Schrader and Haworth, 1906. —— 1908, Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 98. Describe type outcrops at Iola and erroneously refer to a 30-foot limestone [Argentine] in the bluffs of Kansas City as equivalent to the Iola. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 98. Class the Iola as uppermost member of the Kansas City formation. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 37. Same as Moore and Haynes, 1917. —— 1932, Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Notes that the so-called Iola limestone at Kansas City is a younger formation than the type Iola, and proposes the new term, Argentine limestone, for it. States that the Iola is represented at Kansas City by the Raytown limestone and an underlying thin limestone. —— (1935) 1936, Newell, N. D., and Jewett, J. M., Kan. Geol. Survey, Bull. 21, pp. 51, 175.

1896, Not *Iola limestone,* Adams, G. I., Kan. Univ. Geol. Survey, vol. 1, pp. 24, 25. Erroneously classes as Iola the limestone capping Table Mound, 6 miles northwest of Independence. This is Stanton limestone. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 28, 119. Accept Haworth and Bennett's correlation of the Iola limestone with Broadhead's No. 98 [Argentine limestone] at Kansas City, where it is prominent "Crusher ledge" capping bluffs. The "Iola" is classed as uppermost member of the Kansas City formation. —— 1933, Bartle, G. G., Mo. Bur. Geol. and Mines, 57th Bien. Rept., App. 3, p. 24. Same as Hinds and Greene.

1915, *Chanute shale* (part), Hinds, H., and Greene, F. C., op. cit. The Iola limestone at Kansas City and elsewhere in Missouri is included in the so-called Chanute shale. —— 1933, Bartle, G. G., op. cit.

Type locality, Iola, Kan. Well exposed at the cement plant quarry, NE¼ sec. 2, T. 25 S., R. 18 E.

The Iola limestone is a prominent light-gray limestone about 30 feet thick at Iola where it is extensively quarried. Beneath this limestone is the Chanute shale and above it at Iola is the Lane-Bonner Springs shale which is formed by the coalescence of the Lane and Bonner Springs shales of northeastern Kansas. At Kansas City and neighboring territory the limestone that has long been identified as Iola is now known to be an entirely different formation that belongs above the Lane shale. The main part of the true Iola is represented in northeastern Kansas and northwestern Missouri by the limestone called Raytown which has previously been classed as a subdivision of the Chanute shale.

At the type locality, the Iola limestone is composed chiefly of light bluish-gray, irregularly thin-bedded fine-grained limestone that contains numerous thin veinlets of calcite. In fresh exposures the rock appears massive, but where weathered the bedding is distinct. The basal part of the limestone, 1.5 to 2 feet, appears slightly more bluish and more massive than the higher part of the formation from which it is separated by a few inches of shale, but study of the section at Iola would hardly lead one to notice this unless he had followed the outcrop of the formation for many miles northeastward. Between Iola and Kansas City the lowermost bed of the Iola becomes increasingly distinct as a unit and is identifiable as a typical "middle limestone" member of the sedimentary cycle. The shale above this limestone persistently carries small phosphatic nodules which aid in identifying the horizon, and part of the shale becomes black and fissile, as may be expected of the shale next above a "middle limestone." As has been stated, the main body of the Iola is traced into the Raytown limestone at Kansas City. Three members are accordingly recognized in the Iola formation, the Paola limestone member below, the Muncie Creek shale member in the middle, and the Raytown limestone member above.

The Iola limestone is known to extend northeastward to south-central Iowa and northward to the Platte Valley in Nebraska, in both of which regions the Paola and Muncie Creek members are found to be strongly defined and somewhat more persistent than the Raytown member. In southern Kansas the Iola becomes very thin and appears locally to be absent. The limestone is not found along the state line either in Kansas or Oklahoma, but it is thought to be represented by the Dewey limestone a little farther south. The thickness of the Iola ranges from a feather edge to a maximum of about 30 feet, near Iola. The average thickness of the formation in northeastern Kansas is about 7.5 feet.

IOLA LIMESTONE
PAOLA LIMESTONE MEMBER, Newell, 1932

1932, **Paola limestone*, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Name applied to blocky, dense, blue limestone, 1 to 2 feet thick, classed as the basal member of the Iola formation. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 52.

Type locality, north edge of Paola, Kan.

The Paola limestone member lies at the base of the Iola formation. It consists of fine-grained, dense, hard limestone that in part is like lithographic stone in texture. The rock is brittle and breaks with a subconchoidal fracture. It occurs as a single massive bed, one to two feet thick, and is typically intersected by vertical joints. The color of the fresh rock ranges from dark blue to bluish-gray, and unlike some of the higher beds in the formation which weather creamy or brown, the Paola limestone remains bluish-gray after weathering. The upper surface of the member is slightly hummocky, being marked by irregularly disposed depressions and protuberances. Worm borings, marked by iron-stained unevenly cylindrical rock material that differs slightly from the matrix, extend downward a few inches from the top of the bed. The Paola member is identified near Independence in southern Kansas and is persistent northward as far as the Iola is known.

IOLA LIMESTONE
MUNCIE CREEK SHALE MEMBER, Newell, 1932

1932, **Muncie Creek shale*, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Comprises 1 to 3 feet of shale between the Paola limestone below and the Raytown limestone above. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 52.

Type locality, Muncie Creek, Wyandotte county, Kansas. Typically exposed in the bluffs between Muncie and City Park, Kansas City, Kan.

The Muncie Creek shale member of the Iola limestone overlies the Paola limestone member and occurs beneath the Raytown limestone member. In the type region just west of Kansas City, Kan., where the shale is excellently exposed for several hundred yards in highway cuts, the lower part of the member is composed of black fissile shale, such as normally overlies the "middle limestones" in the sedimentary cycle. The upper part of the member is gray or buff clay shale containing numerous dark-gray or black phosphatic concretions, one fourth inch to one half inch in diameter. The surface of these concretions weather light-gray or nearly white, but the interior remains dark. Phosphatized specimens of *Conularia crustula* occur also in this zone. Northward the black shale is very persistent but to the south it becomes thinner and disappears in southern Johnson county. The light-colored shale and the zone of concretions can be traced to Iola. In exposures near Independence the black fissile shale reappears.

The thickness of the Muncie Creek shale ranges from less than one foot to a maximum of about 3 feet. If it were not for the geographic persistence and significance of this unit in terms of cyclic sedimentation, differentiation of such a thin shale as a distinct member would hardly be justified. Despite its thinness, the Muncie Creek member is by no means the least important element in the Iola formation.

Iola Limestone

RAYTOWN LIMESTONE MEMBER, Hinds and Greene, 1915

1915, **Raytown limestone,* Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 27. Name proposed for a 5-foot limestone in the upper part of the "Chanute shale" at Raytown, Jackson county, Missouri. —— 1932, Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Notes that the Raytown bed, instead of being a member of the Chanute shale, is in reality the upper, main part of the Iola limestone. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 52.

Type locality, Raytown, Jackson county, Missouri. Well exposed in railroad cut just west of the town.

The Raytown limestone member of the Iola limestone overlies the Muncie Creek shale. It is clear from the description of Hinds and Greene that the Raytown limestone, as defined by them, does not include the Muncie Creek shale and Paola limestone, and consequently the name is here used in the precise sense of the original definition. The member is found to represent the main part of the Iola limestone, however, rather than a local bed in the Chanute shale.

The Raytown limestone is a dark-gray or buff limestone that in part weathers dark-brown. Presumably due to mottled coloration and to an abundance of large fossil shells that add a light-gray pattern to the weathered rock surface, the Raytown is commonly termed the "calico ledge" by quarrymen at Kansas City. It is also sometimes termed the "large fossil bed" in this region. Near Raytown the member appears very massive or on weathered crops rather even beds a few inches to a foot or more in thickness are evident. Southwestward the limestone becomes gradually thinner bedded, with uneven wavy partings between the layers. The color changes also to a light-gray and weathered outcrops appear light-buff or creamy-white. This is the character of the member at Iola. The Raytown member contains abundant fossils at most places but the composition of the fauna differs somewhat in the south and in the north. At Iola a large variety of brachiopods, bryozoans and, near the top of the member, crinoids has been obtained. Near Kansas City, large productids, especially *Linoproductus, Echinoconchus* and somewhat smaller *Juresania,* are very abundant. *Neospirifer dunbari* is locally common and bryozoans occur in profusion.

The thickness of the Raytown limestone averages about 5 feet near Kansas City. In Miami county, Kansas, it is about 6 feet, but farther south the member gradually thickens to 28 feet near Iola. The Raytown limestone is persistent in northern Missouri and in Iowa, but is locally absent where the underlying Muncie Creek and Paola members are found.

LANE SHALE, Haworth and Kirk, 1895

1895, **Lane shale,* HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 3, p. 277. —— 1895, HAWORTH, E., Am. Jour. Sci. (3), vol. 50, p. 460. "Passing upwards from the Iola limestone and leaving unnoticed a shale bed 40 to 50 feet thick and a limestone one-fourth as great, we come to the Lane shale, which in many places reaches 150 feet in thickness." —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 100. Used for the shale between Iola and †Allen [in different places Wyandotte and Plattsburg] limestone. "The term Lane shales was applied by Haworth in 1895 to the bed of shales first above the Iola limestone, and is here used with the same significance." —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 99. Lane shale classed as a member of the Lansing formation. Includes beds between Iola [Argentine at Kansas City] and Plattsburg limestones. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 38. Same as Moore and Haynes. —— 1932, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Notes that the limestone overlying Lane shale at Lane, Franklin county, Kan., is not the Plattsburg formation, but an unnamed limestone for which the name Wyandotte is proposed. It is stated that the shale bed at Kansas City between the Raytown and "Iola" [Argentine] limestones, called upper Chanute by Missouri geologists, is really the Lane shale. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 55.

1896, Not *Lane shale,* KIRK, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 79. Describes as Lane shale the shale and sandstone between †Carlyle [Stanton] limestone and †Garnett [Oread] limestone west of Neosho Falls. This really includes beds belonging to the Pedee and Douglas groups. —— 1896, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 1, p. 134. Used for shale between †Carlyle [Plattsburg] and †Garnett [Stanton] limestones. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 28. Apply the name to the shale between Iola [Argentine] and Plattsburg limestones. Names the Farley limestone as a member of the "Lane."

1904, †*Concreto shale* (part), ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 20. Applies this name to shale about 75 feet thick above the Iola limestone and below the †Allen [Plattsburg] limestone, near Iola. Type locality is a small town north of Gas (not shown on Iola quadrangle map). —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 14. Use this term for clay shale about 60 feet thick between the Iola and †Allen [Plattsburg] limestones, in the Independence quadrangle. Classed as a member of the Wilson formation. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 3. Same as Schrader and Haworth.

Type locality, Lane, Franklin county, Kansas. Comprises thick shale above flood plain level in river bluffs in S½ sec. 33, T. 18 S., R. 21 E.

The Lane shale includes beds between the top of the Iola limestone and the base of the Wyandotte limestone. It is developed as a distinct unit from the type locality in Franklin county northward, but disappearance of the Wyandotte limestone a short distance south of Lane makes it impossible to recognize the upper boundary of the Lane shale. Accordingly in this region the Lane is combined with overlying shale under the designation Lane-Bonner Springs shale.

Confusion in identification of the Lane shale and consequent misuse of the term in many sections is due to lack of understanding of the adjacent limestones. The Iola limestone which lies next below the Lane at the type locality has been miscorrelated with a higher formation, now called Argentine limestone, at Kansas City and nearby places. Hence the Lane shale was supposed to belong above the Argentine. Field studies have shown also that the limestone next above the Lane shale at Lane is not the †Allen [Plattsburg] as determined by Haworth, but a lower formation that is not present in Allen county. The base of the Plattsburg limestone does not mark the upper boundary of the Lane shale, as inferred by several geologists. The limestone next above the Lane shale is traced into limestone that is called Argentine.

The Lane shale, thus defined, is variable both in lithologic characters and in thickness. At some places the entire unit consists of dark bluish-gray clayey shale. This type of deposit is mostly found where the formation is thin, that is, about 15 to 35 feet in thickness. Locally, as in parts of the Kansas City region, the clay shale contains fairly common marine invertebrates, including remarkably preserved complete crinoid calices with attached arms. Where the Lane shale is thick, that is, 50 to about 110 feet, most of the shale is sandy and micaceous. The color varies from light-gray to yellowish-brown or buff. Thin plates and beds of friable sandstone appear, especially near the top where in many places there is a zone of thin alternating bands of gray sandy shale and yellow brown sandstone. The thick sandy shale contains carbonaceous streaks but coal beds have not been observed. Fossils are mostly lacking, a few plant remains being found at some outcrops.

The Lane shale is rather thin but it is persistent from eastern Miami county, Kansas, northeastward and northward. It has been recognized in northern Missouri, Iowa and in the Platte Valley section of Nebraska. The thickness of the shale in Johnson and eastern Miami counties, Kansas, ranges from 16 to 40 feet, the average being about 25 feet. In western Miami and eastern Franklin counties the thickness of the Lane increases to about 100 feet and locally measurements up to 110 feet have been made. To the southwest the Lane merges with the overlying Bonner Springs shale to form the Lane-Bonner Springs shale. This combined unit thins southward to about 75 feet near Iola and about 60 feet in southern Kansas. The Lane-Bonner Springs shale is dark bluish or bluish-gray, clayey to fine silty and is used at several places for manufacture of bricks. It is sparsely fossiliferous or barren of fossils as seen in different places.

WYANDOTTE LIMESTONE, Newell, 1932

1866, †*Cave limestone,* SWALLOW, G. C., Kan. Geol. Survey, Prel. Rept., pp. 20-21, 75. Describes "bluish-gray and brown jointed limestone with marly partings, on Beaver creek, Sugar creek, and at Lecompton, 15 to 30 feet thick," occurring next below †"Stanton limestone series." Field work has shown that excepting at Lecompton, where the beds belong to a very much higher horizon, this is the Wyandotte limestone, occurring first below the type Stanton limestone, which is now called Plattsburg. —— 1867, SWALLOW, G. C., Am. Ass'n Adv. Sci., Proc., vol. 15, p. 68. Same.

1895, †*Garnett limestone* (part), HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 460. Includes beds near Lane, Franklin county, now known to belong in the Wyandotte limestone.

1899, †*Parkville shale* (part), KEYES, C. R., Am. Geologist, vol. 23, p. 305. Includes beds between top of the Iola [Argentine] and base of Plattsburg. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 87 Same.

1908, *Iola limestone,* HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 98. Refers to Frisbie-Argentine portion of Wyandotte limestone at Kansas City. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 28. Same.

1908, †*Allen limestone,* HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 100. Refer under this name to outcrops of Wyandotte limestone near Lane, eastern Franklin county.

1915, *Lane shale* (part), HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 28. Includes beds between top of "Iola" [Argentine] and base of Plattsburg. The Farley limestone, here defined, and "lower Lane shale" are now included in the Wyandotte limestone.

1932, **Wyandotte limestone,* NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Includes beds between the Lane shale below and the Bonner Springs shale above. Contains the following members, named in order upward, Frisbie limestone, Quindaro shale, Argentine limestone, Island Creek shale, and Farley limestone. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 58.

Type locality, along Kansas river in southern Wyandotte county, Kansas. Typical exposures in quarry of Lone Star Cement Co., at east edge of Bonner Springs.

The Wyandotte limestone comprises the beds between the top of the Lane shale and the base of the Bonner Springs shale. As has been noted in discussing the Lane shale, the limestone that rests on this shale at Lane is not equivalent to the †Allen [Plattsburg] as supposed by Haworth but is traceable into the "Iola" [Frisbie-Argentine] limestone capping the bluffs at Kansas City. This limestone is found to coalesce with beds named Farley by Hinds and Greene, and accordingly the Wyandotte limestone is regarded as including the Farley member. Additional reasons for recognizing the Wyandotte limestone as a distinct formation are the prominence of these beds in northeastern Kansas and northwestern Missouri, the proof that they are separate from the true Iola below and from the Plattsburg above, and the discovery of typical elements of the sedimentary cycle within the Wyandotte that with some variation duplicate development of these elements in the Iola and Plattsburg.

The Wyandotte limestone consists predominantly of light-colored limestone but it contains two shale members of which the upper one locally attains a thickness of 20 feet or more. The lithologic and faunal characters of the formation will be described more fully in paragraphs devoted to the respective members. As a whole, the formation is readily traceable on the basis of physical characters, and stratigraphic position and because of its influence on topography. It is, however, variable in thickness and in the development of its constituent members in different places. The Wyandotte has a thickness of about 40 feet in Wyandotte and Johnson counties, but is somewhat thinner (20 to 25 feet) in most of Miami and Franklin counties. The formation pinches out rather abruptly southwest of Lane and is not recognized farther south. It has been traced far to the north, however, and is identified in sections measured in southwestern Iowa and along the Platte valley in Nebraska.

The Wyandotte limestone contains the following members, named in upward order: Frisbie limestone, Quindaro shale, Argentine limestone, Island Creek shale, and Farley limestone.

Wyandotte Limestone
FRISBIE LIMESTONE MEMBER, Newell, 1932

1908, *Iola limestone* (part), Haworth, E., and Bennett, J. (See under Wyandotte limestone.)

1932, **Frisbie limestone member,* Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 59.

Type locality, Frisbie, center N. side sec. 17, T. 12 S., R. 23 E., in northern Johnson county, Kansas.

The Frisbie limestone member of the Wyandotte limestone is the basal subdivision of the formation. It consists of dark-blue or blue-gray dense limestone that differs from succeeding beds in its massive character and where typically developed in the presence of vertical joints. The member is not very fossiliferous but commonly shows thin irregular calcite veinlets that appear to be of organic origin. The thickness of the Frisbie limestone ranges from 1 to 3 feet. It corresponds to the "middle" limestones of the Shawnee limestone formations of the Virgil series, and is homologous to the Middle Creek member of the Swope limestone, the Canville member of the Dennis limestone, and the Paola member of the Iola limestone.

Wyandotte Limestone
QUINDARO SHALE MEMBER, Newell, 1932

1908, *Iola limestone* (part), Haworth, E., and Bennett, J. (See under Wyandotte limestone.)

1932, **Quindaro shale,* Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 59.

Type locality. Named from Quindaro township in northeastern Wyandotte county, Kansas. Typically exposed at Boyn's quarry, NW. cor. sec. 30, T. 10 S., R. 25 E., northeast of Welborn, Kan.

The Quindaro shale member of the Wyandotte limestone lies between the Frisbie limestone member below and the Argentine limestone above. Locally this shale is black, fissile and carbonaceous, as is the normal character of shale overlying dense blue "middle" limestones, but in many exposures the Quindaro consists of yellowish calcareous shale. There are a few outcrops in which the Quindaro member is represented by shaly limestone that grades without sharp demarcation into the limestones above and below. The thickness of the Quindaro shale is only 1 to 2 feet.

WYANDOTTE LIMESTONE
ARGENTINE LIMESTONE MEMBER, Newell, 1932

1895, †*Garnett limestone* (part), HAWORTH, E. (See under Wyandotte limestone.)

1908, †*Allen limestone* (part), HAWORTH, E., AND BENNETT, J. (See under Wyandotte limestone.)

1908, *Iola limestone* (part), HAWORTH, E., AND BENNETT, J. (See under Wyandotte limestone.)

1932, **Argentine limestone,* NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 60.

Type locality, Argentine station, Kansas City, Kan. Typically exposed in quarry just south of 26th St. and Metropolitan Ave., Kansas City, Kan.

The Argentine limestone member of the Wyandotte limestone overlies the Quindaro shale member and is overlain by the Island Creek shale member, or where this is absent by the Farley limestone member. As previously noted, the Argentine limestone comprises the main part of the so-called "Iola limestone" of previous reports on the geology of the Kansas City district and in northeastern Kansas and Missouri. It is called the "crusher ledge" at Kansas City.

The Argentine limestone is light bluish-gray in color when fresh and weathers creamy-white, light-buff, or in part grayish-white. The bedding is thin and uneven, many of the layers being distinctly nodular. Very thin wavy partings of clay shale occur between many of the beds. The rock is mostly very fine-grained but there is much crystalline calcite in the form of thin irregular veinlets and small cavity fillings. Fossils are numerous in most places, the fauna consisting chiefly of brachiopods and bryozoans. The Argentine limestone is about 30 feet thick at Kansas City and has an average thickness of 20 feet in Johnson and Miami counties. The limestone disappears a short distance south of Lane in eastern Franklin county but is persistent northward in Missouri. It is identified in sections in Iowa and on the Platte in eastern Nebraska. Because of its thickness and resistance to erosion the Argentine makes a well defined escarpment, but where the Island Creek shale is thin the Argentine and Farley limestones together form an escarpment or a bench on the slope below the outcrop of Lansing limestones.

WYANDOTTE LIMESTONE
ISLAND CREEK SHALE MEMBER, Newell, 1932

1899, †*Parkville shale* (part), KEYES, C. R. (See under Wyandotte limestone.)

1915, *Lane shale* (part), HINDS, H., AND GREENE, F. C. (See under Wyandotte limestone.)

1932, **Island Creek shale,* NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 60.

Type locality, Island Creek, in quarry at NW. cor. sec. 11, T. 10 S., R. 23 E., near Wolcott, Wyandotte county, Kansas.

The Island Creek shale member of the Wyandotte limestone lies between the Argentine limestone below and the Farley limestone above. It corresponds to the lower part of the "Lane shale" as described by Hinds and Greene in northwestern Missouri. At the type locality the Island Creek member consists of 43 feet of bluish to greenish clay shale. The thickness of this shale is quite variable, the maximum being about 40 feet and the minimum a feather edge. The shale is fairly uniform in lithologic character and it is mostly unfossiliferous.

WYANDOTTE LIMESTONE
FARLEY LIMESTONE MEMBER, Hinds and Greene, 1915

1899, †*Parkville shale* (part), KEYES, C. R. (See under Wyandotte limestone.)

1915, **Farley limestone,* HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 29. Classed as a member of the Lane shale. —— 1932, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Classed as the uppermost member of the Wyandotte limestone. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 60.

Type locality, Farley, Platte county, Missouri. Exposures north of bridge just north of center sec. 34, T. 52 N., R. 35 W., Missouri.

The Farley limestone is classed as the uppermost member of the Wyandotte limestone because in parts of Wyandotte, Leavenworth, Johnson and Miami counties, where the Island Creek shale is very thin or absent, the Farley is very closely associated or is in contact with the Argentine limestone. Also, in many places the Farley exhibts the characters of a "super" limestone, including oölitic beds, fragmental, apparently brecciated limestone, and dense blue, massive to flaggy layers. These types of deposits are found in other formations above the normal light-colored, thin, wavy-bedded "upper" limestones. It must be noted, however, that some of the Farley outcrops contain beds that are not readily classifiable as typical "super" lithology. The variety of kinds of limestone and the variation of the member from place to place, on the other hand, do accord with classification of the Farley as a "super" limestone. Near Farley this member is represented by three beds of blue limestone separated by shale, the thickness of all amounting to about 13 feet. Farther south, in the vicinity of Parkville, Mo., and in part of eastern Wyandotte county, Kansas, the Farley is represented by brownish-gray, slightly ferruginous oölite about 8 feet thick. In central and southeastern Johnson county the Farley comprises about 20 feet of light-gray somewhat thinly bedded fragmental limestone. In southwestern Johnson and northwestern Miami counties the Farley cannot be differentiated clearly from the underlying Argentine limestone.

BONNER SPRINGS SHALE, Newell, 1932

1899, †*Parkville shale* (part), KEYES, C. R. (See under Wyandotte limestone.)

1904, †*Concreto shale* (part), ADAMS, G. I. (See under Lane shale.)

1915, *Lane shale* (part), HINDS, H., AND GREENE, F. C. (See under Wyandotte limestone and Lane shale.)

1932, **Bonner Springs shale*, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93. —— 1932, DUNBAR, C. O., AND CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 5, p. 17, table C. —— 1933, CONDRA, G. E., AND UPP, J. E., Neb. Geol. Survey, (2), Paper 4, p. 15. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 67.

Type locality, Lone Star Cement Plant quarry, northeast of Bonner Springs, Kan.

The Bonner Springs shale includes strata between the Wyandotte limestone, below, and the Plattsburg limestone above. It corresponds to the upper part of the so-called "Lane shale" of Hinds and Greene in northwestern Missouri. The formation consists of 10 to 25 feet of gray or buff shale, the lower part of which is sandy and in places grades into soft sandstone. The upper part of the shale consists of olive-green clay shale and, near the top, 1.5 feet or less of maroon clay shale which is persistent in Miami and Johnson counties. The maroon shale is commonly overlain by a thin layer of ocher-yellow or greenish calcareous shale or soft nodular limestone. The sandy beds in the lower part of the Bonner Springs shale contain remains of land plants in some places. Locally, as at

De Soto and one half mile west of Bonner Springs, the Bonner Springs shale is absent, apparently due to nondeposition or perhaps to erosion preceding deposition of the Plattsburg, for the latter formation with a shell breccia at the base rests directly on the Farley member of the Wyandotte limestone. The maximum observed thickness of the Bonner Springs shale is about 45 feet, reported by Newell in township 14 south, range 24 east. South of the point in southeastern Franklin county where the Wyandotte limestone disappears, the Bonner Springs shale rests directly on the Lane shale and since it is not practicable to separate the two lithologically similar units, the part of the section between the Iola and Plattsburg limestones may be designated as Lane-Bonner Springs shale.

LANSING GROUP (Hinds, 1912), Moore, 1932

1887, †*Dun limestone,* HAY, ROBERT, Kan. Acad. Sci., Trans., vol. 10, p. 7. Named from Dun, west of Neodesha, Wilson county, Kansas. Includes Plattsburg, Vilas, and Stanton formations.

1894, †*Garnett limestone,* HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 110. Comprises formations now designated Plattsburg limestone, Vilas shale and Stanton limestone. —— 1894, HAWORTH, E., Kan. Univ. Quart., vol. 2, pp. 120, 125. —— 1895, HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 460. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 41. States that the Garnett limestone is a synonym of †Carlyle and that both are synonymous with Stanton.

1898, †*Pottawatomie formation* (part), HAWORTH, E. (See under Bronson group.) Includes strata from base of †Erie [Bronson group] limestone to top of †Garnett [Lansing group] limestone.

1899, *Plattsburg limestone,* KEYES, C. R., Am. Geologist, vol. 23, p. 305. Includes strata now classed as Plattsburg, Vilas and Stanton.

1900, *Stanton limestone,* KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 88. Includes strata now classed as Plattsburg, Vilas and Stanton.

1906, †*Wilson formation* (part), SCHRADER, F. C., AND HAWORTH, E., see under Kansas City group. Includes strata from base of Chanute shale to top of †Piqua [Stanton] limestone.

1912, *Lansing formation,* HINDS, H., Mo. Bur. Geol. and Mines, (2), vol. 2, p. 7. Includes beds from base of Lane [Island Creek-Bonner Springs] shale to top of Stanton limestone. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 155. Same.. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 99. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, pp. 37-38. Same.

1932, **Lansing group,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 92. Revised to include beds from base of Plattsburg limestone to top of Stanton limestone. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 70.

Type locality, Lansing, Leavenworth county, Kansas.

The Lansing group, as redefined by me, includes the strata from the base of the Plattsburg limestone to the top of the Stanton limestone. The Vilas shale, which occurs between these limestones, is mostly rather thin, so that the group is a fairly compact segregation of limestones that stand out as a distinct, widely persistent stratigraphic unit. It makes an escarpment that is readily traced across Kansas. Subsurface studies show that the group is recognizable throughout the eastern and central parts of the state where these rocks are buried, but in western Kansas the Lansing is not clearly separable from underlying Kansas City beds.

The reasons for changing the lower boundary of the Lansing group from the position originally designated, at the top of the limestone that is now called Argentine, are (1) observation that this boundary cannot be traced where the Farley limestone coalesces with the Argentine and where, through absence of the Wyandotte limestone, the Bonner Springs shale lies directly on Lane shale, (2) discovery that supposed faunal distinctions, such as the reported occurrence of *Enteletes* in Lansing, but not in older beds, do not hold, and (3) conclusion that the lithologic grouping as modified is much more natural. Throughout most of eastern Kansas south of the Kansas river the formerly designated boundary between Kansas City and Lansing beds cannot be followed, but the base of the Plattsburg, on the other hand, can be traced easily. *Enteletes* and other common "Lansing fossils" have been found in the Argentine limestone. In the Kansas City area, where the Argentine and other limestones, here classed as belonging to the Kansas City group, are relatively prominent, there is not so very evident basis for separating the Plattsburg-Stanton beds as a distinct group, but from Miami county southward the Lansing is set well apart from underlying and overlying beds. Finally, if it is agreed that groups are convenient segregations of strata having generally similar lithologic characters and not artificially defined segments of the stratigraphic column with arbitrarily chosen boundaries, it appears that the lower and upper units of a group consisting dominantly of limestone should be limestones. It is not to be supposed that one or other of these units at the bottom and top of the group is a shale.

The thickness of the Lansing group averages about 75 feet, but in parts of southern Kansas it is more than 150 feet.

PLATTSBURG LIMESTONE, Broadhead, 1865

1865, **Plattsburg limestone,* BROADHEAD, G. C., St. Louis Acad. Sci., Trans., vol. 2, p. 317. —— 1872, BROADHEAD, G. C., Mo. Geol. Survey, Rept., 1872. —— 1884, BROADHEAD, G. C., St. Louis Acad. Sci., Trans., vol. 4, p. 482. Notes typical development at Eudora, Kan., of limestone "called Plattsburg limestone" in the Missouri geological report, 1872. "Sixteen feet above this limestone is everywhere found a gray limestone abounding in *Syntrilasma* [*Enteletes*] *hemiplicata*." —— 1895, BROADHEAD, G. C., Mo. Geol. Survey, vol. 8, p. 378. —— 1915, HINDS, HENRY, AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 29. Notes that the Plattsburg (Broadhead's No. 108) is the lower of two closely associated limestones that together equal Haworth's †"Garnett limestone." Statement that the Plattsburg corresponds to Swallow's †"Cave Rock" limestone in Miami county, Kansas, is believed erroneous, for the latter is apparently the Wyandotte limestone. Statement that the upper limestone equals Swallow's Stanton in Miami county, Kansas, is also erroneous, for Swallow's Stanton is really Plattsburg. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 99. "Plattsburg limestone member" of "Lansing formation" occurs between Lane shale and Vilas shale. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 38. —— 1932, NEWELL, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93. Designates members of the Plattsburg limestone, in upward order, Merriam limestone, Hickory Creek shale, and Spring Hill limestone. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 70, 181.

1865, *Stanton limestone,* SWALLOW, G. C., Geol. report of Miami county, Kansas, Kan. Geol. Survey, p. 75. Original definition of Stanton limestone, which field work shows to be the same as Broadhead's Plattsburg.

1894, †*Carlyle limestone,* HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, pp. 109, 119. "North of Iola about 5 miles a new limestone formation occurs at the little station of Carlyle. This is approximately 75 feet vertically above the Iola limestone. . . . The rock is exposed in great abundance by the roadside just north of Carlyle and consists of relatively thin system composed of different layers, the whole aggregating 8 or 10 feet in thickness at this place. The rock is a compact, buff-colored limestone sufficiently sound to be very durable." —— 1896, KIRK, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 78. Limestone 75 to 100 feet above the Iola along Neosho river. Well exposed at Carlyle, 5 miles north of Iola, where it is 15 to 20 feet thick. Exposed near Neosho Falls. —— 1898, HAWORTH, E., footnote in paper by Adams, G. I., Kan. Univ. Quart., vol. 3, p. 97. States †Carlyle is now known to be lower member of the †Garnett. —— 1898, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 104. Says †Carlyle is known to be a synonym of †Garnett and has to be abandoned. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 41. States that the †Carlyle limestone is a synonym of

Stanton. Field work shows that the †Carlyle limestone at the type locality is an exact equivalent of the Plattsburg limestone. Adams was correct in considering †Carlyle a synonym of Stanton, inasmuch as the type Stanton is shown to be typical Plattsburg limestone.

1898, †*Earlton limestone,* ADAMS, G. I., Kan. Univ. Quart., vol. 7, p. 96. Designates limestone that makes prominent escarpment west of Earlton and Chanute. It is said to occur between the "Chanute [Lane-Bonner Springs] shale" below and the Vilas shale above. —— 1898, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, pp. 51, 103. Included near the top of the †Thayer shale, below the Iola limestone, which is erroneous. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 39. Notes that Haworth and Piatt (Kan. Univ. Quart., vol. 2, p. 115, 1894) described this limestone at Altoona but confused it with the †Erie [Bronson] limestone. Through miscorrelation the †Earlton has commonly been supposed to be older than the Iola limestone but it is actually younger.

1899, *Plattsurg limestone* (part), KEYES, C. R., Am. Geologist, vol. 23, p. 305. Refers to prominent limestone at Plattsburg, Parkville, and Waldron, Mo., consisting of two principal limestone units separated by a few feet up to 12 feet of shale, total thickness 35 to 40 feet. The upper limestone is gray and especially marked by "*Syntrilasma hemiplicata,*" the lower limestone being buff. It is clear that Keyes uses Plattsburg for beds here called Plattsburg, Vilas, and Stanton.

1904, †*Allen limestone,* ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 20. "In the vicinity of Carlyle this limestone formation has a thickness of about 25 feet. It thins to the south gradually so that it has a thickness of about 10 to 15 feet along the west border of the [Iola] quadrangle. Its outcrops forms a narrow belt west of Neosho river. A number of irregular areas of this formation occur to the east of Neosho river capping hills and mounds." —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 13. Use †Allen for a limestone 5 to 70 feet thick between the Vilas shale above and the †Concreto shale below. Classed as a member of the †"Wilson formation." —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 101. Apply the name to the lower member of the †Garnett limestones. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 3. Follows the same usage as Schrader and Haworth, 1906.

Type locality, Plattsburg, Clinton county, Missouri, T. 55 N., R. 35 W.

The Plattsburg limestone overlies the Bonner Springs shale and occurs beneath the Vilas shale. It is the lower of the two associated limestone formations that form most of the Lansing group which is separated by thick shale from the next important limestone above and except in part of northeastern Kansas from the next limestone below. Study of Swallow's description of the type locality of the Stanton limestone and field work in this region shows that the formation now recognized as Plattsburg is identical with the original

Stanton. The latter term, introduced in the same year as Plattsburg, has come to be applied to the upper limestone formation of the Lansing group and in this sense is well established by usage.

The Plattsburg shows little variation in lithologic and faunal characters and in most exposures it can be recognized without difficulty. The basal limestone, called the Merriam member, is a blocky blue or gray dense rock that is persistent and distinctive. It is characterized by the common occurrence of large *Myalina, Osagia* and worm borings. A thin shale, the Hickory Creek member, commonly occurs above this lower limestone. The upper limestone, termed the Spring Hill member, comprises the main part of the formation. It is light bluish-gray, fine-grained and occurs in thin or massive beds. In places oölite occurs at the top. Marine fossils, especially the brachiopods *Enteletes, Marginifera* and *Composita*, are common in certain zones. A varied sponge fauna occurs in the Plattsburg throughout much of central and southern Kansas.

The thickness of the Plattsburg limestone ranges from less than 5 feet to more than 100 feet, the average being about 20 feet. A noteworthy feature is the considerable variation of thickness in small distances along certain parts of the outcrop. The formation has been traced from northwestern Missouri to a point near the Oklahoma boundary where it disappears, but the formation apparently reappears farther south in Oklahoma, being represented in the upper part of the Ochelata formation west of Ramona and elsewhere.

PLATTSBURG LIMESTONE

MERRIAM LIMESTONE MEMBER, Newell, 1932

1932, **Merriam limestone*, NEWELL, N. D., Mss., cited by Moore, R. C., Guidebook, Sixth Ann. Field Conf., p. 93. Name applied to a thin, dense, blue limestone, 1 to 3 feet thick, locally oölitic, the lowermost member of the Plattsburg formation. —— (1935) 1936, NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 71.

Type locality, village of Merriam, in quarry at NW. cor. sec. 7, T. 12 S., R. 25 E., in northern Johnson county, Kansas.

The Merriam limestone is the lowermost member of the Plattsburg limestone. In many places it contains two distinct divisions, the lower being a blocky, even drab to light-gray layer that weathers gray or white, and the upper consisting of fine-grained, dense, vertically jointed bluish limestone. The lower limestone is highly fossiliferous at many localities. It contains numerous productids and a few other brachiopods, including in some exposures a zone of

Composita at the base. The large flat pelecypod, *Myalina ampla,* is characteristic of the lower Merriam limestone, as is also the alga *Osagia* which commonly occurs in sufficient abundance to form an appreciable part of the rock. Locally this part of the Merriam member is oölitic. The thickness of the lower Merriam limestone ranges from a few inches to about 5 feet. The upper part of the Merriam is a typical "middle" limestone that in many places very closely resembles the Paola member of the Iola limestone, but on the whole it is slightly lighter in color and less dense. The bed is mostly poor in fossils but the upper part contains numerous irregularly disposed cylindrical tubes that are commonly filled with yellowish-brown ferruginous clay. These tubes are regarded as worm borings. The upper division of the Merriam limestone member is about 1 foot thick.

Plattsburg Limestone
HICKORY CREEK SHALE MEMBER, Newell, 1932

1932, **Hickory Creek shale,* Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93. Designates shale one half foot to 40 feet thick, locally, between the Merriam and Spring Hill members of the Plattsburg limestone. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 71.

Type locality, Hickory Creek in eastern Franklin county, Kansas. Typically exposed in roadcuts in SE¼ sec. 1, T. 17 S., R. 20 E.

The Hickory Creek shale member of the Plattsburg limestone lies above the Merriam limestone and beneath the Spring Hill limestone. This shale ranges in thickness from less than an inch, in a few places, to a maximum locally of about 40 feet. Where thin the shale contains a black carbonaceous zone, as is characteristic of the shales that overlie "middle" limestones of the limestone formations of the Missouri series and the Shawnee group of the Virgil series. Where the shale is thick, it is gray or yellowish in color and clayey. Fossils are rare or lacking in the Hickory Creek shale member.

Plattsburg Limestone
SPRING HILL LIMESTONE MEMBER, Newell, 1932

1932, **Spring Hill limestone,* Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93. Employed for the upper, main part of the Plattsburg limestone. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 71.

Type locality, Spring Hill, railroad cut near center E. side sec. 14, T. 15 S., R. 23 E., southern Johnson county, Kansas.

The Spring Hill limestone member of the Plattsburg formation is the uppermost division. It consists in the lower part of thin-bedded bluish-gray, fine-grained brittle limestone with numerous *Enteletes* and *Marginifera,* and in the upper part of light-gray oölitic limestone, or granular drab-colored somewhat argillaceous limestone that commonly contains much fragmental fossil material. Abundant echinoid spines and numerous specimens of a robust *Composita* are found in the upper part of the Spring Hill limestone. The lower division of the Spring Hill member has an average thickness of about 5 feet and the upper division about 7 feet. The thin-bedded portion of the Spring Hill limestone corresponds to the "upper limestone" of various other limestone formations in the Mid-Continent Pennsylvanian section, and the oölitic or fragmental portion represents the "super limestone" of these formations.

VILAS SHALE, Adams, 1898

1898, **Vilas shale,* Adams, G. I., Kan. Univ. Quart., vol. 7, p. 96. Name applied to shale between †Earlton [Plattsburg] limestones and "Iola [Stanton] limestone" west of Chanute. —— 1898, Haworth, E., Kan. Univ. Geol. Survey, vol. 3, p. 51. Same. —— 1903, Adams, G. I., U. S. Geol. Survey, Bull. 211, p. 39. "Shale between †Earlton [Plattsburg] limestone below and the "Iola [Stanton] limestone" above." —— 1904, Adams, G. I., U. S. Geol. Survey, Bull. 238, p. 20. Refers to the shale between the †Allen [Plattsburg] limestone below and †Piqua [Stanton] limestone above. It has a thickness of 75 feet at Vilas, thinning to 20 feet at the north edge of the Iola quadrangle. —— 1906, Schrader, F. C., and Haworth, E., U. S. Geol. Survey, Bull. 296, p. 13. Same as Adams, 1904, but the Vilas shale is classed as a member of the †Wilson formation. —— 1908, Schrader, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 3. Same as Schrader and Haworth, 1906. —— 1908, Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 103. Designate the shale between the †Allen [Plattsburg] and Stanton limestones. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 29. Apply the name to the shale between the Plattsburg and Stanton limestones. Classed as a member of the Lansing formation. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 39. Same. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 75.

Type locality, Vilas, Wilson county, Kansas. Typically exposed in sec. 30, T. 27 S., R. 17 E., and surrounding area.

The Vilas shale is the middle formation of the Lansing group, as redefined. It occurs above the Plattsburg limestone and beneath the Stanton limestone. The Vilas shale is gray to buff, clayey and sandy, and is mostly barren of fossils. Near Kansas river a persistent zone of gray hard ripple-marked sandstone occurs near the top or at the middle. Farther south there is locally a considerable thickness of reddish-brown soft sandstone and sandy shale in the Vilas. North of Kansas river the Vilas shale has an average thickness of about 15 feet but to the south the thickness gradually increases to more than 80 feet.

STANTON LIMESTONE (Swallow, 1865), Haworth and Bennett, 1908

1865, Not *Stanton limestone,* SWALLOW, G. C., Prelim. Rept., Kan. Geol. Survey, p. 75. Swallow's original Stanton limestone refers to what is now called Plattsburg limestone. —— 1867, SWALLOW, G. C., Am. Ass'n Adv. Sci., Proc., vol. 15, p. 67. Refers to first prominent limestone [Burlingame] below the "Chocolate limestone" [Tarkio] southwest of Topeka. —— 1898, BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. Refers to Burlingame and Wakarusa limestone of present classification. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 88. As used in this paper, "Stanton" is equivalent to Lansing as defined in the present report. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 41. Notes that Stanton is equivalent to †Carlyle [Plattsburg] limestone and also to †Garnett [Plattsburg-Stanton] limestone.

1894, †*Ottawa limestone,* HAWORTH, E., Kan. Univ. Quart., vol. 2, pp. 121, 122, 125. Notes that the †Garnett limestone [Plattsburg-Stanton] is in bed of the river at Ottawa, Kan., 35 feet below the Atchison, Topeka and Santa Fe Railway. North of the river is another limestone on the east side of the tracks at about the same level as the railroad. This limestone is the Stanton of modern usage. The name Ottawa is preoccupied by Ottawa gneiss, Selwyn, Canadian Geol. Survey, Rept. for 1877-1878, p. 10a, 1879.

1896, †*Eudora limestone,* BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, p. 113. Equals Stanton limestone of modern usage at Eudora. —— 1896, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 1, p. 136.

1904, †*Piqua limestone,* ADAMS, G. I., U. S. Geol. Survey, Bull. 238, p. 20. Consists of thick-bedded limestone 50 feet thick above the Vilas shale, appearing in the northeast corner of Iola quadrangle. —— 1906, SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 12. A limestone 1 to 50 feet thick, classed as the uppermost member of the †Wilson formation in the Independence quadrangle. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 3. Same.

1908, **Stanton limestone,* HAWORTH, E., AND BENNETT, J., Kan. Geol. Survey, vol. 9, p. 104. Apply this name to the upper of the two limestones that comprise the old †Garnett limestone. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 29. Classed as uppermost member of the Lansing formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 100. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 39.

Same. —— (1935) 1936, NEWELL, N. D., AND JEWETT, J. M., Kan. Geol. Survey, Bull. 21, pp. 76, 183.

Type locality, Stanton, Miami county, Kansas, but name has been shifted by usage to limestone next above that exposed at Swallow's type locality. Typically exposed in roadcuts near SE. cor. sec. 3, T. 13 S., R. 21 E., and adjacent area along Captain Creek.

The Stanton limestone is the uppermost formation of the Lansing group. It overlies the Vilas shale and is succeeded conformably by the Weston shale of the Pedee group. The Stanton limestone forms a fairly prominent escarpment that is traceable from northeastern Kansas to the southern part of the state. The formation contains five members that are designated in upward order, Captain Creek limestone, Eudora shale, Olathe limestone, Victory Junction shale, and Little Kaw limestone. The thickness of the formation ranges from about 20 feet to more than 100 feet. In northeastern Kansas and in Missouri the formation is fairly uniform in character and thickness, but in parts of east-central and southern Kansas there are great local variations. For example, the thickness of the Stanton near Elk City in Montgomery county is about 100 feet, but within 3 miles to the south the thickness of the formation is less than 10 feet. Near the Oklahoma-Kansas boundary it is difficult to trace the Stanton, but south of Bartlesville, Okla., the formation is thick and readily identified.

STANTON LIMESTONE

CAPTAIN CREEK LIMESTONE MEMBER, Newell, 1936

(?) 1915, *Meadow Creek limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 22. Designate 2.5 to 4 feet of dense, massive limestone outcropping in the Platte Valley west of Meadow Sta., Sarpy county, Nebraska. Classed as a member of the Braddyville [Calhoun-Topeka] formation. This limestone is now thought by Condra to be part of the Stanton limestone.

(?) 1927, *Meadow limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 51. Same as Meadow Creek limestone. Through erroneous correlation classes it as a limestone member of the Calhoun shale. —— 1930, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 12. Recognizes that the Meadow and associated beds belong in the Lansing rather than the Shawnee group.

1932, **Captain Creek limestone,* NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 76.

Type locality, exposures on Captain Creek 2 miles east of Eudora, Kan. Road-cut near SE. cor. sec. 3, T. 13 S., R. 21 E.

The Captain Creek limestone is the lowermost member of the Stanton limestone. It is readily identified in most sections by its distinctive lithologic character and by its occurrence beneath black fissile shale of the Eudora member. The limestone of the Captain Creek member is dark-gray or blue, sugary or dense, brittle and hard. It is massive or even-bedded and in most places shows prominent vertical joints. Beautifully preserved specimens of the brachiopod, *Enteletes pugnoides,* are abundant in the Captain Creek limestone throughout most of northeastern Kansas, and a robust *Triticites neglectus* occurs commonly on bedding planes of the member. At the top of this limestone in some exposures is a peculiarly brecciated siliceous bed a few inches thick that is mottled pink and blue. The thickness of the Captain Creek limestone is 4.5 to 5.5 feet along Kansas River and to the north, but southward, according to measurements by Newell, it increases to more than 10 feet in parts of Miami county and 40 feet northwest of Independence, Kansas. The dense blue limestone is typical of the "middle limestone" members of limestone formations in the Missouri series and of the Shawnee group in the Virgil series, but the siliceous, brecciated, mottled layer at the top is an element foreign to most "middle" members. It is thought to represent the .7 or "super" phase of the sedimentation cycle which is commonly found above the "upper limestone" members and definitely, but less commonly above "lower limestone" members of the limestone formations. If this is correct the occurrence strengthens the conclusion that each limestone formation like the Stanton, Oread, Deer Creek, and others is compounded of two or more sedimentary cycles.

The Captain Creek limestone is identified throughout northern Kansas and northwestern Missouri, and has been recognized by Condra in the section of the Platte Valley in Nebraska. Although the name has been used in a number of different stratigraphic senses, Condra has apparently intended to designate this limestone by the term Meadow limestone. The Captain Creek member is not differentiated definitely in northern Oklahoma.

Stanton Limestone
EUDORA SHALE MEMBER, Condra, 1930

1930, **Eudora shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 12.
—— (1935) 1936, Newell, N. D., and Jewett, J. M., Kan. Geol. Survey, Bull. 21, pp. 76, 183.

Type locality, road-cut exposure near NE. cor. sec. 4, T. 13 S., R. 21 E., 1½ miles northeast and 2 miles east of Eudora, Kan.

The Eudora shale member of the Stanton limestone lies between the Captain Creek limestone below and the Olathe limestone above.

It is very constant in northeastern Kansas and northwestern Missouri. The lower part consists of black fissile shale or in some places of dark clay shale with a thin carbonaceous layer. The upper part is greenish-gray to bluish-gray in color, and is soft and clayey. The thickness of the member ranges from one or two feet in some northern exposures to 50 feet in part of Montgomery county, Kansas. The average thickness is about 5 feet. Megascopic fossils are rare or absent in the Eudora shale in northeastern Kansas, but are fairly common in southern Kansas.

STANTON LIMESTONE

OLATHE LIMESTONE MEMBER, Newell, 1936

(?) 1930, *Stoner limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 11. Includes †Louisville limestone, †Kiewitz shale, and "DuBois limestone" as previously designated in the Platte Valley section of Nebraska. Named from Stoner farm, northwest of South Bend, Neb. This limestone is thought to be a part of the Stanton limestone of Kansas. —— 1932, DUNBAR, C. O., AND CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 5, p. 18, table C. Classed as a member of the Stanton limestone.

(1935) 1936,* *Olathe limestone,* NEWELL, N. D., Kan. Geol. Survey, Bull. 21, p. 76.

Type locality, quarries at west edge of Olathe, in secs. 34 and 35, T. 13 S., R. 23 E., Johnson county, Kansas.

The Olathe limestone member of the Stanton is the thickest limestone subdivision of the formation. It overlies the Eudora shale and occurs beneath the Victory Junction shale. The Olathe limestone is light bluish-gray to nearly white and commonly weathers very light-gray, creamy-white, or buff. The beds are mostly thin and wavy, with thin shaly partings between the layers. The rock is fine-grained, but in places there is much irregularly distributed crystalline calcite. This member is 11 to about 15 feet thick along the Kansas river and in northeastern Kansas but in parts of southern Kansas, where the Stanton attains a thickness of about 100 feet, the member measures about 50 feet. The lithologic character, thin wavy bedding, large relative thickness and stratigraphic position in the formation are all typical of the "upper limestone" members as seen in other Pennsylvanian limestone formations of Kansas, but the Olathe limestone is less fossiliferous on the average than other "upper limestones." To the north it contains abundant *Triticites* of the *T. irregularis* type.

Because of its thickness and therefore its greater resistance to erosion, and because of the occurrence in most places of thick, weak shale above the Stanton, the outcrop of the Olathe limestone is marked by a fairly prominent escarpment. The Little Kaw limestone which occurs a little above the Olathe member is thin and is not generally found at the edge of the Stanton escarpment. The Olathe limestone is quarried at many places. It is traced from northwestern Missouri across Kansas, but is not clearly differentiated from other parts of the Stanton formation in southern Kansas and northern Oklahoma.

The term Stoner limestone, introduced by Condra from exposures in the Platte valley of Nebraska, is possibly applicable to the member of the Stanton that is here called the Olathe limestone. That is not certain, however, because it is not possible to trace the Platte beds southward to northeastern Kansas outcrops. There has been much confusion in the classification and correlation of the Platte valley section, and it seems inadvisable, at least on the basis of present knowledge, to introduce in Kansas such terms as Stoner and other Platte valley units that are thought to belong to the Stanton but are not certainly placed.

STANTON LIMESTONE

VICTORY JUNCTION SHALE MEMBER, Newell, 1936

(?) 1927, *Rock Lake shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 59. Shale above the †Louisburg limestone and below the South Bend limestone in the Platte Valley section of Nebraska. Through erroneous correlation classed as a member of the Scranton shale. —— 1930, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 27. Regarded as belonging in the Stanton formation. —— 1932, DUNBAR, C. O., AND CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 5, p. 18, table C. Same.

(1935) 1936,* *Victory Junction shale,* NEWELL, N. D., Kan. Geol. Survey, Bull. 21, pt. 1, p. 76.

Type locality, Victory Junction, west edge of Wyandotte county, Kansas. Exposed in road cut on highway near NW. cor. sec. 6, T. 10 S., R. 23 E., just west of Victory Junction.

The Victory Junction shale member of the Stanton limestone occurs next above the Olathe limestone and beneath the Little Kaw limestone. The contact at the base of the shale in many places is irregular, suggesting a possible disconformity. There is commonly a thin layer of greenish or gray clay shale in the lower part of the member, but most of this unit consists of sandy shale or soft reddish-brown or dark-buff sandstone. The sandstone is generally even-bedded or massive. It is distinguished from overlying sandstone of the Stranger formation by the presence of marine fossils, mostly mollusks, in the Victory Junction beds. The thickness of this member ranges from about 1 foot to 15 feet. The Victory Junction shale is possibly the same as that called Rock Lake shale in Nebraska. This shale contains locally a remarkable assemblage of well preserved land plants of "Permian" aspect, including abundant *Walchia,* mingled with remains of amphibians, fishes, a scorpion and marine invertebrates.[22]

Stanton Limestone

LITTLE KAW LIMESTONE MEMBER, Newell, 1936

(?) 1915, *South Bend limestone,* Condra, G. E., and Bengston, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 23. Limestone 8 to 9 feet thick exposed near South Bend and other localities in the Platte Valley, Neb. Classed as a member of the Braddyville [Calhoun-Topeka] formation. —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 58. Through erroneous correlation classed as a member of the Scranton shale. —— 1930, Condra, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 27. Classed as uppermost member of the Stanton limestone. —— 1932, Dunbar, C. O., and Condra, G. E., Neb. Geol. Survey, (2), Bull. 5, p. 18, table C. Same.

(1935) 1936, **Little Kaw limestone,* Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 77. Upper member of Stanton formation.

Type locality, Little Kaw Creek north of Loring, Leavenworth county, Kansas. Typical road-cut exposures just west of Victory Junction, and at Camp Naish, east of Bonner Springs, Kan.; quarry one fourth of a mile west of the S. E. cor. sec. 26, T. 10 S., R. 23 E.; section west of road; south edge of sec. 8, T. 11 S., R. 23 E.

The Little Kaw limestone is classed as the topmost member of the Stanton limestone. It overlies the Victory Junction shale and occurs conformably beneath the Weston shale. Exposures in the area adjacent to the Kansas River and along the Missouri commonly show one or two beds of dark-gray, fine-grained limestone belonging to this member. The lower part is sandy and in places there is a thin bed of buff sandstone and some sandy shale between the limestone beds. Fossils are most abundant where the member is least sandy. The brachiopod *Meekella striatocostata* and a fusulinid similar to *Triticites moorei* are the most common fossils. The thickness of the Little Kaw limestone in northeastern Kansas is rather constantly about 4 to 5 feet. The member is identified at numerous exposures in northwestern Missouri.

A limestone that is possibly equivalent to the Little Kaw member of the Stanton as here described occurs in the Platte Valley section

22. See Moore, R. C., Elias, M. K., and Newell, N. D., A "Permian" flora from Pennsylvanian rocks of Kansas: Jour. Geology, vol. 44, pp. 1-31, 1936.

of southeastern Nebraska. This has been called the South Bend limestone and is now classed by Condra as uppermost member of the Stanton. If the Stanton is correctly identified in Nebraska and if the South Bend corresponds to the Little Kaw, the name South Bend has priority but this is not satisfactorily established. The South Bend limestone clearly represents a cycle of sedimentation that is distinct from that which is comprised mainly of the Stoner limestone, for in places there are definitely identifiable "super" beds at the top of the Stoner, the Rock Lake shale contains a red zone which signifies emergence, and the South Bend contains abundant fusulinids. The Little Kaw limestone is similarly set apart from the underlying Olathe limestone and is believed to represent part of a cyclothem that is distinct from the one containing the Olathe member. This conclusion is supported by the local occurrence of a disconformity at the base of the Victory Junction shale, which is followed by conglomerate, sandstone and near Garnett by the rich land plant shale bed which is followed in turn by the Little Kaw limestone. A peculiar weathering of certain massive layers in the South Bend limestone, which gives rise to a strongly concave smooth face, is seen also in some exposures of the Little Kaw limestone.

PEDEE GROUP, Moore, 1932

Douglas group or formation (part), of authors. See under Douglas group.

1932, **Pedee group,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 79.

Type locality, Pedee Branch in vicinity of Weston, Mo.

The strata occurring between the top of the Stanton limestone and the disconformity that defines the top of the Missouri series are included in the Pedee group. These beds were formerly classed as part of the Douglas group but it is clear that they should be differentiated from the rocks that disconformably overlie them. The Pedee beds are designated as a separate group rather than as an addition to the Lansing group because the latter is a well characterized compact stratigraphic unit consisting mainly of limestone and because the conformable upper boundary of the Lansing group, as previously drawn and here accepted, is a more usable stratigraphic datum in mapping and in subsurface studies than the uneven surface of the post-Missouri disconformity.

The Pedee group contains two formations, the Weston shale below, and the Iatan limestone above. It is theoretically possible, or indeed probable, that in some places where the Iatan limestone is present there is a certain thickness of shale above the Iatan that belongs below the post-Missouri disconformity and therefore should be included in the Pedee group. Such conditions may exist along the Missouri river in the vicinity of Iatan and Weston where a part of the poorly bedded sandy and clayey beds between the top of the Iatan limestone and the base of the Sibley coal possibly belong to the Missouri series. Evidence of the exact position of the boundary between the Missouri and Virgil deposits is lacking here, but inasmuch as the thickness of the zone in which the boundary belongs is only 5 to 20 feet, this uncertainty is not of great importance. Observation of somewhat variable lithologic characters in this zone, its irregular local changes in thickness and at least in some places an unevenness at the top of the Iatan limestone indicates that the disconformity may belong mostly at the top of the Iatan. In any case this boundary is practically the most useful, and accordingly the Pedee group is regarded as including no beds higher than the Iatan limestone. The term †Hardesty shale, which in a classification table published in 1932[23] was applied to strata above the Iatan that were included in the Pedee group, is therefore abandoned. The so-called †Hardesty shale was not properly proposed as a stratigraphic unit, being merely indicated in a chart, and therefore it is a *nomen nudum* that has no standing.

The Pedee group is about 100 feet thick southeast of St. Joseph, Mo., in Buchanan county,[24] but locally, as throughout much of Platte county, Missouri, and in the Kansas River valley, the Pedee beds have been entirely removed by erosion that preceded deposition of the basal Virgil sandstone. In southern Kansas the Pedee beds appear to have a thickness of about 200 feet in some places, as just west of Caney. The Pedee group is well represented in east central and southeastern Kansas. The lower part of what has been called the †Buxton formation in the Independence quadrangle belongs to the Pedee group, as does also the upper part of the Ochelata formation in northeastern Oklahoma.

23. Moore, R. C., and Condra, G. E., Guidebook, Sixth Ann. Field. Conf., Correlation chart, 1932.

24. Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 174, 1915.

WESTON SHALE, Keyes, 1899

1894. †*Le Roy shale* (part), HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 110. The term Le Roy was applied to beds between the †Carlyle [Plattsburg (and Stanton?)] limestone and †Burlington [Oread] limestone. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 43. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 105. Applies to †Le Roy to shale between Stanton and †Kickapoo [Iatan] limestones, but "Kickapoo" as here used also includes Haskell limestone.

1894, *Lawrence shale* (part), HAWORTH, E., Kan. Univ. Quart., vol. 2, p. 122. Includes beds between †Ottawa [Stanton] and Oread limestone. —— 1895, HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 460. Includes beds between †Garnett [Plattsburg-Stanton] and Oread limestones. —— 1896, HALL, J., Kan. Univ. Geol. Survey, vol. 1, p. 102. Same. —1896, BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, p. 113. Same. —— 1896, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 1, p. 136. Same. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 90. Classifies Weston shale as lowermost member of the Lawrence.

1898, Not †*Weston limestone*, GALLAHER, J. A., Mo. Geol. Survey, Bien. Rept., p. 52. Not clearly defined. Apparently refers to what is now called Iatan limestone. —— 1900, GALLAHER, J. A., Mo. Geol. Survey, vol. 13, p. 206. Same.

1899, **Weston shale*, KEYES, C. R., Am. Geologist, vol. 23, p. 300. Applies name to shale between Stanton and Iatan limestones. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 90. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 30. Class Weston as member of the Douglas formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 101. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 40. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 34. Same.

1906, †*Buxton formation* (part), SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 11. The †Buxton formation includes beds from the top of the †Piqua [Stanton] limestone to the base of the †Painterhood [Oread] limestone. Beds in the shale pits near Caney and Fredonia are Weston. —— 1908, SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio, 159, p. 3. Same.

Type locality, Weston, Platte county, Mo.

The Weston shale includes the beds between the top of the Stanton limestone, below, and the base of the Iatan limestone, above. Where the Iatan is absent, the top of the Weston is marked by the disconformity at the base of the Virgil series. Here the next beds above the Weston may consist of coarse conglomerate, massive or irregularly bedded sandstone, red shale, or sandy yellowish to bluish shale.

The Weston shale is a fairly uniform dark bluish to bluish-gray marine clay shale that in many places is characterized by the occurrence in it of numerous flattish, elliptical ironstone concretions. Fossils are not very numerous in most parts of the shale, but in places there are thin highly fossiliferous limestone beds that can be traced for several miles. No coal beds or sandstones have been observed in the Weston shale of northern Kansas and northwestern Missouri, but toward the south there are some layers of shaly to even-bedded sandstone and much of the shale is silty to fine sandy in texture. The thickness of the Weston shale ranges from a feather-edge to a maximum of about 140 feet. On account of the post-Missouri erosion the thickness of the Weston in neighboring sections may be very dissimilar.

IATAN LIMESTONE, Keyes, 1899

1894, †*Le Roy shale* (part), HAWORTH, E. (See under Weston shale.)

1894, *Lawrence shale* (part), HAWORTH, E. (See under Weston shale.)

1898, †*Weston limestone,* GALLAHER, J. A., Mo. Geol. Survey, Bien. Rept., p. 52. Evidently refers to what is now called Iatan limestone, but name is not properly defined. —— 1900, GALLAHER, J. A., Mo. Geol. Survey, vol. 13, p. 206. Same.

1899, **Iatan limestone,* KEYES, C. R., Am. Geologist, vol. 23, p. 300. Applies name to limestone at foot of bluffs near Iatan, Mo. Occurs next above Weston shale. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 90. Classes Iatan limestone as middle member of Lawrence shale, with Weston shale below and †Andrews shale above. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 30. Class Iatan as middle member of Douglas formation, with Weston shale below and Lawrence shale above. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 101. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 41. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 34. Same.

1908, †*Kickapoo limestone,* HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 106. Synonymous with Iatan which has priority. The village of Kickapoo is on the west side of the Missouri, 5 miles south of Iatan.

Type locality, Iatan, Platte county, Mo., about 10 miles west of north from Leavenworth.

The Iatan limestone conformably overlies the Weston shale and is disconformably overlain by shale of the Stranger formation. As previously noted, however, it is possible that in places some of the shale immediately above the Iatan is conformable on the limestone and really belongs to the Pedee group.

The color of most of the Iatan limestone is light bluish-gray or nearly white, both in fresh and weathered exposures, but parts of the formation are mottled with brown after prolonged weathering. The bedding is indistinct and somewhat uneven, so that the rock appears rough and shelly but very massive. Large blocks separated by joint planes tend to break from the outcrop and creep down steep slopes. The texture of the limestone is very fine and dense, but there are very numerous thin, irregular plates of clear calcite that weather in relief or are differentially etched by weathering. Some of these calcite plates are apparently shell fragments, seen in section, but most of them are too large and irregular in form to be explained in this manner. Nevertheless, they are probably organic, possibly algal, in origin. Numerous nodular fragments of dense limestone are thought to be algal deposits. Brachiopods, bryozoans, crinoid stem fragments and locally small corals are the most common fossils, but in most places fossil remains are not abundant. Fusulinids are numerous at the top of the formation between Weston and Iatan and in the lower half of the Iatan outcrops at St. Joseph. At the latter place the upper bed of the Iatan is a typical "super" limestone, containing *Derbya* and mollusks and crowded with large *Osagia*.

The thickness of the Iatan ranges from less than 5 feet to about 22 feet, the maximum being observed a short distance south of Iatan. The formation is extensive in northeastern Kansas and northwestern Missouri, north of Leavenworth, and has been identified along the Platte Valley in Nebraska. It is cut out by the post-Missouri disconformity near Leavenworth and southward at least to the vicinity of Baldwin. The limestone that has been called Iatan in country farther south appears to be the Haskell, but it is possible that outcrops representing the true Iatan occur. A limestone that belongs beneath the post-Missouri disconformity and above the Stanton limestone is observed near Caney in southern Kansas and northern Oklahoma.

VIRGIL SERIES

VIRGIL SERIES, Moore, 1932

1892-1933, *Missouri group* (part) of authors.

1932, *Virgil series*, Moore, R. C., Geol. Soc. Am., Bull., vol. 43, p. 279. —— 1932, Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 89. —— 1932, Ver Wiebe, W. A., and Vickery, W. R., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 109. —— 1933, Schuchert, C., and Dunbar, C. O., Historical Geology, p. 248, New York, Wiley. —— 1933, Moore, R. C., Historical Geology, pp. 293, 300, 304-305, New York, McGraw-Hill. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 79.

The name Virgil series is proposed to include Upper Pennsylvanian strata between the unconformity that marks the upper boundary of the Missouri series, as redefined in this paper, and the unconformity marked by local prominent channel sandstones that cut the Brownville and subjacent beds in parts of Oklahoma, Kansas and Nebraska. The unconformity at the Missouri-Virgil boundary occurs between the Stanton limestone, below, and sandstone or conglomerate of the Stranger formation, above, in sections on Kansas river near Bonner Springs, Kan. To the north and south of Kansas river the basal Stranger rests on the Stanton, on a varying thickness of Weston shale, which overlies the Stanton, or on Iatan limestone, which occurs above the Weston. At one place in Wyandotte county, Kan., the unconformity almost reaches the base of the Stanton limestone and according to studies by N. D. Newell it may cut downward beneath the Plattsburg limestone in T. 28 S., R. 17 E., near Earlton, Kan. The unconformity that is regarded as marking the top of the Virgil series is not clearly evident in most sections, for the Towle shale and Aspinwall limestone seem to follow the Brownville limestone conformably. The existence of a stratigraphically significant break between the Brownville and Aspinwall, however, is inferred on the basis of the occurrence of several large channel sand bodies that in places cut 100 feet or more into the very uniform succession of beds underlying the Brownville. These sandstones are distributed along at least 300 miles of outcrop and all occur next beneath the Aspinwall limestone. In many places the Aspinwall is brecciated or conglomeratic and there are irregularities in the stratigraphic succession 50 feet or more above the Brownville that indicate unusually variable conditions such as one might expect in the initial deposits of a marine invasion following a time of emergence. In areas where channel sandstones are absent it is possible that the red beds in the Towle shale represent the unconformity and accordingly this may mark the upper boundary of the Virgil series. The beds above the Virgil are assigned to the Big Blue series of the "Permian."

Previous references to the Virgil series indicate the position of the upper boundary at the base of the Foraker or Americus limestone. This preliminary definition was based on my conclusion of several years' standing that the beds below the Cottonwood limestone, extending at least to the base of the Foraker and Americus, show such lithologic and faunal similarity to the succeeding Big Blue beds and in general such dissimilarity to underlying Pennsylvanian strata that the boundary between Virgil and Big Blue should be drawn not higher than this horizon. It was recognized that the succession in this part of the stratigraphic column is conformable and that the suggested boundary at the base of the Foraker limestone is measurably arbitrary. Field studies of the past two years have brought to light evidence of the widespread but obscure unconformity between the Brownville and Aspinwall limestones, at a horizon about 100 feet below the base of the Foraker, and this break is now considered to mark the upper limit of the Virgil series.

The name Virgil is derived from a town in eastern Greenwood county, Kansas (sec. 8, T. 24 S., R. 13 E.), located about midway between the lower and upper limits of the Virgil series outcrop in this part of the state. The exposures along Verdigris river from west of Madison to Virgil and southeastward to central Wilson county may be designated as showing typically the characters of beds included in the series and as exhibiting clearly the boundaries indicated. In this region the thickness of the Virgil series is about 960 feet.

Correlation. The Virgil series is represented in northern Oklahoma by beds from the base of the Nelagoney formation to the basal part of the Sand Creek formation. In southern Oklahoma the unconformity at the base of the Virgil is believed to belong at the contact of the Vamoosa formation and underlying Belle City or other beds. There is evidently a large hiatus at this point. The Grayhorse limestone which marks the base of the Sand Creek formation is the top bed of the Caneyville limestone in Kansas and this lies only 15 feet or so below the Brownville limestone which marks the upper limit of the Virgil series in most places. Locally in Oklahoma it appears that the so-called Grayhorse limestone includes the Brownville. Accordingly the base of the Sand Creek or top of the Vanoss beds may be considered as the top of the Virgil series. The Texas equivalents of the Virgil series cannot yet be defined. It is believed that parts of the upper Canyon and lower Cisco belong here. The occurrence of tentatively identified Virgil fusulinids in the Home Creek limestone of the Caddo Creek formation and of Missouri fusulinids in the underlying Ranger limestone, indicates that the lower boundary of the Virgil series belongs below the top of the Canyon group. The first fusulinids of Big Blue type occur in the upper part of the Harpersville formation, and the upper boundary of rocks equivalent to the Virgil series is tentatively located in the mid portion of the Harpersville.

The Merom sandstone at the top of the Pennsylvanian section of Illinois is believed probably to represent the initial deposits of Virgil age in this region, but younger beds that may once have existed here are now removed. The Monongahela beds of the Appalachian district correspond approximately to the Virgil series, but neither the lower or upper boundaries of the Monongahela are probably exactly equivalent to the boundaries of the Virgil.

Subdivision.—The Virgil series is divided into three groups on the basis of general differences in lithologic characters and in the nature of the cyclothems. In upward order these groups are named Douglas, Shawnee and Wabaunsee. As noted elsewhere, the content of each of these groups has been redefined.

DOUGLAS GROUP (Haworth, 1898), Moore, 1932

By R. C. Moore and N. D. Newell.

1898, *Douglas formation* (part), Haworth, E., Kan. Univ. Geol. Survey, vol. 3, p. 93. Includes strata from top of Stanton limestone to top of Oread limestone. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 30. Same. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, pt. 100. Same. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 40. Same. —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 33. Same.

1908, *Douglas stage* (part), Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 75. Includes same as Douglas formation above.

1932, **Douglas group*, Moore, R. C., Guidebook, Sixth Ann. Field Conf., Kan. Geol. Soc., p. 93. Restricted to include only beds from post-Missouri disconformity to base of Oread limestone. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, pp. 79-82.

Type locality, Douglas county, Kansas.

The Douglas group comprises the lowermost part of the Virgil series, extending from the disconformity that marks the lower boundary of the series to the base of the Oread limestone. As originally defined by Haworth, the "Douglas formation" included the strata from the top of the †Garnett [Stanton] limestone to the top of the Oread limestone. In many places where the disconformity beneath the Virgil reaches the Stanton limestone, the lower boundary of the Douglas group as here redefined coincides with the limit indicated by Haworth, but elsewhere the boundary occurs above a varying thickness of Weston shale or Iatan limestone, which overlie the Stanton, or possibly still higher, and locally the disconformity cuts well below the top of the Stanton. The upper boundary of the Douglas group is here set at the base of the Oread limestone rather than at the top, because the Oread in all respects is most naturally associated with the succeeding strata that make up the Shawnee group, and because the most readily mappable geologic boundary is at the base rather than the top of the scarp-forming limestone.

As thus defined, the Douglas group consists primarily of clastic deposits in which fairly thick bodies of massive or crossbedded sandstone, shaly sandstone, and sandy shale are prominent. The group contains two persistent, though rather thin, limestone beds, the Haskell and Westphalia limestones in the middle or lower part, and there are some coal beds. Locally, especially at the base of the group, there are deposits of conglomerate. The thickness of the group ranges from about 150 feet in northeasternmost Kansas to over 700 feet in northern Oklahoma.

When the Douglas group was redefined by Moore in 1932 to its present limits the existence of an extensive unconformity within the group was not generally known. The regional relations of the Douglas units are now worked out so that a further refinement and revision of the earlier classification seems imperative.

The proposed revision in the classification of the Douglas group is indicated in the following table:

Group.	Standard classification.[25]		Revised classification.	
	Formation.	Member.	Formation.	Bed or member.
Douglas	Lawrence	Ireland ss.	Lawrence	Williamsburg coal Ireland ss.
			Stranger	Robbins sh.
	Haskell limestone			Haskell ls.
	Stranger	Vinland sh.		Vinland sh.
				Westphalia ls.
		(Sibley coal) Tonganoxie ss.		(Sibley coal) Tonganoxie ss.

25. Moore, R. C., Elias, M. K., and Newell, N. D., Pennsylvanian and "Permian" rocks of Kansas: Chart published by the Kansas Geological Survey, 1934.

The revisions in the classification focus chiefly on proper recognition of the importance of the hiatus below the Ireland sandstone, and the regional extent of a limestone shortly below the Haskell, the Westphalia member.

STRANGER FORMATION (Newell, 1932), Moore and Newell, 1936

1894, †*Le Roy shale* (part), Haworth, E., and Kirk, M. Z., and authors. (See under Weston shale.)

1894, *Lawrence shale* (part), Haworth, E., and authors as cited in references under Weston shale. Also, —— 1908, Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 106. Includes beds between †Kickapoo [Iatan] (miscorrelated with Haskell) and Oread limestones. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geology and Mines, (2), vol. 13, p. 31. Include in the "Lawrence member of Douglas formation" the beds between Iatan and Oread, part of which is now separated as the Stranger formation. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 101. Same. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 40. Same.

1917, *Weston shale* (part), Moore, R. C., Kan. Geol. Survey, Bull. 3, p. 101. Through confusion of the Iatan and Haskell limestones, strata here classed as Stranger were included under Weston. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 40. Same.

1932, **Stranger formation*, Newell, N. D., Mss., cited by Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93. —— (1935)

1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 79. Formal description.

Type locality, Stranger Creek, in bluffs on east side sec. 3, T. 12 S., R. 21 E., southern Leavenworth county, east of Tonganoxie, Kan.

This formation was originally defined to embrace the nonmarine channel sandstone at the base of the Virgil series and shaly beds above up to the base of the persistent Haskell limestone. The division, thus defined, is not a natural one inasmuch as the upper limit was arbitrarily selected. A more desirable boundary for the top of the formation is the marked hiatus at the base of the Ireland sandstone commonly classed in the Lawrence shale. Detailed observations show that this unconformity is commonly, if not invariably at or near the top of the Haskell limestone in northeast Kansas, so that a redefinition of the Lawrence shale at Lawrence, Kansas, is not necessary. In southern Kansas a considerable body of marine shale occurs between the Haskell limestone and the hiatus above. This shale, the Robbins, constitutes the highest division of the Stranger formation, as redefined.

Stranger Formation

TONGANOXIE SANDSTONE, Moore, 1934

1934, **Tonganoxie sandstone,* Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, "Pennsylvanian and 'Permian' rocks of Kansas," graphic stratigraphic section, issued December, 1934. Shows Tonganoxie sandstone as basal member of the Stranger formation. —— (1935) 1936, Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 82. This term, first described and defined in this reference, was originated by Moore, but is here erroneously attributed to J. M. Patterson, master's thesis.

Type locality, area east of Tonganoxie, Leavenworth county, Kansas. Good exposures are found along U. S. highway 40 in secs. 26 and 35, T. 11 S., R. 21 E., about seven miles east of Tonganoxie and on Stranger creek and its tributaries, north of Linwood.

The Tonganoxie sandstone member includes heavy cross-bedded channel sandstones, sandy shales, and several coal beds from the base of the Stranger formation to the top of the Sibley coal. Nearly all of the sediments of the Tonganoxie in Kansas are nonmarine, apparently representing broad coastal plains fluviatile deposits.

In much of Douglas, Leavenworth, and Wyandotte counties massive sandstones at the base of the member rest unconformably on various parts of the Stanton, Weston and Iatan formations. In this area, and less commonly to the southward, conglomerate composed of cemented pebbles of limestone occurs at the base of the member. Much of the conglomerate was probably derived from the erosion of the Iatan limestone.

The sand composing the massive beds of the Tonganoxie member is composed chiefly of angular quartz grains, having an average diameter of 0.2 mm.[26] Somewhat larger grains of muscovite are common and characteristic. The sandstones are characteristically cross-bedded, with the foresets in northeastern Kansas dipping generally in a westerly direction. Sufficient observations on the direction of bedding have not been made in southeastern Kansas, but because the sandstones of the Tonganoxie are continuous with certain persistent beds in Oklahoma, probably much of the sand was derived from a southern source. The sandy shales interbedded with the sandstone beds locally contain plant fragments, but do not have marine fossils. Coal beds occur in the member in the vicinity of Kansas and Missouri rivers, but they drop out to the southward. Some and possibly all of the coals in the lower part of the member are detrital, having been reworked before final deposition. One of these beds is mined one half a mile west of Blue Mound, about 6 miles southeast of Lawrence. It is about 55 feet below the top of the member. Another thin coal occurs southeast of Blue Mound about 30 feet below the top of the Tonganoxie. Thin coal beds were observed near the base in western Wyandotte county interbedded in massive sandstone. Probably none of these coals, with the possible exception of the one 55 feet below the top, should be classed as the regular coal phase 1c of the ideal cyclothem because they do not represent normal conditions of coal deposition.

The Tonganoxie sandstone at the outcrop in Kansas is a series of more or less discontinuous lenses, channel-fillings. The basal contact of these lenses is obviously unconformable on the underlying sediments as evidenced by overlap relations, irregular sharp contact, and local masses of conglomerate at the base.

As seen in profile there are at least five separate channel deposits in Kansas. Nothing is known as yet about the trend of these channels. Possibly the channels seen at the outcrop represent random sections across one or two major stream courses instead of five. Toward the margins the channel fillings wedge out into homogeneous shale, as for example near Baldwin, west of Garnett, near Yates Center, and near Elk City, close to Independence, Kansas. These areas represent old divides between stream channels. Commonly the recognition of the precise horizon of the hiatus cannot be deter-

26. Patterson, J. M., master's thesis, University of Kansas, 1933.

mined in these areas. In field practice the Sibley coal, or Westphalia limestone was mapped as the base of the Douglas group in those limited areas in which the hiatus could not be located.

The *Sibley coal*[27] at the top of the Tonganoxie sandstone is the most extensive of the coal beds that are known in the member. It is traceable from the vicinity of Baldwin northeastward to Iatan, Mo., but is absent at St. Joseph, Mo. The southward extent of the bed is not yet determined. The coal is thin, averaging about 4 inches, but locally east of Tonganoxie, where it is mined, the bed is 1.5 feet thick. A peculiarity of the Sibley coal near Leavenworth and northward is a fine interbedding of thin coal streaks and black carbonaceous shale. In the Blue Mound area, between Lawrence and Vinland, at least three other thin coal beds are present in the Tonganoxie member. The lowest of these has a thickness of 1.5 feet where it has been mined in sec. 21, T. 13 S., R. 20 E., about one half mile west of Blue Mound.

At several places in Douglas, Leavenworth, and Wyandotte counties, Kansas, and in western Platte county, Missouri, the basal bed of the Tonganoxie sandstone member as already noted, consists of conglomerate, 1 to 9 feet in thickness. The pebbles in the conglomerate are mostly of light-gray, dense limestone that lithologically closely resembles the Iatan, but there are also pebbles of dark-gray and bluish limestone and of clay ironstone like the ferruginous concretions in the Weston shale. The pebbles are embedded in a calcareous sandy matrix. It is probable that scattered crinoid stem fragments and brachiopods that are found in the conglomerate are derived from the Weston and Iatan formations which appear to have supplied most of the materials of the conglomerate. Locally, the upper part of the Stanton limestone was eroded before deposition of the basal Tonganoxie beds and accordingly some constituents of the conglomerate may have come from the Stanton. Where the limestone conglomerate is interbedded with typical standstone of the Tonganoxie member or where lateral graduation of the conglomerate and sandstone can be observed there is no difficulty in recognizing the stratigraphic relationships, but locally, as at East Leavenworth, Mo., superficial resemblance of the conglomerate to the somewhat fragmental appearing Iatan limestone necessitates careful field observation to show that the conglomerate is definitely younger than Iatan. There is also the question whether certain exposures of conglomerate and sandstone that unconformably lie on Stanton or

27. Named by J. M. Patterson, master's thesis, Kan. Univ., 1933, from outcrops near Sibley (sec. 33, T. 13 S., R. 20 E.), southeast of Lawrence, Kan.

Weston belong to the Tonganoxie member of the Stranger formation or to the Ireland member of the Lawrence shale, for the latter is known to cut out the upper Stranger beds locally and it may in some places occupy depressions cut entirely through the Stranger formation.

The Tonganoxie member is exceedingly variable in thickness, ranging from three or four feet near Elk City, Kansas, to nearly a hundred feet in eastern Leavenworth county.

Reconnaissance field work in northern Oklahoma indicates that the base of the Bigheart, Revard, and Cheshewalla sandstones constitute a stratigraphic horizon defining the base of the Douglas group. These sandstones are, therefore, partly equivalent to the Tonganoxie sandstone.

If the local coals in the lower part of the Tonganoxie are truly detrital the member represents the lower four elements of one typical cyclothem. The channel sandstones are included in phase 0, sandy shale above in 1*a*, and the underclay and Sibley coal at the top in phases 1*b* and 1*c*.

Stranger Formation

WESTPHALIA LIMESTONE MEMBER, Moore and Newell, 1936

Type locality, named here from a village in western Anderson county, Kansas. Typical outcrops may be seen in roadside exposures along the north part of section 12, T. 21 S., R. 17 E., and at the NE cor. section 20, T. 21 S., R. 18 E.

Throughout the outcrop area the Westphalia is characterized by abundant fusulinids representing apparently only one form, *Triticites secalicus oryziformis* Newell. The member is not definitely recognized north of T. 19 S. at the outcrop. At its northern-most unquestioned outcrops, near Amiot in northwestern Anderson county, the member is sharply overlapped by a channel filling of the Ireland sandstone. The Westphalia and its equivalents are cut out by the Ireland channel throughout southern Franklin county. Where the channel rises above these beds in the area west of Ottawa the Westphalia limestone cannot be recognized, but its approximate position is occupied by the southernmost extent of the Sibley coal. Although the Sibley coal does not occur in the area of the typical Westphalia, there is some basis for correlating the Sibley with a position just under the Westphalia limestone.

A thin limestone overlies the Sibley coal locally around Baldwin, Kansas, and Iatan, Missouri. Ordinarily this limestone is only two or three inches thick or less, but the thickness ranges up to one foot. The limestone is finely laminated and commonly contains thin layers of reworked coaly material. Well-preserved plant fossils are generally found on the bedding planes. Although megascopic marine fossils have not been observed in these local lenses of limestone, Patterson[28] has found specimens of the marine ostracode *Jonesina howardensis* Kellett and interiors of minute gastropods. The intervals between the limestone and the base of the Haskell above ranges between about 15 and 25 feet. The Westphalia limestone at the type area occurs the same distance below the Haskell limestone so that a correlation of the Westphalia with the local lenses of limestone at the top of the Sibley coal seems justified.

The Westphalia was well known in the subsurface to petroleum geologists before it was recognized at the outcrop. The member together with the Haskell limestone can be recognized in the subsurface as far west as R. 6 W.[29] where they apparently are overlapped by younger beds on the flanks of the Central Kansas Uplift.

The Westphalia throughout its outcrop chiefly represents the fusulinid or number 5 phase of the cyclothem. Apparently it belongs to the same cyclothem as the Tonganoxie member.

Stranger Formation

VINLAND SHALE MEMBER (Patterson and Addison, 1934), Moore and Newell, 1936

1934, **Vinland shale,* Patterson, J. M., and Addison, C. C., cited from master's thesis, Kan. Univ., J. M. Patterson, first publication in this paper. —— 1934, Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, "Pennsylvanian and 'Permian' rocks of Kansas," stratigraphic chart, issued December. Shows position and relations of Vinland shale.

Type locality, about 2 miles northeast of Vinland, Douglas county, best exposures in NW sec. 12, T. 14 S., R. 20 E.

The Vinland shale member of the Stranger formation includes shale and sandstone, probably all marine, between the Westphalia and Haskell limestones. Originally the base of the member was defined as the top of the Sibley coal, but recognition of the regional importance of the Westphalia limestone at the top of the coal makes a further restriction of the Vinland desirable.

The member ordinarily consists of from 9 to 50 feet or more of gray argillaceous limy or sandy shale, locally with some sandstone, as at Lawrence, and in western Anderson county. In the vicinity

28. Op. cit., p. 18.

29. Kellett, Betty, Geologic cross-section, Sixth Annual Field Conf., Kansas Geol. Soc., 1932.

of Yates Center, in Woodson county, the member contains a dark green layer near the middle, reminiscent of a persistent variegated layer known at this horizon in the subsurface[30] of central Kansas.

This member is more than ordinarily fossiliferous at various places along the outcrop. A well preserved molluscan fauna occurs in the shale near Iatan and Weston and includes topotypes of *Nuculana arata* Hall described from this area in the early days. Near Lawrence the member is sandy and rather unfossiliferous, but from Vinland southward into Oklahoma a zone of prolific myalinas occurs near the top. Locally in the Vinland and Baldwin area thin calcareous sandstone or sandy limestone occurs just under the myalinas. This arenaceous layer is not to be confused with the Westphalia limestone which appears to occur several feet below at the top of the Sibley coal.

In the area around Westphalia, in Anderson county, there is some indication of a hiatus within the member. Gray, silty shale, ranging from 6 to 17 feet, occurs at the base of the member. The shale is overlain with clean, irregular contact by 6 to 10 feet or more of slabby sandstone. The sandstone is absent or relatively obscure in other areas.

Both the Westphalia and Haskell limestones contain fusulinids, and therefore each represents the culminating phase of separate cyclothems. The regressive phase of the Westphalia cyclothem and the transgressive phase of the Haskell cyclothem must be contained in the Vinland shale. The sandstone in the Vinland in western Anderson county, and the purple shale near Yates center probably represent the initial deposits of the Haskell cyclothem. The molluscan faunas in the upper part of the Vinland shale undoubtedly belong in phases 2 and 3 of the Haskell cyclothem.

Stranger Formation

HASKELL LIMESTONE MEMBER, Moore, 1932

1894, †*Le Roy shale* (part), Haworth, E., and Kirk, M. Z., and authors. (See under Weston shale.)

1894, *Lawrence shale* (part), Haworth, E., and references cited under Weston shale.

1900, †*Lawrence oölite*, Beede, J. W., and Rogers, A. F., Kan. Univ. Quart., vol. 9, pp. 233-254.

1908, †*Kickapoo limestone* (part), Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 106. Name misapplied because of erroneous correlation to outcrops near Lawrence and elsewhere now identified as Haskell.

30. Kellett, Betty, op. cit.

1917, *Iatan limestone* (part), MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 101. Includes beds now called Haskell. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 41. Same.

1932, **Haskell limestone,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93.

Type locality, on Fifteenth street, NE¼ sec. 5, T. 13 S., R. 20 E., at east edge of Lawrence. Named from Haskell Institute, Lawrence.

The Haskell limestone is remarkably persistent and uniform in character and undoubtedly is the best key horizon between the Lansing and Shawnee groups in Kansas. Throughout much of the outcrop the Haskell is bluish-gray, blocky, fine-grained limestone, occurring as a single ledge without shale partings. This phase of the Haskell contains banded algae like *Ottonosia* (*"Cryptozoon"*) and a few scattered fusulinids and brachiopods. Locally, as at Lawrence, oölitic layers occur at the base and top of the member. The upper oölite layer at Lawrence furnished the types for several of the pelecypod species of Beede and Rogers. Toward the northeast into Missouri the member becomes shaly. Ordinarily the Haskell measures from two to four feet in thickness, but to the south of Elk City and Peru, in Chautauqua county, the member is less than a foot thick. The shale just under the Haskell contains in Chautauqua county a prolific molluscan fauna having a facies like that associated with the so-called Wildhorse limestone of Osage county, Oklahoma. Probably the two limestones are the same.

STRANGER FORMATION

ROBBINS SHALE MEMBER, Moore and Newell, 1936

Type locality, named from the Robbins farm in sec. 11, T. 26 S., R. 15 E., southwest of Yates Center, Kan.

Above the Haskell limestone lies a marine, argillaceous shale having a variable thickness. The term Robbins is proposed here for this shale, as the topmost member of the Stranger formation. It is overlain by the unconformable Ireland sandstone. Heretofore the shale above the Haskell and below the Oread limestone has been classed as a single formation, the Lawrence shale. Inasmuch as the hiatus at the base of the Ireland sandstone extends clear across Kansas it supplies a horizon of stratigraphic cleavage compatible with the modern ideas of classification based on diastrophism. In northeastern Kansas the base of the Ireland sandstone rests at or near the top of the Haskell limestone. The Lawrence shale, whose original limits were the Haskell and the Oread limestones, needs revision in this area. The Ireland sandstone, however, rises toward the south so that a thick wedge of argillaceous shale separates it from the Haskell in southern Kansas. In this area the Lawrence, as defined by the base of the Ireland, occurs some scores of feet above the Haskell.

The region around Lawrence, Kan., occurs between two channel deposits of the Ireland. In this area the Ireland cannot be recognized. However, the marginal phases of an Ireland lentil at Leavenworth appear to rest directly or nearly so on the Haskell. The same situation occurs around Baldwin, Kansas, to the south of Lawrence, where an Ireland wedge first appears almost immediately above the Haskell. The Lawrence shale in this area may arbitrarily be defined to include nearly all of the clastic beds between the Haskell and Oread limestones. In the Lawrence area a few inches of shale immediately above the Haskell contains marine fossils and should be excluded from the lower Lawrence, which apparently is ordinarily non-marine.

South of Lawrence the Robbins shale is first definitely recognized in the Baldwin area where it is commonly 1 to 5 feet thick. At several outcrops in this area and the area west of Ottawa the Robbins and Haskell are cut out and overlapped by the Ireland. A persistent zone of ellipsoidal phosphatic concretions occurs at the base of the Robbins shale from near Baldwin to Leavenworth. These concretions commonly contain the brain casts of fish, and a few have been discovered containing ammonoid cephalopods. Southward from Yates Center in Woodson county the Robbins shale thickens to an average of about 100 feet, consisting chiefly of gray argillaceous and silty shale.

Some massive sandstone beds appear abruptly in the Robbins in Chautauqua county. Probably these units continue into Oklahoma.

LAWRENCE SHALE (Haworth, 1894), Moore and Newell, 1936

1894, *Lawrence shale* (part), Haworth, E., Kan. Univ. Quart., vol. 2, p. 122. Applies name to beds between the †Ottawa [Stanton] limestone and the Oread limestone. For additional references see under Weston shale.

1896, Not *Lawrence shale,* Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 79. Erroneously describes beds above the †Garnett ("Burlington") [Oread] limestone as Lawrence shale.

1908, *Lawrence shale,* Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 106. Revises application of Lawrence shale to include beds between †Kickapoo [Iatan], which was miscorrelated with the Haskell limestone at Lawrence, and Oread limestones. For additional references see under Stranger formation. Also, —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 35. *—— 1936, MOORE, R. C., and NEWELL, N. D., this paper.

Type locality, Lawrence, Kan.

The term Lawrence has customarily been applied to those strata between the Haskell and Oread limestones. The recognition of a regional unconformity within the interval between the Haskell and Oread limestones affords a basis for a two-fold division of the Lawrence as formerly defined. It is proposed to restrict the term Lawrence to beds from the base of the Ireland sandstone to the base of the Oread limestone. The Ireland is locally unrecognizable at Lawrence, but the lower contact of the Lawrence in this area may arbitrarily be placed at the top of the fossiliferous layer of phosphatic concretions which is known to occur in the Robbins elsewhere. This arbitrary definition excludes 1 to 2 feet of shale above the Haskell from the Lawrence as redefined.

Some of the named divisions in the Lawrence are relatively local in extent so that the detailed correlation of beds from place to place is difficult and much work remains to be done on them.

The Ireland sandstone[31] at the base of the Lawrence shale is bounded below by a regional unconformity recognized from Leavenworth, Kansas, southwestward into Oklahoma. The upper limit of the sandstone is indefinite and probably does not constitute a single stratigraphic horizon. Although the lower part of the Ireland is almost invariably massive cross-bedded sandstone devoid of marine fossils, the upper part becomes shaly and grades into sandy shale above. In those areas where the Ireland is well developed it occupies the lower half to two-thirds of the formation, not uncommonly attaining a thickness of 100 feet or more and most of the sandstone is relatively massive.

The Ireland as seen along the outcrop constitutes several more or less disconnected lenses of sandstone resting unconformably on older beds. In this respect the Ireland is similar to the Tonganoxie, but contains a greater bulk of sandstone. At least five lenses, apparently representing stream valley cross-profiles, are recognized. The most famous of these occurs at Leavenworth. Formerly it was believed that all of the channel sandstone at Leavenworth belongs in the Stranger formation.[32] Recent work by Patterson,[33] and con-

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31. Named by R. C. Moore, Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93. Type locality, on Ireland Creek and farm of W. E. Ireland, 5 miles southwest of Yates Center, Kan.

32. Newell, N. D., Kan. Geol. Survey, Bull. 21, p. 80 (1935), 1936.

33. Patterson, J. M., The Douglas group of the Pennsylvanian system in Douglas and Leavenworth counties, Kansas: Master's Thesis, Kan. Univ., pp. 28-30, 1933, unpublished.

firmed by us, demonstrates that Ireland and Stranger sandstones are both represented in the Leavenworth area. The Ireland rests disconformably on the lower Stranger so that locally the contact between them cannot be recognized. The identification of the Ireland in this area rests on the fact that the upper part of the great sandstone mass rises topographically 30 or 40 feet above the Haskell limestone, and the Haskell is missing in the sandstone area, although clearly recognizable to the northeastward at Weston and Iatan, Mo.

In addition to the Ireland channel-filling at Leavenworth, another equally prominent one occurs in southwestern Douglas and western Franklin counties. This channel was long known to Dr. John L. Rich. In this area Rich[34] described angular coal fragments in the basal part of the Ireland. The coal fragments, derived from the Sibley coal bed, were shown to have been coalified before pre-Ireland erosion. According to Rich the long time probably involved in the formation of coal prior to pre-Ireland erosion suggests a major hiatus at the base of the Ireland. The evolutionary change in invertebrates between the Stanton and Oread formations is not pronounced, and there is scarcely any faunal break whatsoever in this part of the stratigraphic column. Apparently the time involved in the pre-Stranger hiatus plus that of the pre-Lawrence hiatus is negligible compared with the general rate of evolution in the Pennsylvanian faunas.

Other large lenses connected laterally along the outcrop are found across Woodson county, western Wilson county, and Chautauqua county. From northern Woodson county far into Oklahoma the Ireland makes a continuous prominent escarpment.

The basal sandstones of the Ireland division are continuous with the base of the Jonesburg and Bigheart sandstones of Osage county, Oklahoma. The upper part of the Lawrence has been differentiated in Oklahoma and several units named so that it is improbable that the top of the Bigheart and Jonesburg sandstones correspond even approximately to the upper part of the Ireland.

At least two persistent coal beds occur in the upper part of the Lawrence in the northeastern part of the state The more persistent of these is the Williamsburg coal lying from 15 to 40 feet below the Oread. This coal extends from the vicinity of St. Joseph, Missouri, to northeastern Greenwood county, Kansas. Ordinarily it is only three or four inches thick, but it is over a foot thick near Williams-

34. Rich, John L., Geol. Soc. America, Bull., vol. 44, pp. 865-870, 1933.

burg in Franklin county, where it is mined. The second coal extends from the St. Joseph area to the vicinity of Baldwin, in southern Douglas county, Kansas, and occurs sporadically as far north as Woodston county. It occurs from 5 to 30 feet below the Williamsburg coal and invariably is quite thin.

A massive nodular limestone ranging up to 15 feet thick occurs some 25 to 60 feet below the Oread in northwestern Missouri, the interval increasing toward the south. Near its southern extent north of Iatan, Missouri, this limestone, the *Amazonia limestone* of Missouri geologists, occurs about 65 feet below the Oread and 70 feet above the Haskell. It appears to lie 15 or 20 feet below the lower coal in the Lawrence. A thin, mottled, almost unfossiliferous limestone extends from Williamsburg, Kan., southward into Greenwood county. In the northern area it occurs immediately beneath the Williamsburg coal but farther south it occurs 20 feet or so below the coal. In spite of the fact that the Amazonia of the type region in Missouri occurs a considerable distance below the Williamsburg coal, it may be represented in the eastern Kansas area by the limestone under the Williamsburg coal.

A persistent clayey and limy maroon shale occurs from about 5 to 30 feet under the Oread. The maroon shale commonly occurs in one irregular bed, from 1 to 5 feet thick, but in some instances the maroon shale occurs in three or more layers separated by greenish or buff shale. The maroon shale zone extends from the St. Joseph area southwestward to the Baldwin area in southern Douglas county, Kansas. Southward the horizon is generally absent or obscure across eastern Kansas until it reappears in Elk county. Maroon shales are common in and above the Ireland sandstone in Chautauqua county, Kansas, and northern Osage county, Oklahoma.

The detailed stratigraphy of the Lawrence shale is still too poorly known to attempt an analysis into cyclothems.

Lawrence Shale

IRELAND SANDSTONE MEMBER, Moore, 1932

1932, **Ireland sandstone member,* of the Lawrence shale, Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 93.

Type locality, on Ireland Creek and farm of W. E. Ireland, 5 miles southwest of Yates Center, Woodson county, Kansas.

Massive or irregularly cross-bedded buff or brownish sandstone, some tens of feet in thickness, is prominent in the Lawrence shale at some places. The sandstone occurs partly in the form of large sheets of varying horizontal extent and thickness, and partly as channel fillings, in the latter case associated locally with deposits of limestone conglomerate up to 8 or 9 feet thick in the bottom of the channel depressions. The base of the channel sandstone deposits of the Lawrence shale in Douglas and Leavenworth counties is in contact with the lower part of the Lawrence shale, Haskell limestone, Stranger formation and probably in places with the Iatan limestone and Weston shale. The sandstone is highly micaceous and in general is rather easily friable, although in some places the grains are tightly cemented. The quartz sand grains average about 0.2 mm. or slightly less in diameter. Excepting occasional macerated and carbonized plant remains the sandstone is unfossiliferous.

In the type region the top of the Ireland sandstone is only a few feet below the top of the Lawrence shale, but north of Kansas river and in subsurface sections extending to west-central Kansas sandstone bodies in the middle and lower part of the formation have been classed as Ireland.

Lawrence Shale

AMAZONIA LIMESTONE MEMBER, Hinds and Greene, 1915

1908, †*Kickapoo limestone,* Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 106. Erroneously identify outcrops of limestone in Doniphan county.

1915, **Amazonia limestone bed* (in the Lawrence shale member of the Douglas formation), Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, pp. 31, 170. Occurs "25 to 100 feet below top of Lawrence shale." —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 35.

Type locality, Amazonia, in southern Andrew county, Mo.

The Amazonia limestone member occurs about 24 feet below the top of the Lawrence shale at Amazonia, at the Heumader quarry, 1.5 miles northwest of St. Joseph, Mo., and near Wathena, Kan. Southward the shale above the Amazonia gradually thickens to more than 60 feet southeast of Atchison. Hinds and Greene report as much as 100 feet of Lawrence beds above the Amazonia, between Rushville and St. Joseph, Mo. At the type locality the Amazonia member is 9 feet thick. Near St. Joseph and Wathena it is 13 feet thick but southward it gradually diminishes and disappears.

The physical characters of the Amazonia limestone are very similar to those of the Iatan limestone. It is a light-gray rock when fresh and weathers nearly white with irregular brownish mottling. Most of the beds are very fine-grained and dense but in places the upper part is coquinoid or appears fragmental, with rounded or angular pieces of dense gray rock in a brownish matrix. Bedding is poorly developed and the member tends to weather, therefore, as a very massive ledge which breaks along joint planes allowing large blocks to slump downward on steep slopes. Weathering of the faces of these blocks or of the bed in places reveals a faint but distinct uneven, wavy stratification. Fossils are not abundant generally, but in some outcrops and in certain parts of the member numerous brachiopods, bryozoans, crinoid fragments and some other invertebrate remains may be found. Sponges are abundant in exposures of the Amazonia southeast of Atchison. Fusulinids probably occur in some layers but have not been observed.

SHAWNEE GROUP (Haworth, 1898), Moore, 1932

1898, *Shawnee formation,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 93. Includes beds from top of Oread limestone to top of †Osage (Scranton) shale. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 31. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 102. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 42. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 38.

1908, *Shawnee stage,* HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 76.

1921, *Shawnee group,* FATH, A. E., Kan. Geol. Survey, Bull. 7, pp. 39, 43, pl. 7, according to classification of U. S. Geol. Survey. —— 1932, *MOORE, R. C., Kan. Geol. Survey, Guidebook, Sixth Ann. Field Conf., pp. 93-94. Revises boundaries to include beds from the base of the Oread limestone to the top of the Topeka limestone.

Type locality, Shawnee county, Kansas.

As originally defined and subsequently used in Kansas and adjacent states, the Shawnee group or "formation" includes the beds from the base of the Kanwaka shale to the top of the Scranton shale. There is no evident reason for this segregation of strata except convenience in including together the beds between two well-defined readily mappable escarpments. Consistency, even on this basis, would require the inclusion of the Oread limestone in the Shawnee group, because the line that is followed in mapping an escarpment is the base rather than the top of the resistant bed, which may have a dip slope of several miles.

The Shawnee group is now redefined to include the beds from the base of the Oread limestone to the top of the Topeka limestone. Thus limited, the group is a very well differentiated segregation of beds in which thick limestones and a distinctive type of cyclic sedimentation are prominent features. In tracing these beds underground it is found that the limestones converge to form a thick body of nearly solid limestone that is readily separated from the clastic Douglas beds below and from the shaly strata and thin limestones of the Wabaunsee group above. Paleontologic characters of the Shawnee beds are in harmony with the grouping that is here defined.

The Shawnee group contains the following formations, named in upward order: Oread limestone, Kanwaka shale, Lecompton limestone, Tecumseh shale, Deer Creek limestone, Calhoun shale, and Topeka limestone.

Equivalents of the Shawnee group in northern Oklahoma include the topmost beds of the Nelagoney formation (Oread), the Elgin sandstone, the Pawhuska formation, and approximately the lower 50 feet of the Buck Creek formation. It is not yet possible to indicate with any definiteness correlation of the Shawnee beds with distant Pennsylvanian sections. In north-central Texas beds of Shawnee age are believed to occur in the lower part of the Cisco group. The Shawnee appears to be younger than any part of the Pennsylvanian rocks of Illinois. It is probably represented in the lower Monongahela of the Appalachian district.

OREAD LIMESTONE (Haworth, 1894), Haworth, 1895

1894, †*Burlington limestone,* Haworth, E., and Kirk, M. Z., Kan. Univ. Quart., vol. 2, p. 110. —— 1894, Haworth, E., Kan. Univ. Quart., vol. 2, p. 120. Name preoccupied by Burlington limestone, 1856, Mississippian of Iowa, Illinois, and Missouri.

1894, †*Garnett limestone,* Haworth, E., Kan. Univ. Quart., vol. 2, pp. 110, 120. Includes Oread near Burlington and other places. —— 1896, Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 79. Same.

1894, *Oread limestone,* Haworth, E., Kan. Univ. Quart., vol. 2, p. 123. Name applied to massive 10-foot buff limestone next above Lawrence shale, overlain by 8 feet of shale and 1-foot limestone. Original use is synonymous with "lower Oread" of later writers. *—— 1895, Haworth, E., Am. Jour. Sci., (3), vol. 50, p. 461. Name applied to two limestones each about 15 feet thick separated by about 20 feet of shale (indicates "lower Oread" and "upper Oread" of later writers, the latter probably including also the beds now called Kereford limestone. —— 1896, Hall, J., Kan. Univ. Geol. Survey, vol. 1, p. 103. Same. —— 1896, Bennett, J., Kan. Univ. Geol. Survey, vol. 1, p. 114. Includes at top of "upper" member flaggy bed equivalent to Kereford limestone of Condra, 1927. —— 1896, Haworth, E., Kan. Univ. Geol. Survey, vol. 1, p. 138. Mentions two main limestone members. —— 1903, Adams, G. I., U. S. Geol. Survey, Bull. 211, p. 44. Mentions two limestone members. —— 1908, Haworth, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 107. Notes presence of three limestone members. —— SCHRADER, F. C., U. S. Geol. Survey, Geol. Atlas, Folio 159, p. 3. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 31. Classes as a member of Douglas formation and recognizes four limestone beds, including limestone above "upper" member, equivalent to Kereford limestone of Condra, 1927. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 102. Classes as member of Douglas formation and mentions three limestone beds. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 11. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 36. Same, applies names to all members.

1899, *Plattsmouth limestone,* KEYES, C. R., Am. Geologist, vol. 23, p. 306. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 90. There is no ground for assigning priority in the use of this name to F. B. Meek (in Hayden, F. V., Final Rept. U. S. Geol. Survey Neb., p. 94, 1871) as claimed by Keyes, for the context of Meek's paper plainly indicates that he did not use Plattsmouth as a stratigraphic term. —— 1928, KEYES, C. R., Pan-Am. Geologist, vol. 50, p. 62.

1906, †*Painterhood limestone,* SCHRADER, F. C., AND HAWORTH, E., U. S. Geol. Survey, Bull. 296, p. 11. Named from Painterhood Creek, T. 30 S., R. 12 E., Elk county, synonymous with Oread.

Type locality, Mount Oread, campus of University of Kansas, Lawrence, Kan.

The Oread limestone is a prominent scarp-forming limestone, named from the hill on which the University of Kansas at Lawrence is situated. Haworth (1894) first applied this name only to the lowermost limestone of the formation as here developed, but later (1895) he extended the name to include the overlying thick light-gray limestone now commonly known as the upper Oread or Plattsmouth limestone. An intermediate thin blue limestone (Leavenworth member) was not recognized in the early reports. As here defined, the Oread includes not only these three limestones and the intervening shales, but a locally developed still higher limestone that is oölitic or a dense dark-blue flagstone. This upper bed, called "Waverly flagging" is the algal or molluscan limestone phase of the Oread megacyclothem, and was properly included with the Oread beds by Bennett (1896) and Hinds and Greene (1915). It was named the Kereford limestone by Condra (1927).

The Oread limestone contains the following members, named in upward order: Toronto limestone, Snyderville shale, Leavenworth limestone, Heebner shale, Plattsmouth limestone, Heumader shale, and Kereford limestone.

The total thickness of the Oread formation in the neighborhood of the type locality at Lawrence is 45 feet. The Lawrence shale lies conformably beneath the Oread and the Kanwaka shale is conformable above. Where the Kereford limestone is absent, the boundary between the Oread and Kanwaka formation is defined at the top of the Plattsmouth limestone.

Because of the resistance to erosion afforded by the Oread limestone its outcrop is marked by a prominent escarpment that may be traced entirely across Kansas from Doniphan county in the north to Chautauqua county in the south. In the northern half of the state the shale members of the Oread are moderately thin, and the limestone members accordingly are close together, forming subordinate benches of a single escarpment. In southern Kansas, however, the Snyderville shale member increases in thickness to 75 feet or more, so that separate escarpments which are locally a mile or more apart are made by the Toronto ("lower Oread") limestone and the Leavenworth-Plattsmouth ("middle" and "upper Oread") members. Coincident with the increase in thickness of the Snyderville member is an increasing prominence of red shale and an appearance of subordinate nodular limestone and calcareous sandstone beds in this part of the formation. Disappearance of the limestone members of the Oread in northern Oklahoma makes it impracticable to differentiate the formation as a stratigraphic unit in this region. The equivalent strata are included in the upper part of the Nelagoney formation.

OREAD LIMESTONE

TORONTO LIMESTONE MEMBER, Haworth and Piatt, 1894

1894, **Toronto limestone,* HAWORTH, E., AND PIATT, W. H. H., Kan. Univ. Quart., vol. 2, p. 117. Named from Toronto, Woodson county, Kansas.

1894, *Oread limestone,* HAWORTH, E., Kan. Univ. Quart., vol. 2, p. 123. This name was first applied to this limestone but later redefined to include higher beds.

(?) 1915, *Weeping Water limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., vol. 9, p. 10. Defined as a member of the "Andrew (Lawrence) shale," the first important limestone below the Plattsmouth limestone which was thought to be equivalent to the Oread limestone. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 36. Classed as lowermost member of the Oread limestone. Similarly used in several later papers.

Type locality, Toronto, Woodson county, Kansas.

This member of the Oread limestone, the "lower Oread" of Kansas geologists, is distinguished by its strongly brown color in weathered outcrops and its massive character. The rock breaks in uneven slabby fragments that are variously inclined to the poorly defined bedding. Fossils are numerous locally but in many places they are scanty. Fusulinids are common, and associated with them are brachiopods, bryozoans, crinoid remains, and in places mollusks. The upper few inches to 2 or more feet of the Toronto limestone in many exposures is clearly to be differentiated from the underlying part of the member, both on lithologic and faunal grounds. This upper part is distinctly algal in some places and lacks fusulinids. It represents the limestone element of the cyclothem designated by the index number .7, whereas the main part of the Toronto, containing more or less abundant fusulinids, is the element numbered .5.

The thickness of the Toronto limestone exceeds 6 feet in most outcrops but in a few places it is more than 10 feet thick. Locally this member is distinctly sandy.

Condra has classed the Weeping Water limestone, typically exposed on Weeping Water Creek, T. 10 N., R. 12 E., and near Plattsmouth, Nebraska, as the lowermost member of the Oread formation. There is sufficient doubt, however, as to the equivalence of the "lower Oread" limestone of Kansas and the Weeping Water limestone of Nebraska to make use of the latter name undesirable as a subdivision of the Kansas Oread. This doubt is based partly on the contrasting lithologic characters of the typical "lower Oread," which is massive, strongly brownish in weathered outcrops and decidedly ferruginous, and of the Weeping Water which is more thinly bedded, light-gray in color and not ferruginous. Possibly more significant is the observation that no other Shawnee limestone formation in Nebraska certainly contains a representative of the "lower" limestone member. The absence of the Spring Branch[35] ("lower" Lecompton) and "Curzen" ("lower" Topeka) limestones in Nebraska has been recognized by Condra. Examination of Deer Creek outcrops in Nebraska by me in July, 1934, indicates that the Rock Bluff limestone member, supposed "lower" Deer Creek, is really the "middle" limestone and thus it appears that there is no "lower" Deer Creek limestone now known north of Kansas. The Weeping Water limestone occurs in the stratigraphic position of the "lower" Oread, but it is possible that this is really a quite different limestone comparable or perhaps exactly equivalent to the Amazonia limestone in the Lawrence shale.

35. Conclusion that the Spring Branch limestone is absent in Nebraska may require modification when restudy of the correlation of the "Plattsmouth limestone" section of the Snyderville quarries and other places in Nebraska has been completed, for it is possible that the topmost part of the "Plattsmouth" as previously identified may prove to be the Spring Branch limestone.

Oread Limestone

SNYDERVILLE SHALE MEMBER, Condra, 1927

1927, **Snyderville shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 38. Defined to include the beds between the Weeping water [? Toronto] limestone below and the Leavenworth limestone above. Classed as a member of the Oread limestone. Similarly used in several later papers.

Type locality, Snyderville quarry on Heebner Creek, west of Nehawka, Neb.

The Snyderville shale member of the Oread limestone is a bluish to grayish and in part red shale that occurs next above the Toronto limestone. In northern Kansas and Nebraska it is clayey and its maximum thickness is mostly less than 18 feet, its average being about 12 feet. To the south this member becomes more sandy in at least some parts, and it includes subordinate earthy limestone and sandstone beds. Red shale becomes increasingly evident in this region also. The thickness of the shale increases to about 75 feet, exceeding the total thickness of such shale formations as the Tecumseh and Calhoun as developed in southern Kansas. Accordingly the stratigraphic classification here indicated seems less natural for the southern than for the northern area. Equivalence of the various units in the two regions is well established and their relation to cyclothems indicates that the northern Kansas classification should be used also in the south.

Most outcrops of the Snyderville shale in northern Kansas and in Nebraska show that all of the member except the topmost 1 or 2 feet consists of structureless gray clay that weathers in irregularly shaped blocky fragments. It has the character of an underclay such as occurs typically below a coal bed, but underclays 10 to 12 feet thick are decidely unusual in the Pennsylvanian section of Kansas. That this part of the Snyderville is, in fact, an underclay (representing part of cyclothem element numbered .1 is indicated by its position above the algal "super" bed (No. .7) of the Toronto limestone, by the local occurrence of a carbonaceous streak (where a coal bed should occur in the normal cyclic sequence) at the top of the blocky shale, and by the character of the upper 1 to 2 feet of the Snyderville which is well laminated shale bearing a marine fauna of brachiopods, bryozoans and some pelecypods (element No. .2 or possibly .4). The overlying Leavenworth limestone contains fusulinids and is clearly a No. .5 bed of the typical cyclothem.

If, as previously suggested, the "lower" Oread limestone of Kansas is not equivalent to the Weeping Water limestone of Nebraska, use of the term Snyderville may be open to question as applied to the shale between the "lower" and "middle" Oread limestones of Kansas. There is no doubt, however, concerning identity of the Leavenworth ("middle" Oread) limestone which next overlies the Snyderville shale at the type locality, and since no name has been applied to the shale between the Leavenworth and Toronto limestones in Kansas, we may provisionally call this Snyderville shale.

Oread Limestone

LEAVENWORTH LIMESTONE MEMBER, Condra, 1927

1927, **Leavenworth limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 38. This name is applied to the "middle member" of the Oread limestone and is so used in several later papers.

Type locality, Leavenworth, Kan. (road cut on upland spur northwest of federal penitentiary).

The Leavenworth limestone member of the Oread, commonly called "middle Oread" by geologists, is very distinctive in physical characters and for hundreds of miles along the outcrop is rarely found to have a thickness less than 1 foot or more than 2 feet. Such a thin bed might well be presumed by one who did not know[36] to be an inconsequential unit of probably very local distribution. Instead, the member is found to extend without break or essential change of characters form central Iowa to Oklahoma. The chief lithologic peculiarities of the Leavenworth limestone are the uniform fine-grained dense and hard character of the rock, its dark-blue color, and the prevalence of vertical joints. The member consists of a single massive layer. On weathering a thin surface film is altered to a light-gray or slightly creamy color and the substance of the rock is slowly removed by solution. This tends to round the edges of joint blocks giving rise eventually to bouldery remnants of the bed along some long weathered outcrops. Fossils are fairly numerous but cannot be broken readily from the limestone. Fusulinids and molluscoids are most common but in many places there are abundant mollusks in the lower and upper part of the bed.

36. See Keyes, C. R., Pan-Am. Geologist, vol. 50, p. 66, 1928.

OREAD LIMESTONE

HEEBNER SHALE MEMBER, Condra, 1927

1927, **Heebner shale*, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 37, "The first shale below the Plattsmouth limestone," classed as a member of the Oread limestone. Similarly designated in several later papers.

Type locality, Heebner Creek and farm, west of Nehawka, Neb.

The lower portion of the Heebner shale member is characteristically black, carbonaceous, hard and very fissile. It contains conodonts but mostly lacks megascopic fossils. The upper part is a bluish to yellowish gray clayey shale which in places contains numerous fossils, chiefly molluscoids. The thickness of the member varies little from 5 feet, and this is true in southern Kansas as in Nebraska. The fact that black "slaty" shale is seen in no other part of the Oread formation and the occurrence of this shale between the very distinctive "middle" and "upper" limestones make recognition of the Heebner member easy and certain (unless one has to do with the shale above the "middle" limestone of the Lecompton, Deer Creek or Topeka limestones).

OREAD LIMESTONE

PLATTSMOUTH LIMESTONE MEMBER, (Keyes, 1899), Condra, 1927

1899, *Plattsmouth limestone,* KEYES, C. R., Am. Geologist, vol. 23, p. 306. Indicates total thickness at type locality as about 30 feet but does not give stratigraphic definition. F. B. Meek (in Hayden, F. V., U. S. Geol. Survey Neb., p. 93, 1871) gives a section at Plattsmouth, Neb., of beds representing the upper part of the Lawrence shale and the entire Oread limestone as now classified, and in discussing correlation (p. 94) casually refers to "the Plattsmouth beds." Keyes is not justified in assigning authorship of Plattsmouth as a stratigraphic name to Meek, but in using Plattsmouth himself, Keyes evidently includes all of the Oread. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 90. Same. —— 1915, CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Pub., vol. 9, No. 2, p. 10. Applies name to 30-33 feet of beds equivalent to Leavenworth, Heebner and Plattsmouth members of later classification. *—— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 37. Restricts name to apply to "upper Oread" limestone above black slaty shale, and classes it as a member of the Oread limestone. Similarly used in several later papers.

Type locality, Plattsmouth, Neb.

The Plattsmouth limestone member of the Oread formation, commonly termed "upper Oread" by Kansas geologists, is the thickest limestone unit, averaging about 15 feet and locally attaining nearly twice this thickness. It is distinguished by the very light bluish-gray color of the rock which weathers light creamy yellow to nearly white. The beds are thin and irregular, with wavy thin shale partings. The texture is very fine to almost lithographic, but there are commonly thin to coarse streaks and patches of clear crystalline calcite. Chert occurs in parts of the member, being more prominent in some localities than in others. Fossils are fairly common. Fusulinids and molluscoids predominate. This is the topmost limestone along the Oread escarpment in most places, for the overlying Kereford limestone, when present, is mostly found at some distance back from the front of the escarpment.

According to observations made by me in July, 1934, of the type Plattsmouth exposures near Plattsmouth, Neb., and of the excellent section in the Snyderville quarry west of Nehawaka, Neb., which is regarded by Condra as showing uppermost beds of the Plattsmouth limestone that are eroded at Plattsmouth, it appears that Condra's definition of this unit includes equivalents not only of the "upper" Oread limestone of Kansas, but also of the Kereford limestone member of the Oread, the Clay Creek limestone member of the Kanwaka shale and other limestones that appear in the northern part of the Kanwaka shale. If this is true, the name Plattsmouth is not applicable to the "upper" Oread limestone alone unless restricted to use in this sense. Since it was evidently Condra's intention to designate only the "upper" Oread limestone member as Plattsmouth, and since the Kereford and other stratigraphic units in the type Plattsmouth section can be recognized, it seems best to restrict application of Plattsmouth to the limestone beds between the Kereford (Heumader shale absent at Plattsmouth) and Heebner members of the Oread.

Oread Limestone

HEUMADER SHALE MEMBER, Moore, 1932

1932, **Heumader shale,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., pp. 94, 96. Mentioned and listed in table but without formal proposal. References to this unit are included in several recent papers by Condra.

Type locality, Heumader quarry, bluffs of Missouri river just north of St. Joseph, Mo.

The few feet of shale that lies between the base of the Kereford limestone where that member is present and the top of the Plattsmouth limestone may be termed Heumader shale and classed as a member of the Oread formation. The shale is clayey to sandy and in most cases appears dark-gray. Some exposures show the presence of fairly numerous mollusks and some other fossils but in some places the shale is unfossiliferous. Its thickness ranges from almost nothing to 10 feet. Where the Kereford limestone is absent the Heumader and possibly shaly equivalents of the Kereford are not differentiated. Although stratigraphic continuity with units classified as parts of the Oread formation is recognized, the shale next above the Plattsmouth is then included with the Kanwaka shale.

Oread Limestone

KEREFORD LIMESTONE MEMBER, Condra, 1927

1927, **Kereford limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 45. Applies this name to "dense, somewhat arenaceous, in part oölitic and quite fossiliferous" limestone "near Lecompton and Atchison, Kan., and at Amazonia, Mo.," in the lower portion of the Kanwaka shale. Type locality not mentioned. —— 1932, Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 94. Classed as uppermost member of the Oread limestone. Similarly used in later papers by Condra.

Type locality, Kereford quarry at south edge of Atchison, Kan.

The Kereford limestone is a very interesting stratigraphic unit that is perhaps chiefly characterized by its very local development, by the variation of its lithologic features, and by the richness of its fossil content. All of these are characters that distinguish the "super" members of the limestone formations in the Pennsylvanian of Kansas. Unlike the other limestones which are, in general remarkably constant in thickness and physical nature, the Kereford ranges in thickness in a few miles from a featheredge to 10 or 12 feet, and there are many miles along the outcrop in which no representative of the member has been observed. It is probably present in many places where it has not yet been observed, however, for conditions are not in general very favorable for showing its presence. Some exposures show that the member consists locally almost wholly of oölite and in these places the rock is somewhat slabby and crossbedded. In other places the Kereford is a single dense, dark bluish massive hard limestone, apparently somewhat siliceous. In still other outcrops it is a blue flagstone, consisting of several feet of alternating even-bedded dense blue limestone layers and approximately equal thicknesses of shale. Almost all of these types of deposits contain numerous very well preserved fossils in which mollusks are strongly predominant and fusulinids, so far as known, absent. Condra at first regarded this lenticular limestone as an element in the Kanwaka shale, but it seems rather to be associated definitely with the cycle of limestone and marine shale deposits in the Oread formation. It was so regarded by Hinds and Greene in Missouri, and Condra now agrees with Moore in classing the Kereford as a member of the Oread.

An exception to the statement concerning absence of fusulinids in the Kereford limestone appears in outcrops at Lecompton, Douglas county, west of Tonganoxie, southwestern Leavenworth county, and elsewhere in northeastern Kansas and northwestern Missouri that are identified as Kereford on the basis of stratigraphic position. The limestone at these places, separated by a few feet of shale from the underlying Plattsmouth, lacks the characteristic wavy bedding and other lithologic features of the Plattsmouth, and differs from the normal Kereford in containing abundant small fusulinids.

KANWAKA SHALE, Adams, 1903

1898, *Lecompton shale,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 64. Includes shale between Oread and Lecompton limestones. The name Lecompton is now restricted to the limestone formation overlying this shale.

1896, *Lawrence shale,* KIRK, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 79. Through error Kanwaka and other beds along Neosho river are classed as Lawrence shale.

1902, **Kanwaka shale,* ADAMS, G. I., Mss., name used by Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 163. Applies name to beds between Oread limestone and Lecompton limestone. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 45. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 108. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 32. Classes as member of the Shawnee formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 103. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 43. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 44. Same, but includes Kereford limestone.

Type locality, Kanwaka township, exposures east of Stull, about 9 miles due west of Lawrence. Well exposed near SE cor. sec. 26, T. 12 S., R. 18 E., Douglas county.

The name Kanwaka shale is applied to beds between the top of the Kereford limestone or, where the Kereford is absent, the top of the Plattsmouth limestone member of the Oread formation and the base of the Lecompton limestone. From the standpoint of general lithologic character and topographic expression the Kanwaka shale appears to be a well defined formational unit. It includes both marine and nonmarine deposits, however, and comprises the terminal part of the Oread cyclothem, all of the Clay Creek cyclothem, and the initial part of the Lecompton cyclothem. Sandy shale in the lower part contains in places remains of land plants. Limestone in the upper middle part is found in central and northern Kansas, and probably equivalent sandstone and shale with marine fossils occurs in southern Kansas and northern Oklahoma. The limestone contains a varied fauna of brachiopods, bryozoans, and some mollusca, and in places abundant fusulinids. The upper part of the shale is sandy and contains remains of land plants. A few feet below the Lecompton limestone is a persistent sandstone, which thickens southward to form the main part of the Elgin sandstone. Above this sandstone locally is a coal bed. The sandstone is regarded as forming the initial deposit of the Lecompton megacyclothem.

The Kanwaka shale is divided into three members, named in upward order: Jackson Park shale, Clay Creek limestone, and Stull shale.

Kanwaka Shale

JACKSON PARK SHALE MEMBER, Moore, 1932

1932, **Jackson Park shale,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., pp. 94, 96. Indicates as member of Kanwaka shale including beds between top of Oread limestone and base of Clay Creek limestone. This publication lacks data necessary in formal proposal, but subsequent reference is made to it by Condra (Neb. Geol. Survey, (2), Paper 2, p. 23, 1933).

Type locality, Jackson Park, southeast part of Atchison, Kan.

The Jackson Park shale is bounded below by the Kereford limestone, or where that member is absent by the top of the Plattsmouth limestone member of the Oread formation. The upper limit is marked at the base of the Clay Creek limestone, which at the type locality near Atchison occurs about 24 feet above the top of the Kereford limestone. Along Kansas river the Jackson Park shale is over 50 feet thick. Bluish-gray and yellowish-brown sandy shale, in part containing remains of land plants, compose most of the Jackson Park shale section. At the present time this member is clearly defined only in the northern half of the state, because the Clay Creek limestone has not been traced definitely into south-central Kansas. If, as appears from a recent examination of outcrops at Plattsmouth and near Snyderville, Neb., classified by Condra[37] as belonging to the Plattsmouth limestone, the Clay Creek limestone is included in these limestone sections, it may be said that the Jackson Park shale thins to less than one foot in Nebraska.

37. Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 37, 1927.

Kanwaka Shale
CLAY CREEK LIMESTONE MEMBER, Moore, 1932

1932, **Clay Creek limestone,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., pp. 94, 96. This publication lacks data necessary in formal proposal but subsequent reference to it is made by Condra (Neb. Geol. Survey, (2), Paper 2, p. 23, 1933).

Type locality, Clay Creek, about one mile west of Atchison, Kan.

The Clay Creek limestone is a thin but persistent limestone, dark-blue to bluish-gray in color, medium fine-grained to granular, and moderately hard. In fresh exposure the rock is apparently massive and dense, the top and bottom of the bed are fairly even, vertical joints are distinct, and in many respects the bed resembles features seen in the Leavenworth ("middle") limestone member of the Oread. Unlike this limestone, however, the Clay Creek typically weathers in shelly chips, and in this feature and some other details differs from any of the previously described Shawnee limestones. The fossils consist of fusulinids and molluscoids, with a few mollusks, crinoid stems, and other forms. In some places the fusulinids are extremely abundant. On Clay Creek, just west of Atchison, this rock forms a low falls. Its thickness is about 2 feet. Numerous good exposures of the bed have been seen from Doniphan county southward at least to Osage county. It has also been tentatively identified in Greenwood and Elk counties. To the north a molluscan and algal bed (No. .7 of the cyclothem) is developed above the fusulinid-bearing bed, and east of Stull there is a thin mollusk-bearing limestone (No. .3 of the cyclothem) at the base of the Clay Creek.

Kanwaka Shale
STULL SHALE MEMBER, Moore, 1932

1932, **Stull shale,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., pp. 94, 96. Includes beds from the top of the Clay Creek limestone to the base of the Lecompton limestone; classed as a member of the Kanwaka shale. This publication lacks data necessary in formal proposal but reference to it has subsequently been made by Condra (Neb. Geol. Survey, (2), Paper 2, p. 23, 1933).

Type locality, SE cor. sec. 26, T. 12 S., R. 18 E., near village of Stull, Douglas county, Kansas.

The Stull shale includes the upper portion of the Kanwaka shale between the Clay Creek limestone and the basal member of the Lecompton limestone. It consists mainly of yellowish-brown sandy shale, containing fossil land plant remains, and in most places where well exposed is seen to contain a soft friable sandstone which is interpreted as the initial deposit of the Lecompton cyclothem. Just above the sandstone there is locally a thin coal bed. The thickness of the Stull shale member near Stull is about 30 feet, but in the vicinity of Atchison it is 45 feet thick.

LECOMPTON LIMESTONE, Bennett, 1896

1894, †*Strawn limestone*, HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 104. Limestone at Strawn, Coffey county, and on hilltops south of Burlington. Name preoccupied by Strawn group, Pennsylvanian, of Texas, Cummins.

1896, **Lecompton limestone*, BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, p. 116. Name applied to "triple system of limestones capping hills around Lecompton"; consisting of a lower brown fusulinid-bearing 5-foot limestone overlain by 5½ feet of shale, a middle blue limestone 1¼ feet thick overlain by 4 feet of shale with bituminous streak in middle, and an upper light-gray easily weathered limestone 10 feet thick. —— 1902, BEEDE, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 164. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 46. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 109. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 32. Classes as member of Shawnee formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 104. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 44. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 45. Includes a fourth limestone (Avoca) at the top and applies names to all subdivisions. Similarly used in several later papers.

1898, †*Elk Falls limestone* (part), HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 65. Applies name to beds in southern Kansas representing Lecompton to Topeka limestones inclusive.

Type locality, Lecompton, Douglas county, Kansas.

The Lecompton limestone, according to present definition, includes four closely associated limestones, which with the included shales have a total thickness in the vicinity of the type locality of 35 to 40 feet. The formation is underlain by the Kanwaka shale and overlain by the Tecumseh shale. Because of the thickness and resistance of the Lecompton limestone and because the shale formations below and above are 60 feet or more in thickness, the Lecompton makes a distinct escarpment in the Kansas River region and throughout most of northern Kansas. Thinning of the limestones and thickening of the shale members of the Lecompton, accompanied to some extent by thinning of the Tecumseh shale in central and southern Kansas, reduces the prominence and distinctness of the Lecompton escarpment, so that in places it is a subordinate bench on the prominent escarpment capped by the Deer Creek and Topeka limestones. Physical continuity of the formations that have been mapped across the state, and persistence of lithologic and paleontologic characteristics of the Lecompton permit definite identification of this formation and of various members at many exposures from Nebraska to Oklahoma. In southernmost Kansas and northern Oklahoma, however, some of the limestones disappear, and going southward, eventually all of the limestone members disappear. Stratigraphic equivalents of the Lecompton limestone in northern Oklahoma are included in the Pawhuska formation.

The Lecompton limestone contains the following members, named in upward order: Spring Branch limestone, Doniphan shale, Big Springs limestone, Queen Hill shale, Beil limestone, King Hill shale, and Avoca limestone.

Lecompton Limestone

SPRING BRANCH LIMESTONE MEMBER, Condra, 1927

1896, †"*Fusulina limestone,*" Bennett, J., Kan. Univ. Geol. Survey, vol. 1, p. 116. Applies this name to basal brown 5-foot fusulinid-bearing limestone of the Lecompton formation. Invalid because not a geographic term.

1927, **Spring Branch limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 47. Classes as bed of the "Lecompton limestone member of the Shawnee formation." Similarly used in several later papers.

Type locality, Spring Branch, north of Big Springs, Douglas county, Kansas. Typically exposed in bluff at west edge of Lecompton, near NW cor. sec. 35, T. 11 S., R. 18 E., and in road cut near center S. line sec. 36, T. 11 S., R. 17 E.

This member, the "lower Lecompton" limestone of Kansas geologists, is characterized by its strong brown color on weathered outcrops, by its thick, slightly uneven bedding, and in most places by extreme abundance of fusulinids. In addition to the disseminated iron oxide which is responsible for the brown color, there is commonly an appreciable content of earthy or sandy impurities. In southern Kansas the member commonly is represented by very sandy brown limestone containing few fossils, or by very calcareous brown sandstone. The average thickness of the Spring Branch limestone near the type locality and throughout northern Kansas is 5 feet. In most of the southern outcrops it is a very impure sandy limestone 2 to 3 feet thick. This member is not recognized in Nebraska. In all respects this limestone is strikingly similar to the lower limestone member of the Oread formation.

An interesting bed that occurs at the top of the Spring Branch member at places both in northern and southern Kansas is a very dense light drab gray, somewhat nodular algal (?) limestone about a foot in thickness. This bed appears to represent the No. .7 element of the typical cyclothem. Some exposures also, as in southwestern Douglas and southeastern Shawnee counties, Kansas, show the presence of 1 to 2 feet of coquinoid, somewhat conglomeratic limestone with abundant discoid algal growths, classed as *Osagia*. This represents a typical development of the No. .7 element of the cyclothem.

Lecompton Limestone

DONIPHAN SHALE MEMBER, Condra, 1927

1927, **Doniphan shale*, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 47. Applies name to shale between Spring Branch and Big Springs limestone beds of "Lecompton limestone member of Shawnee formation." Similarly used in several later papers.

Type locality, northern Doniphan county, Kansas.

The shale is mostly bluish and yellowish-brown and clayey, but southward some red shale appears. The thickness of the Doniphan shale member throughout observed exposures ranges from about 5 to 10 feet. Unlike the Snyderville member of the Oread, it does not thicken greatly southward. Fossils are rare or in many outcrops lacking.

It is apparent from recent studies in northeastern Kansas and northwestern Missouri that the beds which Condra evidently intended to designate as the Doniphan shale consist largely of impure thinbedded limestone and shale. These calcareous beds are rather clearly identifiable as representing the No. .6 and .7 elements of the cyclothem that includes the Spring Branch limestone. Farther south, where equivalent limestone (No. .7) is harder and more conspicuous, it has been included as the uppermost part of the Spring Branch member. This latter classification appears to be preferable, and if it is applied to sections in Doniphan county and vicinity the thickness of beds that are to be designated as Doniphan shale must be greatly reduced.

Some sections of the Doniphan shale in southeastern Shawnee county show the blocky clay characters that have been described in the Snyderville shale of northern Kansas. This zone is considered to represent an underclay and together with underlying sandy shale and an overlying thin coaly streak represents the No. .1 element of the typical cyclothem. The top portion of the Doniphan shale may contain marine invertebrates.

Lecompton Limestone
BIG SPRINGS LIMESTONE MEMBER, Condra, 1927

1927, **Big Springs limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 47. Name applied to "middle" bed of "Lecompton limestone member of Shawnee formation," underlying black fissile shale of Queen Hill bed. Similarly used in several later papers.

Type locality, near Big Springs, Douglas county, Kansas. Typically exposed in road cut near center S. line sec. 36, T. 11 S., R. 17 E., about 4.5 miles west of Lecompton.

The Big Springs limestone is a dark-bluish, dense, fine-grained limestone, 1 to 3 feet thick. Like the Leavenworth ("middle") member of the Oread limestone, it occurs commonly in a single massive bed and contains prominent vertical joints. In some exposures, however, there are two or three beds separated by shaly partings. On weathering a thin surface film of the rock is altered in color to light yellowish-brown or bluish-gray, and the extremely abundant fusulinids that it contains in almost all places stand weathered slightly in relief. The rock does not break down into small fragments, but is slowly removed by solution that produces somewhat rounded bouldery blocks from the originally rectangular masses defined by joint planes. The member overlies the Doniphan shale and occurs beneath the distinctive black fissile shale in the lower part of the Queen Hill shale member. The Big Springs limestone is very persistent, having been recognized from Iowa and Nebraska southward to Oklahoma.

Lecompton Limestone
QUEEN HILL SHALE MEMBER, Condra, 1927

1927, **Queen Hill shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 46. Name applied to shale above Big Springs limestone. Bed of "Lecompton limestone member of Shawnee formation." Similarly used in several later papers.

Type locality, Queen Hill, northeast of Rock Bluff, T. 11 N., R. 14 E., Nebraska.

The Queen Hill shale is commonly divisible into two parts: a lower division which is somewhat hard, black, and fissile, and an upper division that is softer and is bluish to yellowish and argillaceous. The black shale contains conodonts. The thickness of the member commonly ranges from 3 to 6 feet. The Queen Hill shale is recognizable along the outcrop entirely across Kansas, but in southern exposures the black shale is not commonly found.

Lecompton Limestone
BEIL LIMESTONE MEMBER, Condra, 1930

1915, †*Cullom limestone,* Condra, G. E., and Bengston, N. A., Neb. Acad. Sci., Pub., vol. 9, p. 20. Name (from Cullom station, Cass county, Neb.) applied to supposed division of Lecompton limestone. Name abandoned when later work (Condra, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 11, 1930) indicated that type exposure is equivalent to the De Kalb limestone. Still later work by Greene, Condra, and Moore in October, 1932, indicates "Cullom limestone" is lower part of Westerville limestone, a formation of the Kansas City group. —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 45. Same.

1930, **Beil limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 10. The name Beil limestone is substituted for "Cullom" but without designation of type locality or discussion. Beil is used as a bed in the "Lecompton limestone member of the Shawnee formation" in several later papers by Condra.

Type locality, Beil farm, on Missouri river bluffs, mouth of Kenosha Creek, south of Rock Bluff, Nebraska.

The Beil limestone consists of alternating layers of somewhat flaggy, hard limestone and very calcareous fossiliferous shale. Fossils, especially including the corals *Campophyllum torquium* and *Syringopora multattenuata* and numerous fusulinids, are especially abundant in this member, and are characteristic of it in most exposures from Nebraska to Oklahoma. The thickness of the Beil member ranges from 5 to 10 feet in most places. Outcrops in southernmost Kansas and northern Oklahoma show several feet of solid limestone that exhibit the somewhat wavy bedding and other peculiarities characteristic of the Plattsmouth ("upper") member of the Oread, but in general the Beil limestone resembles this division much less closely than in the case of other members. The characteristic assemblage of fossils and the stratigraphic association of this member permit positive recognition, and it is an important horizon marker in the Shawnee group.

The top bed of the Beil limestone, as well shown at the type locality and in other Nebraska, Iowa, and northern Kansas exposures, is a massive *Osagia*-bearing bed, 1 to 1.5 feet thick, that appears coarsely granular or oölitic. It represents the No. 7 bed of the typical cyclothem.

LECOMPTON LIMESTONE
KING HILL SHALE MEMBER, Condra, 1927

1927, **King Hill shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 45. Name applied to uppermost shale member of the Lecompton limestone, between †Cullom [Beil] and Avoca limestone members. Similarly used in several later papers by Condra.

Type locality, King Hill southeast of Rock Bluff, T. 11 N., R. 14 E., Nebraska.

The King Hill shale member is a bluish-green to reddish blocky, clayey or in places sandy shale about 7 feet thick in the type locality. Its thickness is about 5 feet in sections near Lecompton, but in southern Kansas it increases to 16 feet or more. Fossils are in most cases rare or lacking except near the top of the shale where numerous brachiopods may be found. Exposures of the King Hill shale in northern Kansas and Nebraska commonly show the presence of one or two very irregular nodular impure limestones that weather yellowish brown.

LECOMPTON LIMESTONE
AVOCA LIMESTONE MEMBER, Condra, 1927

1927, **Avoca limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 45. Designated as the uppermost bed of the "Lecompton limestone member of the Shawnee formation." Similarly used in several later papers by Condra.

Type locality, on south fork of Weeping Water Creek, 3 miles east of Avoca, Otoe county, Neb., T. 10 N., R. 12 E.

The Avoca limestone is a dense dark bluish, somewhat earthy limestone that occurs in one or two beds with a total thickness in most outcrops of 1 to 2 feet. Near Lecompton, however, this bed becomes 4.5 feet thick, and is very hard and massive. It lies conformably on the King Hill shale and is overlain by shale classed as part of the Tecumseh shale. The Avoca is a persistent stratigraphic unit, being identified at very many outcrops from Nebraska and Missouri to southern Kansas. Fairly robust fusulinids are the most common fossils in the Avoca limestone and these occur in almost all places where the rock is exposed.

The Avoca limestone is classed as a member of the Lecompton formation because, throughout the outcrop area, the bed is separated from the underlying Beil limestone by only a few feet of shale. It is evident, however, that the Avoca is a No. .5 element of the cyclothem, as shown by the abundant fusulinids and by the characters of the beds below and above. The bed appears to be homologous to the fusulinid-bearing portion of the Kereford limestone (element D.5 in the Oread megacyclothem), and it may be classed as the fourth fusulinid unit (element D.5 in the Lecompton megacyclothem) of the Lecompton formation. The problem of classifying the Avoca is considered further under discussion of the Ost limestone member of the Tecumseh shale.

TECUMSEH SHALE, Beede, 1898

1898, **Tecumseh shale,* Beede, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 28. Applies name to shale about 75 feet thick underlying †Calhoun limestone [Deer Creek]. —— 1902, Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 165. —— 1903, Adams, G. I., U. S. Geol. Survey, Bull. 211, p. 47. Includes shale between Lecompton and Deer Creek limestones; notes that the shale includes †Cave Spring sandstone of Haworth (Kan. Univ. Geol. Survey, vol. 3, p. 66, 1898). —— 1908, Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 109. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 15, p. 32. Classes as member of the Shawnee formation. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 104. Same. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 44. Same. —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 48. Applies name to shale between top of Avoca limestone and base of Deer Creek limestone. Describes †Cedar Creek limestone member in middle, from outcrops in Platte Valley, Neb., which is an error since the supposed Tecumseh shale of this section is not Tecumseh.

Type locality, near village of Tecumseh, sec. 36, T. 11 S., R. 16 E., Shawnee county, Kansas. Well exposed in SE¼ sec. 36, T. 11 S., R. 17 E.

The Tecumseh shale includes strata from the top of the Avoca limestone member of the Lecompton limestone to the basal member of the Deer Creek limestone. The shale is sandy to clayey, and mostly unfossiliferous. In places it contains a thin limestone that has been named the Ost limestone. In the upper part of the Tecumseh shale is a widely distributed sandstone, locally conglomeratic at the base, that marks the initial deposit of the Deer Creek megacyclothem. The thickness of the Tecumseh shale in the type region along Kansas river, east of Topeka, is about 70 feet. In southern Kansas the thickness is about 50 feet.

Three members are recognized in the Tecumseh shale according to present classification. These are, in upward order, the Kenosha shale member, the Ost limestone member, and the Rakes Creek shale member.

TECUMSEH SHALE

KENOSHA SHALE MEMBER, Condra, 1930

1930, **Kenosha shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 52. Classed as the lower subdivision of the Tecumseh shale. Similarly used in later writing by Condra.

Type locality, on Kenosha Creek, the second creek entering Missouri river, south of King Hill, Cass county, Neb.

The shale that lies between the Avoca limestone, below, and the Ost limestone, above, has been named the Kenosha shale. This shale is 6 to 10 feet thick in Nebraska and northern Kansas. It is bluish or somewhat purplish or dark-gray, and in the north is distinctly calcareous. Thin plates and nodules of limestone are common, and well preserved fossils are fairly abundant. In Shawnee and Osage counties, Kansas, the Kenosha comprises 45 to 55 feet of gray silty unfossiliferous shale of uniform texture. In places where the Ost limestone is not found, it is not possible to differentiate the Kenosha shale member.

TECUMSEH SHALE

OST LIMESTONE MEMBER, Condra, 1930

1930, **Ost limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 52. Classed as a bed in the Tecumseh shale. Similarly used in later writing by Condra.

Type locality, Ost farm on south fork of Weeping Water Creek, about 3.5 miles east of Avoca, Otoe county, Neb.

The Ost limestone is somewhat discontinuous limestone that is highly variable in lithologic character in different parts and in different outcrops. It is mainly an oölitic, coquinoid, sandy or conglomeratic limestone that is rich in *Osagia* or contains numerous dense light-gray limestone nodules of probable algal origin. The thickness of the Ost bed ranges from a featheredge to more than 5 feet, an average being about 2 feet. This bed is more persistent in the north than in the south. Lack of horizontal persistence is rather the rule than the exception for limestones of the type of the Ost bed, and it is not surprising, therefore, to find no trace of it in some places.

In the type region of the Ost, Kenosha and Avoca beds, the association of these units as parts of a single cyclothem appears evident. A very good section appears along Nehawka Creek a short distance south of the town of Nehawka, Otoe county, Neb., and similar exposures may be observed along the Missouri River bluffs in western Mills county, Iowa. The presence of common *Myalina* and other mollusks at the base of the Avoca bed indicates the transgressive molluscan phase (Nos. .3-.4 of the simple cyclothem, the Avoca fusulinids mark the culminating phase (No. .5), and the Kenosha-Ost part shows the regressive molluscan phase (No. .6.7). Because the Avoca and Ost limestones are clearly parts of the same cyclothem and because in the type region they are separated by only a few feet of calcareous, fossiliferous sale, it seems natural to group them together as a limestone formation or member. But when these beds are traced southward the Kenosha shale appears to increase in thickness so greatly and to change character so considerably that the combination of Avoca, Kenosha and Ost can hardly be recognized as a natural stratigraphic unit, and certainly it cannot be regarded as a limestone unit. In the sections under consideration it is possible that the true Ost limestone is absent and that the nodular, algal limestone of Ost type (which occurs near the top of the Tecumseh shale) is a different bed. There is, indeed, some suggestion that this latter possibility represents the facts and that elements of a cyclothem younger than the one which includes the Avoca and type Ost and older than the lowermost Deer Creek cyclothem will be recognizable in detailed studies. If the Lecompton megacyclothem is strictly comparable to the Oread megacyclothem the presence of this additional, or fifth, cyclothem is to be anticipated. At present, wherever a bed of Ost lithology is identified between the Avoca and basal Deer Creek it is tentatively designated as Ost limestone.

TECUMSEH SHALE

RAKES CREEK SHALE MEMBER, Condra, 1930

1930, **Rakes Creek shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 53. Classed as a member of the Tecumseh shale. Similarly used in later writing by Condra.

Type locality, on Rakes Creek, in the northwest quarter, sec. 5, T. 10 N., R. 14 E., Cass county, Neb.

The Rakes Creek shale member of the Tecumseh shale is light bluish to brownish in color, clayey and sandy, and in most places includes a fairly prominent, persistent sandstone that marks the initial part of the Deer Creek megacyclothem. The shale is mostly unfossiliferous. Its thickness is about 10 feet. Recent study by me of sections in Nebraska, western Iowa and northwestern Missouri indicate that the Rock Bluff limestone, which next overlies the Rakes Creek shale, is certainly equivalent to the "middle Deer Creek limestone" in Kansas. This need not make use of Rakes Creek shale inapplicable in Kansas, however. The upper boundary of the Rakes Creek shale may be considered as extending to a slightly higher stratigraphic plane in the north than in the south.

DEER CREEK LIMESTONE, Bennett, 1896

1894, †*Pawhuski limestone,* SMITH, J. P., Jour. Geol., vol. 2, p. 199. Applies name to "a bed of massive limestone about 100 feet thick" found by "Mr. H. C. Hoover [later President of the United States], of the Geological Survey of Arkansas. . . . at the government lime-kiln, three miles northwest of Pawhuski [now Pawhuska], Indian Territory." The limestone at the locality indicated is that now called Deer Creek, but the thickness of the main bed that is quarried is only about 10 feet. This suggests a probable typographic error in Smith's description. The term Pawhuska formation is now applied in Oklahoma to 130 to 180 feet of strata ranging from Lecompton to Topeka.

1896, **Deer Creek system,* BENNETT, J., Kan. Univ. Geol. Survey, vol. 1, p. 117. Includes three limestones and the intervening shales, in upward order, (*a*) fossiliferous, unevenly bedded limestone, 6 ft., (*b*) shale, 10 ft., (*c*) a single limestone bed, 2 ft., (*d*) drab blue shale, 4 ft., and (*e*) limestone, 4.5 feet. These beds occur about 60 feet below the Topeka limestone.

1898, *Deer Creek limestone,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, pp. 94, 105. Recognizes three members. —— 1902, BEEDE, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 165. Same. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 47. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 110. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 32. Same, classifying as "member of the Shawnee formation." —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 104. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, pp. 44. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 50. Same, and applies stratigraphic names to each subdivision.

1898, †*Forbes limestone,* GALLAHER, J. A., Mo. Geol. Survey, Bien. Rept., p. 56. Poorly defined designation of limestone at Forbes, Holt county, Missouri, recognizable from description as equivalent to Deer Creek. —— 1899, KEYES, C. R., Am. Geol., vol. 23, p. 309. Same. —— 1900, KEYES, C. R., Ia. Acad. Sci., Proc., vol. 7, p. 93. Same, but erroneously regarded it as equivalent to Burlingame. —— 1915, CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, pp. 7, 12.

1898. †*Nodaway limestone,* GALLAHER, J. A., Mo. Geol. Survey, Bien. Rept., pt. 53. Hinds and Greene note this is equivalent to Deer Creek.

1898. †*Calhoun limestone,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 28. The name Calhoun was also applied to the overlying shale and is now restricted to this shale.

1898, †*Elk Falls limestone* (part), HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 65. Applies name to beds in southern Kansas representing Lecompton to Topeka limestones, inclusive.

Type locality, on Deer Creek, in northeastern Shawnee county, east of Topeka. Typically exposed in road cut in SE¼ sec. 36, T. 11 S., R. 17 E.

The Deer Creek limestone is one of the most important, widely persistent formations of the Shawnee group. The upper limestone member alone attains a thickness of 35 feet in Elk county, Kansas, and the formation has a thickness in most places of more than 40 feet. With very little change in lithologic characters or variation in members the Deer Creek limestone is known to extend from west-central Iowa to southern Oklahoma. Most of the Deer Creek outcrop across Kansas is marked by a very prominent escarpment, and accordingly the formation can be traced readily. The formation is underlain by the Tecumseh shale and is overlain by the Calhoun shale. The Deer Creek limestone is rather readily differentiated on the basis of appearance and on fossil content from the adjacent Lecompton limestone below and the Topeka limestone above, but the Deer Creek members duplicate so strikingly those of the Oread limestone that it is easily possible for a geologist who is familiar with the lithology and sequence of the members to mistake one formation for the other if information as to stratigraphic position is neglected. The Deer Creek limestone is a prominent part of the Pawhuska formation as defined in northern Oklahoma.

The Deer Creek limestone in Kansas contains the following members, named in upward order: Ozawkie limestone, Oskaloosa shale, Rock Bluff limestone, Larsh-Mission Creek shale, and Ervine Creek limestone.

DEER CREEK LIMESTONE
OZAWKIE LIMESTONE MEMBER, Moore, 1936

1932, *Rock Bluff limestone,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 96.

1936, **Ozawkie limestone,* MOORE, R. C., this paper.

Type locality, Ozawkie, in road cut, NE¼ sec. 31, T. 9 S., R. 18 E., Jefferson county, Kansas.

The Ozawkie limestone, "lower Deer Creek" of Kansas geologists, is a brown massive or thick-bedded limestone that in most exposures resembles closely the lowermost limestone members of the Oread, Lecompton and Topeka formations. In contrast to the higher limestone members of the Deer Creek, the Ozawkie appears somewhat sandy and impure, and as indicated by the strongly brown color of weathered outcrops, it is quite ferruginous. The massive rock commonly weathers in irregular shelly slabs. The average thickness of the member is about 5 feet, but near Lyndon, Osage county, it is about 15 feet. Fossils are not very common in most places. Locally, however, there are numerous fusulinids, crinoid stem fragments and fairly common brachiopods, bryozoans and corals. The elements of a nearly complete cyclothem are recognizable in the Ozawkie member in some places, for limestones .3, .5 and .7, separated by shale or without shale partings are clearly defined. Some outcrops show that the member consists locally almost wholly of the fusulinid bed (.5) or in other cases of the oölitic, granular or algal (.7) bed.

Since the designation by Condra[38] in 1927 of the "lower Deer Creek" limestone of Nebraska as Rock Bluff limestone, this name has been applied to the "lower Deer Creek" of Kansas in notes describing Kansas sections of the Deer Creek formation.[39] Examination of the type Rock Bluff limestone, at Rock Bluff, Nebraska, in July, 1934, showed that this unit has the distinctive lithologic characters (dark-blue color, dense fine-grained texture, vertical joints), content of fusulinids, and position immediately below black platy shale that with other peculiarities serve readily to identify the "middle Deer Creek" limestone in Kansas. The correspondence of characters is so complete that I had no hesitation in concluding that the Rock Bluff limestone is the "middle Deer Creek" of Kansas, and therefore it seemed apparent that the "lower Deer Creek" member (here termed Ozawkie) was without a geographic name. It is perhaps conceivable, however, that a "lower" limestone in one part of the Mid-Continent sea basin may take on the peculiarities of a "middle" limestone in another part. This possibility and the need for caution in making too positive correlations of members where they are not continuously traced, is suggested by the "middle" limestone aspect of the fusulinid-bearing bed of the Ozawkie member near Lyndon, Kan. There is no possible confusion of identification of members in the Deer Creek formation here, because the true "middle Deer Creek" is well developed above the Ozawkie member in continuous well exposed sections. In other words, the Deer Creek limestone locally contains two dense blue beds with fusulinids, the upper one being the true "middle Deer Creek," which is overlain by black fissile shale, the lower one in the Ozawkie member not being overlain by black shale. The brown nearly unfossil-

38. Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 50.

39. See Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., 1932.

iferous limestone that is a normal representative of the "lower" limestone members of the Shawnee limestone formations occurs in northern Doniphan county, Kansas, not far from the Nebraska line, and the only dense blue limestone in the Deer Creek formation here is the "middle" member which occurs several feet above the Ozawkie. The southernmost Nebraska sections of the Deer Creek in Cass county, about 30 miles farther north, show the dense blue Rock Bluff bed at the base and lack a brown limestone that is identifiable as Ozawkie. Study of sections in Missouri serving to connect these outcrops indicates that the Rock Bluff limestone in Nebraska is really equivalent to the dense blue "middle Deer Creek" of Kansas and that the Ozawkie limestone disappears in southeastern Nebraska.

Deer Creek Limestone
OSKALOOSA SHALE MEMBER, Moore, 1936

1932, *Larsh shale*, Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 96.

1936, **Oskaloosa shale*, Moore, R. C., this paper.

Type locality, vicinity of Oskaloosa, Jefferson county, Kansas.

The shale member that lies between the Ozawkie limestone below and the dense blue "middle Deer Creek" bed (Rock Bluff limestone) is here named the Oskaloosa shale. It is normally 5 to 10 feet thick in the northern part of Kansas, but to the south it increases to 25 feet or more. The shale is bluish-gray or yellowish and consists of blocky clay with one or two calcareous, somewhat ferruginous siltstones as seen in northern Kansas outcrops, but south of Coffey county parts of the member are distinctly sandy and micaceous, a prominent red zone appears, and there are one or two thin beds of nodular light bluish-gray impure limestone. The Oskaloosa shale member is mostly unfossiliferous, but excepting possibly the red shale appears to be marine in origin.

This shale has been called the Larsh member in notes made on the Kansas outcrop of the Deer Creek formation since Condra[40] in 1927 applied this name to the shale between the lower (Rock Bluff) and middle (Haynies) limestone members of the Deer Creek in Nebraska. Discovery that the Rock Bluff limestone is not the same as the "lower Deer Creek" limestone in Kansas indicates that the name Larsh shale is not applicable to the shale next above the Ozawkie limestone. Accordingly, the term Oskaloosa shale is introduced.

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40. Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 43, 49, 1927.

Deer Creek Limestone
ROCK BLUFF LIMESTONE MEMBER, Condra, 1927

1918, *Plummer limestone* (part), Heald, K. C., U. S. Geol. Survey, Bull. 686, p. 46. Includes two dark-blue dense limestones, each about one half foot thick, separated by about 5 feet of dark carbonaceous shale. Classed as a member of the Pawhuska formation.

1927, **Rock Bluff limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 50. Name applied to dense blue lowermost bed of the Deer Creek limestone in Nebraska.

1932, *Haynies limestone,* Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 96. Refers to "middle Deer Creek limestone" in Kansas.

Type locality, Rock Bluff, Neb.

One of the most persistent, uniform and distinctive members of the Deer Creek formation in the northern Mid-Continent region is the dense blue "middle" bed which as seen in most exposures is a single massive stratum 1 to 2 feet thick. The top of the bed is very even but the base may be slightly uneven on account of the presence of "fucoid" markings. Vertical joints are well developed in two systems that intersect approximately at right angles and cause the bed to separate in rectangular blocks along the outcrop. The rock is not broken into small fragments by weathering, as a general rule, but the sharp edges of the blocks are gradually rounded by solution so as to produce bouldery shapes. A very thin surface film of the limestone is altered by weathering to a light bluish-gray or creamy color, and a zone a few inches thick inside this coating may be altered to a purplish or brownish-blue, but because of the dense texture of the rock the deeper interior of blocks remains dark-blue. Fusulinids are the most common fossils in most outcrops of this member but they are not, in general, very abundant. A few brachiopods, bryozoans and small mollusks are present. The thickness of the 'middle Deer Creek" limestone in few cases exceeds 2 feet and in few places is less than 1 foot. In this approximate uniformity of thickness and persistence of distinctive physical characters from Iowa and Nebraska to north-central Oklahoma, this member is a most striking sedimentary unit and stratigraphic marker. Almost all good exposures show the presence of black slaty shale next above the blue limestone.

The proper stratigraphic name for this thin but important member of the Deer Creek formation is a matter of question. Its equivalent is undoubtedly represented in the Plummer limestone as defined by Heald near Pawhuska, Okla., but here there are two blue limestone beds separated by about 5 feet of nearly black carbonaceous shale. The lower one has the typical physical characters of the "middle Deer Creek" as developed in almost all observed sections, whereas the upper bed, although dense, is somewhat lighter colored and is somewhat nodular. It is not certain whether in the slightly abnormal section near Pawhuska only the lower or both of these beds represent the typical "middle Deer Creek" but it is thought that the upper thin limestone is a lense developed in the carbonaceous shale that normally overlies the "middle Deer Creek" bed. If this is true only the lower of the Plummer beds as originally defined represents the "middle Deer Creek." Farther south in Oklahoma, as along Arkansas River near Cleveland, and throughout Kansas only one dense blue limestone occurs at this horizon.

In Nebraska and Iowa Condra[41] designated by the name Haynies, from Haynies Station in Iowa, a blue dense limestone, about 1 foot or a little less in thickness, that occurs persistently between the Rock Bluff limestone below, and the Ervine Creek limestone above. The shales above and below the Haynies limestone are in part black and somewhat slaty. As previously noted, the Rock Bluff member bears such striking resemblance in physical characters to the "middle Deer Creek" of Kansas that equivalence of these is strongly indicated, especially since both are overlain by black fissile shale. The Haynies member seems exactly to correspond to the upper bed of the Plummer limestone as originally defined and it is possible that the Rock Bluff limestone, Larsh shale and Haynies limestone, taken together, are equivalent to the original Plummer limestone. The Haynies is somewhat lighter in hue than the Rock Bluff, is slightly nodular and appears to lack fusulinids. In this case as in the sections showing typical Plummer near Pawhuska, it is possible that both Rock Bluff and Haynies are equivalent to the normal "middle Deer Creek" of Kansas, but it is most probable that the lower one alone is strictly equivalent to the Kansas "middle Deer Creek." Exact correlation of these small subdivisions of the Deer Creek has a bearing on nomenclature and it is important to understanding some features of the Pennsylvanian cyclothems of the Mid-Continent region, but it is a detail in stratigraphic correlation that to many geologists may be considered as having only minor importance. All things considered, it appears best to use the name Rock Bluff for the "middle Deer Creek limestone" of

41. Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 50, 1927.

Kansas. There is no reasonable doubt as to the exactness of correlation and the term Rock Bluff has been much more used than Plummer limestone, which also seems not to be strictly the same as the Kansas bed under discussion.

Deer Creek Limestone
LARSH-MISSION CREEK SHALE MEMBER, Condra, 1927

1927, **Larsh shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 50. Corresponds to lower part of Larsh-Mission Creek shale in Kansas.

1927, **Mission Creek shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 50. Corresponds to upper part of Larsh-Mission Creek shale. —— 1932, Moore, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 96. Applies this name to shale between "Haynies [Rock Bluff] limestone and Ervine Creek limestone.

Type locality, on Ervine and Mission Creeks, Cass county, Neb.

The shale above the "middle Deer Creek limestone" in Kansas contains two persistent subdivisions, the lower half, approximately, consisting of hard black fissile shale and the upper half of gray to yellowish soft clay shale. Because this shale appears to be exactly equivalent to the Larsh shale, Haynies limestone, and Mission Creek shale, as described in Nebraska, the shale between the Rock Bluff and Ervine Creek limestones of Kansas is called Larsh-Mission Creek. Excepting conodonts, fossils are rare or lacking in the black shale and they are not generally found in the upper part. In places, however, the latter contains calcareous brachiopods, bryozoans and other invertebrates. The thickness of the Larsh-Mission Creek shale member ranges from about 2.5 to 7 feet, the average being about 4 feet. There is very little observed change in this member from Doniphan county in the northeastern corner of the state to the point where the Deer Creek formation passes out of Kansas in southern Chautauqua county.

Deer Creek Limestone
ERVINE CREEK LIMESTONE MEMBER, Condra, 1927

1894, †*Pawhuski limestone,* Smith, J. P., Jour. Geol. vol. 2, p. 199. Designates limestone three miles northwest of "Pawhuski [now Pawhuska], Indian Territory," studied by H. C. Hoover (then of the Arkansas Geological Survey, later President of the United States), in 1892. The formation is described as "a bed of massive limestone about 100 feet thick, lying horizontally on heavily bedded sandstone." The limestone at the locality indicated is that now known as Ervine Creek, and the thickness is about 10 feet. Smith's statement of thickness is inferred to be a typographic error because there is no limestone in this region remotely approaching this thickness. Pawhuski, or as later written, Pawhuska, may thus be considered to have priority over Ervine Creek, but in 1918 (Heald, K. C., U. S. Geol. Survey, Bull. 686, p. 30) application of the term Pawhuska was extended to apply to all the strata between the top of the Elgin sandstone [Kanwaka, part] and the top of the Red limestone [Topeka, part].

1927, **Ervine Creek limestone*, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 50.

Type locality, on Ervine Creek, Cass county, Neb.

The Ervine Creek limestone comprises the "upper" member of the Deer Creek formation but examination of the type section and neighboring well exposed outcrops in Nebraska shows that the upper part of this member, as defined by Condra, includes *Osagia*-bearing shale of "super" characteristics, representing the .7 member of the ideal cyclothem. It appears also that in some Nebraska and Iowa sections fusulinid-bearing and other limestone (.5 member) that belongs to the next higher cyclothem, in the Calhoun shale, presently to be described, has been included with the Ervine Creek. As here treated, the Ervine Creek member will be considered to include the "super" (.7) beds that overlie the typical "upper" Deer Creek (.5) light-gray, dense, thin wavy beds, but higher strata are excluded. It may be argued that this is inconsistent since in certain other formations the "upper" (.5) and "super" (.7) units are separately defined as named members. There are numerous cases, on the other hand, in which these units are combined in one member and if these should all be split into their component cyclic elements and these elements were individually named as members, we should have both to extend the list of stratigraphic names unduly and to redefine too many units that are now well established.

Accepting the definition of the Ervine Creek limestone member that is based on examination of the type exposures we recognize in it two parts. Of these the lower is the most persistent and prominent, comprising the bulk of the member in most places. It is the typical "upper" limestone of the Shawnee formations and possesses all the lithologic and faunal characters that distinguish these. The rock is light-gray to nearly white in most places but locally appears bluish and weathers mottled gray and yellowish-brown or exceptionally all brown. The texture of the limestone is fine crystalline to dense, and it is fairly uniform except for veinlets and in some cases irregularly distributed small masses of clear calcite. The bedding is thin and wavy, with partings of clay shale between the layers. Chert nodules occur locally. The thickness ranges from about 3 to 30 feet, and in general it makes up about 80 to 90 percent of the member. Fossils include fusulinids, calcareous brachiopods, corals, crinoid and echinoid fragments, bryozoans, and less commonly mollusks, sponges, and trilobites. A variety of ostracodes and small foraminifera may be washed from the shaly partings between the limestone layers.

The upper part of the Ervine Creek member, not present in some localities, consists mainly of limestone with "super" characters. This part may rest directly on the underlying limestone or it may be separated from it by a few inches or a foot or two of shale that in most cases is somewhat sandy. The lithologic characters and faunal content of the upper limestone are clearly distinguishable from those of the lower in almost all cases but there is much variation in lithology and fauna of the upper limestone from place to place, which in itself is typical of the (.7) element in the cycle. Commonly there is a single very massive bed of uniform texture, moderately to finely granular, containing numerous small *Osagia* but few other organic remains. This limestone appears more or less oölitic. Fusulinids are lacking and the invertebrates found consist of scattered mollusks and calcareous brachiopods. In other cases, the limestone is strongly coquinoid. It consists of a mass of shells and shell fragments pressed together, so that the rock has an irregularly platy or "oatmeal" texture. Pelecypods mingled with certain types of brachiopods such as *Derbya*, *Juresania* and *Linoproductus*, and with bryozoans are the chief fossils. Still other outcrops show the presence of fine-grained earthy to sandy limestone, even-bedded or nodular, mostly lacking in fossils. The thickness of this part of the Ervine Creek member ranges from a feather edge to 5 or 6 feet.

The Ervine Creek limestone appears to be equivalent to the Pawhuski limestone as originally defined in northern Oklahoma and is one of the most prominent and persistent limestones in the Pawhuska formation as now defined in Oklahoma.

CALHOUN SHALE, Beede, 1898

1896, *Lawrence shale*, Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 79. Erroneously describes Lawrence shale as including beds between †Garnett ["Burlington" = Oread] and †Hartford [Topeka] limestones.

1896, **Calhoun sandstone and shale*, Beede, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 29. Includes beds between †Calhoun [Deer Creek] limestone below and Topeka limestone above.

1898, *Calhoun shale*, Haworth, E., Kan. Geol. Survey, vol. 3, p. 94. —— 1902, Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 166. —— 1903, Adams, G. I., U. S. Geol. Survey, Bull. 211, p. 48. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 110. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 33. Class as member of Shawnee formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 104. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 45. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 51. Same, and names three subdivisions, in upward order, Jones Point shale, Meadow limestone, Iowa Point shale.

Type locality, Calhoun Bluffs, near center S. line sec. 14, T. 11 S., R. 16 E., on north side of Kansas river, 3 miles northeast of Topeka.

The Calhoun shale, named by Beede from the so-called Calhoun Bluffs of Kansas river northeast of Topeka, includes the strata consisting chiefly of shale between the top of the Deer Creek limestone below and the base of the Topeka limestone above. In the type region, where the Calhoun attains approximately its maximum thickness of 60 to 70 feet, the formation consists entirely of clayey to sandy shale, except for a sandstone, 6 to 10 feet thick, that occurs a few feet below the Topeka limestone. This sandstone represents the initial deposit of the Topeka megacyclothem. There are almost no invertebrate fossils in the Calhoun shale of the Kansas river region but land plant remains occur in the sandy shale and sandstone. Northward and southward from the type section the thickness of the Calhoun diminishes gradually to 20 feet or less, and accompanying this decrease there is a disappearance of sandstone, and a marked increase in content of calcium carbonate. The shale is calcareous and highly fossiliferous, brachiopods, bryozoans and pelecypods being most abundant. Limestone beds appear in the middle part of the formation and give basis for subdivision of the Calhoun into members. Condra has named these, in upward order, Jones Point shale, Sheldon limestone, and Iowa Point shale.

The Calhoun shale is recognized in Nebraska, Missouri and Iowa. In northern Oklahoma beds equivalent to the Calhoun are included in the upper part of the Pawhuska formation.

CALHOUN SHALE

JONES POINT SHALE MEMBER (Condra, 1927), Moore, 1936

1927, *Jones Point shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 51. Includes lower 8 to 10 feet of Calhoun shale between top of Ervine Creek limestone below and base of †Meadow [Sheldon] limestone above. —— 1936, *MOORE, R. C., this paper.

Type locality, Jones Point on west side of Missouri river, near Union, Neb.

Definition of the Jones Point member of the Calhoun shale, as given by Condra, depends essentially on the boundary selected as the base of the limestone that is now called Sheldon. That is to say, the Jones Point shale includes all of the Calhoun lying below the Sheldon. Since the Sheldon limestone is here redefined (see below) to include fusulinid-bearing limestone and other beds that were classed by Condra in the Jones Point member, the latter is necessarily restricted by this transfer, so that in the type region only 1.5 feet of shale remains to be called Jones Point. Southward the thickness of the member increases somewhat. Where the Sheldon member is not found, the adjoining shale members cannot be recognized. In southern Kansas the Jones Point shale has a thickness of 4 to 5 feet.

CALHOUN SHALE

SHELDON LIMESTONE MEMBER (Condra, 1930), Moore, 1936

1915, †*Meadow Creek limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 22. Classed as member of †Braddyville formation [Calhoun and Topeka]. Named from outcrops in Platte Valley, Nebraska, now known to belong to the Lansing group.

1927, †*Meadow limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 51. Designates middle member of the Calhoun shale, with Jones Point shale member below and Iowa Point shale member above. Type locality same as Meadow Creek limestone.

1930, *Sheldon limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 47. Proposes name to replace Meadow limestone. —— 1933, CONDRA, G. E., Neb. Geol. Survey, (2), Paper 2, p. 5. Classes Sheldon as member of the Deer Creek limestone. —— 1936, *MOORE, R. C., this paper.

Type locality, Sheldon quarry, just east of Nehawka, Neb.

The Calhoun shale in eastern Nebraska and western Iowa is composed largely of limestone. One of the widely recognizable limestone beds occurring 5 feet or less below the Topeka limestone is a massive hard light-gray rock about 3 feet thick. This bed was first called Meadow Creek or Meadow from outcrops in the Platte Valley, Nebraska, but when it was learned that the type exposures of the Meadow belong to the Lansing group instead of the Shawnee, Condra renamed the limestone in the Calhoun shale from outcrops in the Sheldon quarry just east of Nehawka, Neb. Study of this section and several others in eastern Nebraska and western Iowa in July, 1934, showed that the Sheldon limestone is a typical "super" (.7) bed of the ideal cyclothem. It is oölitic, locally somewhat conglomeratic and contains abundant *Osagia*. The invertebrate fauna consists mainly of mollusks. Beneath the Sheldon, as defined by Condra, there is a zone of calcareous shale with limestone nodules 6 to 8 feet thick containing a prolific fauna of pelecypods, gastropods, calcareous brachiopods and some bryozoans. This has been classed as Jones Point shale by Condra. It is clearly identifiable as the .6 member of the cyclothem, the shale with mixed molluscan and molluscoid fauna that occurs between the fusulinid (.5) limestone below and the algal-molluscan (.7) limestone above. Beneath Condra's "Jones Point shale" is a chert-bearing fusulinid limestone about 3 feet thick that overlies an *Osagia*-bearing somewhat oölitic massive limestone that I regard as the topmost unit of the Ervine Creek limestone. Condra, however, has classed all of the beds up to the base of the fossiliferous "Jones Point" shale as Ervine Creek. Because the top of the Ervine Creek can be and I think should be defined on the basis of clyclothem characters, that is, the appearance of *Osagia* limestone, the boundary between the Deer Creek and Calhoun in these sections is placed lower by me than by Condra. If we adopt this lower position for the base of the Calhoun shale, we find a practically complete cyclothem within the Calhoun. The first limestone above the *Osagia* bed of the Ervine Creek is a dense blue vertically jointed rock of "middle" aspect and like the "middle" beds of the Shawnee formations this blue limestone is overlain by black fissile shale. Then comes the fusulinid limestone, one or two beds of dense light-gray limestone, the fossiliferous "Jones Point shale" and the oölitic *Osagia*-bearing "Sheldon limestone." Essentially the same sequence as that observed in eastern Nebraska is found in southern Kansas.

Based on these observations of the cyclic nature of the succession of beds in the Calhoun shale, it seems desirable to group the limestone of the cyclothem in the Calhoun and to class them collectively as a member of the Calhoun shale. There is little need to name the individual subdivisions of this member or cyclothem and therefore the name Sheldon which has previously been applied to a single bed may be extended to include the entire limestone member. The effect of these changes, it is seen, shifts application of the name Jones Point to the shale next above the *Osagia* bed of the Ervine Creek (which is a shale that was included in the Ervine Creek by Condra and extends the lower boundary of the Sheldon limestone member to include beds that have been classed as Ervine Creek by Condra.

The uppermost unit of the Sheldon is well developed in Greenwood county, Kansas, but the fusulinid bed is not found in most places. Farther south, in Elk and Chautauqua counties, Kansas, and in Osage county, Oklahoma, the fusulinid bed of the Sheldon is persistent and locally the molluscan-algal, more or less conglomeratic upper bed is also present. The fusulinid bed or beds of the Sheldon member are distinctive as compared with most other fusulinid limestones because of the close packing and parallel arrangement of the slender, fairly even-sized "wheat-grain" fossils. This parallel orientation of the fusulinids, the long axis lying subhorizontal, suggests action of gentle currents. This horizon is probably the "marker" zone described by Heald[42] in the upper part of the Pawhuska formation of northern Oklahoma.

CALHOUN SHALE

IOWA POINT SHALE MEMBER, Condra, 1927

1927, **Iowa Point shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 51. Includes upper part of Calhoun shale between top of †Meadow [Sheldon] limestone below and base of Topeka limestone above.
—— 1933, CONDRA, G. E., Neb. Geol. Survey, (2), Paper 2, p. 5. Classes Sheldon as topmost member of Deer Creek limestone, thus making Iowa Point shale coextensive with Calhoun, and therefore abandons use of Iowa Point. This classification is believed to be erroneous.

Type locality, Iowa Point, on Missouri river in northeastern Doniphan county, Kansas.

The Iowa Point shale comprises the upper part of the Calhoun, 2 to 20 feet or more in thickness, that lies between the top of the Sheldon limestone member and the base of the Topeka limestone. In eastern Nebraska and western Iowa this upper shale member of the Calhoun is less than 6 feet thick. Condra states that it is quite irregular in character, grading laterally into sandstone and locally containing thin lentils of coal. The sandstone and coal, although included in the Iowa Point shale member, are parts of the Topeka megacyclothem. In the northern sections the basal limestone member (Hartford) of the Topeka is lacking, so that the Iowa Point

42. Heald, K. C., U. S. Geol. Survey, Bull. 691, p. 66, 1918.

member includes beds up to the base of the DuBois limestone, or possibly in some sections to the base of the Coal Creek limestone (upper Topeka). In southern Kansas the Iowa Point shale is highly calcareous to clayey and contains a prolific fauna of calcareous brachiopods and bryozoans in which a variety of *Chonetes granulifer* and *Rhombopora* are exceedingly abundant and well preserved. The Iowa Point is everywhere overlain in this region by limestone representing the Hartford member of the Topeka limestone.

TOPEKA LIMESTONE, Bennett, 1896

1896, *Hartford limestone,* Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 80. Designates limestone exposed along Neosho river in Coffey county, equivalent to lower Topeka as now classified. —— 1902, Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 167. —— 1903, Adams, G. I., U. S. Geol. Survey, Bull. 211, p. 48.

1896, **Topeka limestone,* Bennett, J., Kan. Univ. Geol. Survey, vol. 1, p. 116. —— 1898, Beede, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 29; Kan. Univ. Quart., vol. 7, p. 232. —— 1898, Haworth, E., Kan. Univ. Geol. Survey, vol. 3, pp. 94, 105. —— 1908, Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 110. —— 1915, Hinds, H., and Greene, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 33. Classes as member of Shawnee formation. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 104. Same. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 104. Same. —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 53. Names subdivisions, in upward order, Curzen limestone, Turner Creek shale, DuBois limestone, Holt shale, Coal Creek limestone.

1898, †*Elk Falls limestone* (part), Haworth, E., Kan. Univ. Geol. Survey, vol. 3, p. 65.

Type locality, Topeka, Kan. All members of the Topeka limestone are well exposed in SE¼ sec. 5, T. 11 S., R. 16 E., and vicinity, northeast of Topeka.

The Topeka limestone, named by Bennett from typical outcrops in the vicinity of Topeka, Kansas, comprises the topmost formation of the Shawnee group as here defined. Although somewhat variable in its development from place to place, the Topeka limestone is readily differentiated from the Deer Creek and other limestone formations of the Shawnee below. It is very fossiliferous and where completely developed there are five distinctive members, of which the lowermost is, in general, much the thickest and most prominent at the outcrop. In many places it consists of two or three limestone beds separated by shale, the member as a whole corresponding to the lower limestone members of the other Shawnee formations. In upward order, the members of the Topeka limestone have been named as follows: Hartford limestone, Turner Creek shale, DuBois limestone, Holt shale, and Coal Creek limestone.

The Coal Creek member is clearly the equivalent of the so-called upper limestone members of other Shawnee limestone formations. Locally in southern Kansas there is a fourth limestone representing the terminal molluscan and algal deposits which are normally associated with this type of cyclothem.

The Topeka limestone makes a distinct escarpment that rises some 60 feet or more above the Deer Creek dip slope in parts of north-central Kansas, but to the south the Topeka outcrop is not sharply differentiated from that of the Deer Creek limestone which is the main scarp-maker. The long dip slope on the Topeka is a characteristic topographic feature, however, from northern to southern Kansas, although this is masked somewhat in the extreme northern part of the state and in Nebraska by glacial drift.

The thickness of the Topeka limestone ranges from less than 10 feet in Nebraska to more than 50 feet in parts of southern Kansas. The formation is recognized from southern to northern Kansas, in Nebraska, and in Missouri. It is equivalent to the uppermost part of the Pawhuska formation of Oklahoma and forms the top of what has been called the Braddyville formation in Iowa.

Topeka Limestone

HARTFORD LIMESTONE MEMBER, Kirk, 1896

1896, **Hartford limestone,* Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 80. "The limestone which passes under the river [Neosho] at Hartford," Coffey county, Kansas, is now identified as the lower limestone member of the Topeka. —— 1903, Adams, G. I., U. S. Geol. Survey, Bull. 211, p. 48.

1902, *Hartford (Topeka) limestone,* Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 167. Apparently refers only to lower limestone of the Topeka.

1927, †*Curzen limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 52. Recognizes three limestone beds in the "Topeka member of the Shawnee formation," naming the lowermost Curzen. Condra says (loc. cit.) "Years ago the Missouri Survey used the name Curzen for what seems to be the basal 5 to 8 feet of the Topeka." Hinds and Greene (Mo. Bur. Geol. and Mines, (2), vol. 13, p. 31, 1915) in discussing nomenclature of the Topeka beds do not mention Curzen. Condra's reference is evidently to Gallaher (Mo. Geol. Survey, vol. 13, p. 213, 1900), who includes the name "Curzen's limestone" in a columnar section of the "Forest City lens" but gives no mention of this limestone in the text. The rock to which Gallaher referred is certainly unidentifiable, and therefore Condra is to be cited as author of Curzen limestone. No type locality of Condra's Curzen limestone is given, although presumably it is in the vicinity of Curzon [sic], Mo.

Type locality, Hartford, Coffey county, Kan. Well exposed below highway bridge at north edge of town.

The lower limestone member of the Topeka formation is called Hartford because this name has priority, previous usage in at least three papers, and adequate definition based on description and a designated type locality. Condra agrees[43] that the term Hartford is preferable to Curzen which was introduced by him.

The Hartford limestone member consists typically of one to three or four beds of massive or irregularly bedded bluish-gray limestone that weathers brown. Where two or more beds of limestone belonging to the member are present, they are separated by shale a few inches to several feet in thickness. The thickness of the different limestone beds is quite variable, ranging from less than one foot to more than 20 feet, and the thickness of the member as a whole likewise shows a range from less than one foot to nearly 40 feet. This variation along the strike, both in thickness and in the number of limestone and shale subdivisions, distinguishes the Hartford from other "lower limestones" of the Shawnee limestone formations, although locally the "lower Deer Creek" is expanded to include a number of limestone and shale units. The texture of the limestone beds in the Hartford member is typically fine and dense, but locally there are medium-grained crystalline limestones. In places, the rock is impure and very silty or sandy. Although, in general, the beds are characterized by their ferruginous content, which produces the strong brown color of the weathered rock, some outcrops show pure limestone that weathers nearly white. The distribution and character of fossils in the Hartford member is very irregular. Fusulinids are extremely abundant in some part of the member in most areas but locally they are entirely absent. Some beds contain a profusion of invertebrates of various kinds, but others are almost lacking in identifiable organic remains. Despite all these differences in physical and biologic characters no difficulty is found in distinguishing the Hartford limestone from other members of the Topeka formation, nor in determining the proper boundaries of the Hartford. This is perhaps due mainly to the distinctive characters of the higher members rather than to those of the Hartford, but that is not wholly true. It is interesting to observe that no members other than the Hartford are identified south of the Kansas River, that all of the limestone and shale members of the Topeka appear in Kansas north of Kansas River, and that all except the Hartford are typically developed in eastern Nebraska and western Iowa.

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43. Personal communication, July 8, 1934.

TOPEKA LIMESTONE
TURNER CREEK SHALE MEMBER, Condra, 1927

1927, **Turner Creek shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 52. Shale between †Curzen [Hartford] and Du Bois limestone beds of "the Topeka member of the Shawnee formation."

Type locality, on Turner Creek, a short distance southeast of Du Bois, Neb.

The Turner Creek shale member of the Topeka formation is identified by its assigned stratigraphic position, next below the "middle Topeka" or Du Bois limestone, rather than by any distinctive character of its own. The base of the member is drawn at the top of the uppermost limestone bed of the Hartford. The average thickness of the Turner Creek shale is about 3 feet. It is bluish-gray, clayey to calcareous, and is mostly unfossiliferous. This unit is recognized from Topeka, Kan., northeastward into Nebraska, western Missouri and Iowa.

TOPEKA LIMESTONE
DU BOIS LIMESTONE MEMBER, Condra, 1927

1927, **Du Bois limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 52. "Middle limestone bed of the Topeka member of the Shawnee formation."

Type locality, on Turner Creek southeast of Du Bois, Neb.

The Du Bois limestone member of the Topeka formation underlies black fissile shale of the Holt member which is the only rock of this type in the Topeka. The Du Bois is distinguished also by lithologic peculiarities that are very persistent and after one has become acquainted with these it is readily possible to differentiate the Du Bois from other parts of the Topeka on the basis of physical characters.

The Du Bois member comprises one or two dark-blue or greenish-blue, fine-grained dense limestone beds that in general show prominent vertical joints. Like other "middle" limestones, the bed or beds of the Du Bois are fairly homogeneous from bottom to top, lacking bedding planes within the limestone bed. Fossils are numerous but it is very difficult to free them from the matrix. The edges of the fossil shells weather in relief on the surfaces of joint planes. Mollusks, especially pelecypods, and the brachiopod, *Derbya,* (representing the transgressive molluscan or .3 member of the simple cyclothem) are most common, but in places the fusulinid limestone is also present. The rock does not disintegrate readily on weathering into shelly chips, like the Hartford limestone, but is gradually decomposed by solution. A thin surface film of the rock is altered in color by weathering to a light bluish or greenish blue color.

The thickness of the Du Bois limestone is so inconsiderable that if it were not for the distinctive characters of the unit which serve to make it a stratigraphic marker and if the importance of the limestone in the cyclothem sequence were not recognized, it would not call for differentiation as a named member. The thickness ranges from about one half foot to a maximum of two feet. The member is typically developed in Nebraska, Iowa and northern Kansas as far south as Topeka.

Topeka Limestone

HOLT SHALE MEMBER, Condra, 1927

1927, **Holt shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 52. Shale between the Du Bois and Coal Creek limestone beds of the "Topeka limestone member of the Shawnee formation."

Type locality, "just below Forest City and northwest of Oregon," Holt county, Mo.

Like the Du Bois limestone, the Holt shale is thin but persistent and it is a distinctive member of the Topeka formation. It conformably overlies the Du Bois limestone and underlies the Coal Creek limestone. The lower part of the member consists of black bituminous shale that is hard and fissile. The upper part is bluish and clayey, the contact with the lower part being gradational. Fossils include conodonts and some corneous brachiopods in the lower part and in places pelecypods and some calcareous brachiopods and bryozoans in the upper part.

The thickness of the Holt shale is about 2 to 3 feet in most places. The member has been recognized from western Iowa to the vicinity of Topeka, but not farther southward.

TOPEKA LIMESTONE

COAL CREEK LIMESTONE MEMBER, Condra, 1927

1915, †*Union limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 37. Limestone exposed at Union, Neb., classed as member of Braddyville formation. Name abandoned because preoccupied.

1927, **Coal Creek limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 52. "Upper unit of the Topeka limestone."

Type locality, on Coal Creek, about one half mile north of Union, Neb.

The Coal Creek limestone member of the Topeka formation is the "upper Topeka." It corresponds in cyclic relationships to the Ervine Creek limestone member of the Deer Creek, the Beil limestone member of the Lecompton, and the Plattsmouth limestone member of the Oread. Like these "upper limestones" of other Shawnee formations, the Coal Creek shows a tendency to irregular thin wavy beds separated by shale partings, but where the member consists mostly of limestone the beds are somewhat thick and more even than is typical of "upper limestones." Where the member is shaly, as near Kansas River, there are many thin lenses and nodules of light-blue-gray limestone in a matrix of calcareous shale. The nearly solid limestone phase of the Coal Creek member is developed toward the north. Here the color of the fresh rock is typically dark-blue, and that of the weathered rock light bluish-gray to brownish-gray. Dark-blue to nearly black nodules of flinty chert are common in the Coal Creek limestone of Nebraska and Iowa. Fossils are abundant in the Coal Creek member and most of them are exceptionally well preserved. Those in the calcareous shale beds weather free. Some beds contain a profusion of fusulinids but almost no other fossils. Other parts of the member yield a large variety of brachiopods, bryozoans, and less commonly other invertebrates.

The thickness of the Coal Creek member averages about 8 feet. It has been traced from Iowa, Nebraska and northwestern Missouri to Topeka.

WABAUNSEE GROUP (Prosser, 1895), Moore, 1936

1895, *Wabaunsee formation,* PROSSER, C. S., Jour. Geol., vol. 3, p. 688. Defined to include beds from the top of "Osage coal" [Nodaway coal in the Howard limestone] or "Silver Lake coal" [Elmo coal in the Cedar Vale shale, which were erroneously regarded as equivalent], to the base of the Cottonwood limestone.

1898, *Wabaunsee formation,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 94. Redefines base excluding beds below the Burlingame limestone. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol and Mines, (2), vol. 13, p. 34. Includes beds above Scranton shale but basal member is erroneously called Tarkio limestone. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 105. Defined as by Haworth. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 47. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 59. Same.

1902, *Wabaunsee stage,* PROSSER, C. S., Jour. Geol., vol. 10, p. 704. Boundaries as defined by Haworth in 1898. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 76. Same.

1921, *Wabaunsee group,* FATH, A. E., Kan. Geol. Survey, Bull. 7, pp. 39, 43. The U. S. Geol. Survey classes the Wabaunsee as a group with boundaries as defined by Haworth (1898). —— 1928, BASS, N. W., Kan. Geol. Survey, Bull. 12, p. 38. Same.

Type locality, Wabaunsee county, Kansas.

The Wabaunsee group, as here defined, comprises the beds above the top of the Topeka limestone and below the unconformity at the base of the Towle shale which is regarded as marking the boundary between rocks classed as Pennsylvanian and "Permian" in the northern Mid-Continent region. This definition of stratigraphic boundaries places the lower limit of the group slightly below the original position set by Prosser and fixes the upper limit considerably below Prosser's top of the Wabaunsee which was located at the base of the Cottonwood limestone. As applied to the uppermost Pennsylvanian strata in Kansas, Waubaunsee is a well established name and it has been deemed preferable to retain it in a somewhat modified sense rather than to discard it. The group is distinguished chiefly by lithologic features and by the character of its cyclothems from the underlying Shawnee and the succeeding Big Blue beds, but there are also some faunal peculiarities. Shale is relatively much more prominent in the Wabaunsee group than in adjoining parts of the geologic section. Much of the shale is sandy and at several horizons there are extensive sandstones. The Wabaunsee limestones are very persistent but are uniformily thin, the average thickness of individual members being about two feet. A distinctive feature of the

Wabaunsee group is the character of the cyclic sedimentary succession, which shows regularly alternating nonmarine and marine units in which a grouping of cyclothems in megacyclothems is not evident. This serves especially to set the Wabaunsee beds apart from those of the Shawnee group.

Study of the classification of beds that are included in the Wabaunsee group indicates that a number of previously recognized units, such as Scranton shale, Humphrey shale and McKissick Grove shale, are composed of strata that lie between certain rather arbitrarily selected boundaries. That is to say, names were applied to a few limestones that are fairly distinct in topographic expression and that are seemingly useful stratigraphic "markers" and then the strata lying between these selected markers were named. This is an entirely natural and proper procedure at least in an early stage of stratigraphic study, but as the Wabaunsee section is now understood this classification appears to serve no useful purpose. It is preferable to recognize as independent correlative units each major lithologic element of the sedimentary cycles that is known even though some of these have small thickness. If it is desirable for purposes of mapping to combine some of these units, that is very readily possible. Accordingly, the Wabaunsee group has been divided into alternating shale and limestone formations, the former including shale, sandstone, coal, and in a few cases minor limestone beds that comprise the terminal parts of adjoining cyclothems, and the latter containing limestones and intervening shales that represent the medial part of each cyclothem. This classification is applicable to all of the Wabaunsee beds except one or two seemingly rudimentary cyclothems, which are not separately indicated by the present defined formations.

Each of the Wabaunsee formations contains ideally about ten subdivisions that are sufficiently important and persistent in a majority of cases to justify designation as named members. On the other hand, most of these members are very thin and it is clearly undesirable to burden classification by the addition of some scores of new stratigraphic names. Therefore, it is thought sufficient to designate the subdivisions of formations by the index number or descriptive characterization of the cyclothem phases.

The thickness of the Wabaunsee group in Kansas shows little variation although the thickness of several of its contained formations shows a considerable range. Excepting places where the Indian Cave sandstone at the base of the Big Blue series cuts out the upper beds, the thickness of the Wabaunsee group is about 500 feet. Where the channel sandstone just mentioned occurs, the thickness of the group is reduced 80 to 125 feet.

Northern Oklahoma equivalents of the Wabaunsee beds include all of the Buck Creek formation with the possible exception of the Turkey Run limestone and underlying shale and the basal part of the Sand Creek formation including the Grayhorse limestone and a few feet of the next succeeding beds. It appears, however, that as mapped in much of northern Oklahoma the boundary between the Buck Creek and Sand Creek formations represents the upper limit of the Wabaunsee group, and hence marks the position of the line between Pennsylvanian and "Permian" as recognized in Kansas. This boundary is traceable southward to the flanks of the Arbuckle Mountains. The Texas correlatives of the Wabaunsee group belong in the lower part of the Cisco group, but the exact stratigraphic boundaries are not determined. It is believed that the Thrifty and lower Harpersville formations are essentially equivalent to the Wabaunsee group of Kansas. Correlation with the eastern section of the Pennsylvanian is still less definite, but it is probable that the Wabaunsee is represented by the upper Monongahela beds.

As here classified, the Wabaunsee group contains the following formations, named in upward order: Severy shale, Howard limestone, White Cloud shale, Happy Hollow limestone, Cedar Vale shale, Rulo limestone, Silver Lake shale, Burlingame limestone, Soldier Creek shale, Wakarusa limestone, Auburn shale, Reading limestone, Harveyville shale, Elmont limestone, Willard shale, Tarkio limestone, Pierson Point shale, Maple Hill limestone, Table Creek shale, Dover limestone, Dry shale, Grandhaven limestone, Friedrich shale, Jim Creek limestone, French Creek shale, Caneyville limestone, Pony Creek shale, and Brownville limestone.

SEVERY SHALE, Haworth, 1898

1898, **Severy shale*, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 67. Includes beds between top of Topeka limestone and base of Howard limestone. —— 1902, BEEDE, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 168. Same. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 49. Includes beds between †Hartford [Topeka] and Howard limestones. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 111. As originally defined. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 33. Same, classing it as member of Shawnee formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 104. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 45. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 53. Same.

1898, †*Shunganunga shale,* Beede, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 29. Name applied to beds between top of "Osage" [Nodaway] coal and base of Howard limestone. This unit is included without differentiation in the Severy where the Bachelor Creek limestone member of the Howard limestone is absent.

Type locality, Severy, Greenwood county, Kansas.

The Severy shale is the basal formation of the Wabaunsee group, as here redefined. It conformably overlies the Topeka limestone of the Shawnee group and includes the beds up to the base of the Howard limestone. Depending on variations in the development of the limestone members of these contiguous formations, the lower and upper boundaries of the Severy shale are drawn in different places at slightly different stratigraphic horizons. For example, where the Coal Creek member of the Topeka limestone is recognized, the base of the Severy is at the top of the Coal Creek limestone, but in places where the Hartford is the only member of the Topeka represented, the lower boundary of the Severy is considered to extend to the top of the Hartford limestone. Similar relationships are found in tracing the contact of the Severy and the Howard.

The Severy shale is chiefly a yellowish-brown and blue-gray sandy shale. Near the top the shale grades into very evenly bedded thin layers of tan or buff sandstone separated by partings of sandy shale. This sandy zone is rather distinctive in appearance and is very widespread. In northern Oklahoma the sandstone of the upper Severy is thicker, harder and much more irregularly stratified than in Kansas. It makes a bench that bears numerous scrub oaks. Where the sandstone is soft and thin-bedded, the Severy shale forms a smooth slope along the Howard escarpment extending from the outcrops of the Howard down to the dip-slope plain on the top of the Topeka limestone. Calcareous beds are mostly lacking in the Severy shale and except in southern Kansas and northern Oklahoma no limestone beds are seen in the formation. In this southern area one or more thin hard dark-blue mollusk-bearing limestones are observed in the lower part of the Severy. It is possible, however, that these are related to the cyclic succession of the Topeka beds. Fossils are not found in most of the Severy shale, but small brachiopods and some other invertebrates are abundant locally just below the Howard limestone. The shale beds below the thin limestones included in the lower Severy of southern Kansas contain well preserved gastropods and a few pelecypods.

The thickness of the Severy shale is rather constantly about 70 to 80 feet.

HOWARD LIMESTONE, Haworth, 1898

1866, †*Spring Rock limestone* (part), SWALLOW, G. C., Prelim. Rept., Geol. Survey of Kansas, Lawrence, p. 21. Name invalid because not a geographic term. Also, Swallow confused this limestone with beds much lower in the section. —— 1898, BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. Same.

1896, †*Osage City limestone,* HALL, JOHN, Kan. Univ. Geol. Survey, vol. 1, p. 104.

1898, **Howard limestone,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 67. Name applied to thin limestone overlying Severy shale. —— 1902, BEEDE, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 171. Same. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 50. Same. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 8, p. 111. Same. —— 1915, HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 33. Same, classing it as a member of the Shawnee formation. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 105. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 45. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 54. Same, and names beds.

1898, †*Quitman limestone,* GALLAHER, J. A., Bien. Rept. Bur. Geol. and Mines, Missouri, p. 54. Name preoccupied by a Cretaceous formation of Texas.

Type locality, near Howard, Elk county, Kansas. Typically exposed in NE¼ sec. 7, T. 29 S., R. 11 E.

The Howard limestone is a thin but extremely persistent formation that is of much interest to the student of sedimentation cycles in the Pennlylvanian rocks. The Howard lies between the Severy shale, below, and the White Cloud shale, above. Except in northern Kansas where topographic expression of the stratified rocks is blurred by effects of glaciation, the outcrop of the Howard beds is marked by a fairly distinct escarpment. This escarpment is less prominent than that of the Burlingame-Wakarusa limestones or those of limestones in the Shawnee group, but it is clearly differentiated in most places. South of Topeka for thirty miles the position of the outcrop of the Howard can be determined by the occurrence of numerous areas of coal stripping and by the location of small coal mines. The coal that is mined in this district occurs just below the Howard limestone.

The most complete development of the Howard limestone shows the presence of three limestone members and two shale members. These have been named, in upward order, Bachelor Creek limestone, Aarde shale, Church limestone, Winzeler shale, and Utopia limestone. The lithologic and faunal characteristics of the Howard will be described according to these members. It may be noted here that, although not yet studied in sufficient detail, there are features of the Howard sedimentary cycle that appear intermediate between the typical megacyclothems of the Shawnee group and the apparently simple cyclothems of the Wabaunsee group, in which no grouping into megacycles appears evident. The significance of these intermediate cyclic characteristics remains to be analyzed and interpreted.

HOWARD LIMESTONE

BACHELOR CREEK LIMESTONE MEMBER, Moore, 1932

1932, **Bachelor Creek limestone,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 94. Classed as lowermost member of the Howard limestone.

Type locality, Bachelor Creek, sec. 33, T. 25 S., R. 11 E., about 5 miles east of Eureka, Kan.

The lowermost member of the Howard limestone, called the Bachelor Creek limestone, is developed in southern Kansas from Greenwood county southward. It is a hard, somewhat sandy, impure, bluish-gray limestone, that ranges in thickness up to about three feet. The rock is massive, but on weathering breaks into irregular shelly fragments of yellowish-brown color. Fossils are not common. They consist of scattered crinoid stem fragments and a few brachiopods and bryozoans. The member is distinguished by lithologic characters and by its position below the Nodaway coal.

HOWARD LIMESTONE

AARDE SHALE MEMBER, Moore, 1932

1932, **Aarde shale,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 94. Classed as a member of the Howard limestone.

Type locality, Aarde farm, sec. 4, T. 26 S., R. 11 E., Greenwood county.

The Aarde shale member of the Howard limestone lies between the Bachelor Creek and Church limestone members. It is a bluish-gray to yellowish clayey and sandy shale about 3 to 7 feet thick. The very persistent Nodaway coal occurs in this member, locally near the base, elsewhere near the middle and in a few places near the top. The coal has been identified at numerous exposures from Nebraska, Iowa and northwestern Missouri, across Kansas, and extending 50 miles or more into Oklahoma. It varies in thickness from an inch or two to about 2 feet. The bed is mined at various places in Missouri and in the Osage county field south of Topeka, Kansas. Beneath the coal at some outcrops a distinct underclay, consisting of structureless sticky clay, is seen, but in other exposures well stratified shale is seen next below the coal. Fossil plants are collected from the beds immediately below or above the coal at a number of places, and a marine fauna consisting of pelecypods and a few kinds of calcareous brachiopods occurs rather commonly in the upper part of the Aarde member. Where the Bachelor Creek limestone is absent the Nodaway coal and other beds that are stratigraphically equivalent to the Aarde shale are classed as belonging at the top of the Severy shale, for it is not practicable to draw a boundary between two shale bodies. Moreover, it does not seem desirable in this case to indicate the observed relationships by a hyphenated term, such as Severy-Aarde shale. Beede applied the term Shunganunga shale to the few feet of beds between the top of the Nodaway coal and the base of the Church limestone, but there seems to be no good reason for recognizing this as a separate unit.

Certain details that are important from the standpoint of cyclic sedimentation remain to be worked out in study of the Aarde shale and equivalent strata that are classed as uppermost Severy. Some exposures in south-central Greenwood county in which the Bachelor Creek and Church limestone members are well developed, show in the upper part of the Aarde interval above the Nodaway coal, a few inches of dense, fine-grained bluish limestone. This thin limestone has the typical lithologic character of the so-called "middle limestones" of the Shawnee group megacyclothems, and like them it is overlain by black fissile shale. Some outcrops in northeasternmost Kansas, in southern Nebraska and across the Missouri River in Iowa and Missouri reveal similar black fissile shale with very abundant ostracodes, some corneous brachiopods and pelecypods, occurring a foot or two below the Church limestone. Locally there is an inch or two of calcareous shale or shaly limestone, apparently equivalent to the "middle limestone" at the base of the black shale and 1 to 3 feet above the Nodaway coal. The Bachelor Creek limestone is not present in this northern area. Putting together the known facts as to lithologic and faunal characters of the Howard stratigraphic units in various outcrops, there is good basis for the conclusion that this formation shows features of a rudimentary or partially developed megacyclothem. The Bachelor Creek limestone represents the culminating phase of Cyclothem A which contains the "lower limestone." The Aarde shale contains the terminal part of Cyclothem A, all of Cyclothem B to which the Nodaway coal and the locally developed "middle limestone" are referred, and the initial part of

Cyclothem C, including the black slaty shale and overlying fossiliferous clay shale with corneous brachiopods and mollusks. The Church limestone, which is the only member of the Howard observed to contain fusulinids, is the culminating phase of Cyclothem C, and although it consists of a single massive bed as seen in most exposures, it must be classed as an "upper limestone." The Winzeler shale and Utopia limestone may be interpreted as the terminal parts of Cyclothem C, for the latter exhibits the characters of a "super" or .7 bed in the cycle. This is not certain, however, for there are some exposures that appear to indicate proper classification of the Utopia member as belonging to a cycle next younger than the one to which the Church limestone belongs.

Howard Limestone

CHURCH LIMESTONE MEMBER, Condra, 1927

(?) 1918, *Bird Creek limestone,* Heald, K. C., and Mather, K. F., U. S. Geol. Survey, Bull. 686, p. 153. Name applied to first limestone above the Turkey Run limestone [Topeka] in Osage county, Oklahoma. Subsequently (Okla. Geol. Survey, Bull. 35, p. 78, 1925) included in the formation called Buck Creek.

1927, **Church limestone,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 54. Classed as the lower member of the Howard limestone in southern Nebraska.

Type locality, Church farm, on Turner Creek southeast of Du Bois, Neb.

The Church limestone is the most persistent and important limestone member of the Howard formation. It overlies the Aarde shale or, where the Bachelor Creek limestone is absent and Aarde shale is not differentiated, it is considered as forming the basal unit of the Howard, resting on Severy shale. The Church member is overlain by the Winzeler shale.

The lithologic and faunal characters of the Church limestone are remarkably constant throughout its long outcrop from Nebraska and Iowa to north-central Oklahoma. After one has become acquainted with these characters it is easy to recognize the member and it is a valuable stratigraphic datum. The color of the unweathered limestone is rather dark-blue to blue-gray. On weathering a zone a few inches thick adjacent to exposed surfaces is altered to drab or brownish-blue and a thin coating of rich chestnut brown or chocolate color is developed over the surface. The rock is very hard, dense and brittle, breaking with a subconchoidal fracture when struck by a hammer. Commonly there is a single massive bed that represents the entire thickness of the member, but locally there are two or more even layers. Along the outcrop in most places rectangular joint blocks, somewhat rounded at the edges by solution, are separated from the rock in place. Locally the limestone breaks into irregularly shaped large shelly fragments. The most common fossils are crinoid stem fragments and large productids belonging to the genus *Dictyoclostus*. Specimens of *Enteletes* are common in the Bird Creek (Church ?) limestone in northern Oklahoma. These and less common other fossils are not abundant, but are scattered at random through the fine-grained matrix. Large specimens of *Ottonosia* (*"Cryptozoon"*) are noteworthy in some exposures. At the top of the limestone is a thin crust with very abundant bryozoans among which *Rhombopora* and *Streblotrypa* are especially noteworthy. Fusulinids occur sparsely in the upper part of the Church limestone in southern Kansas and northern Oklahoma. Locally near Topeka there are abundant fusulinids.

The thickness of the Church limestone ranges from about 1.5 to 6 feet, the average being a little over 2 feet.

The Church limestone is believed to correspond exactly to the bed called Bird Creek limestone in Osage county, Oklahoma, but this is not yet determined with sufficient definiteness to warrant use of Bird Creek (which is the older term, and about as much used as Church) as the name of a member of the Howard limestone in place of Church.

HOWARD LIMESTONE
WINZELER SHALE MEMBER, Moore, 1932

1932, **Winzeler shale,* MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 94. Classed as a member of the Howard limestone.

Type locality, Winzeler farm, sec. 4, T. 26 S., R. 11 E., Greenwood county, Kansas.

The Winzeler shale occurs between the Church limestone, below, and the Utopia limestone, above. It is about 3 to 8 feet thick, bluish-gray or yellowish and clayey to calcareous. The lower part contains a marine fauna in which a variety of bryozoans and a few brachiopods are most common. This member is recognizable from Nebraska and Iowa southward to Oklahoma, but locally where the Utopia limestone disappears, the beds immediately overlying the Church limestone are classed as White Cloud shale.

HOWARD LIMESTONE

UTOPIA LIMESTONE MEMBER, Moore, 1932

1932, **Utopia limestone,* MOORE, R. C., Kan. Geol. Soc. Guidebook, Sixth Ann. Field Conf., p. 94. Classed as uppermost member of the Howard limestone.

Type locality, just east of the village of Utopia, sec. 5, T. 25 S., R. 11 E., Greenwood county, Kansas.

The Utopia limestone is the uppermost member of the Howard limestone, occurring between the Winzeler shale member of the Howard, below, and the White Cloud shale, above. It is a rather thin, but very persistent and distinctive stratigraphic unit that differs lithologically and in faunal content from other limestone beds of the Howard formation. In central and southern Kansas the Utopia member consists in most places of a single hard bed of dense rather dark bluish limestone that breaks along vertical joint planes into rectangular blocks. The color of the weathered rock is light brownish-gray. Exposed surfaces are slightly rough because of etching by solution that leaves fine horizontally disposed platy fragments of shells and algal growths standing in relief. The limestone resembles a compacted coquina and hence may be described as coquinoid. This textural feature which in field notes has been described frequently as "oatmeal rock," and the abundance of algal material of the type called *Osagia* are distinguishing characters of this phase of the Utopia limestone. In northern Kansas and southern Nebraska, outcrops of the Utopia member commonly show somewhat shaly light bluish-gray limestone that in places is highly fossiliferous. A variety of brachiopods, bryozoans and some mollusks are observed.

The thickness of the Utopia limestone ranges from less than one foot to a known maximum of about 4 feet.

WHITE CLOUD SHALE (Condra, 1927), Condra, 1930

1895, †*Burlingame shale* (part), HAWORTH, E., Am. Jour. Sci., (3), vol. 50, p. 461. —— 1896, HAWORTH, E., Kan. Univ. Geol. Survey, vol. 1, p. 162. —— 1898, BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. —— 1902, BEEDE, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 174. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 51.

1898, †*Osage shale* (part), HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 67.

1908, *Scranton shale* (part), HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 112. —— 1915, HINDS, H., AND GREENE, F. C., Mo.

Bur. Geol. and Mines, (2), vol. 13, p. 33. Classes Scranton as member of the Shawnee formation. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3, p. 105. Same. —— 1920, Moore, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 45. Same —— 1927, Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 56. Names subdivisions, in upward order: Rock Lake shale, South Bend limestone, †Plattford shale, †Cass limestone, White Cloud shale, Rulo limestone, Silver Lake shale. The first four of these are named from the Platte Valley and do not belong in the Scranton at all.

1927, *White Cloud shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 58. Name applied to beds between the Howard limestone below and the Rulo limestone above. Contains the Happy Hollow limestone in upper part. Classes White Cloud shale as a member of the Scranton shale.

1930, **White Cloud shale,* Condra, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 53. Restricts name to beds between the Howard limestone below and the Happy Hollow limestone above. Classes White Cloud shale as a member of the Scranton shale. —— 1932, Condra, G. E., Moore, R. C., and Dunbar, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Same.

Type locality, near White Cloud, Doniphan county, Kansas.

The White Cloud shale includes beds occurring between the top of the Howard limestone and the base of the Happy Hollow limestone. It comprises the lower part of the succession of beds formerly included in the Scranton shale which was defined to extend from the top of the Howard limestone to the base of the Burlingame limestone. Since the Happy Hollow and Rulo limestones have been discovered to be extremely persistent stratigraphic units that represent the calcareous deposits of separate and distinct cyclothems that are correlative with other Wabaunsee cyclothems, there seems to be no good reason for recognizing as a formation the grouping of beds that has been included under the term Scranton. Consistent application of the principles of classification and nomenclature that are given elsewhere in this paper, requires that the White Cloud shale and other units previously considered as members of the Scranton shale, should be treated as formations.

The White Cloud shale consists of bluish or yellow-brown clayey and sandy shale, about 30 to 80 feet in thickness. Locally there are beds of shaly to massive sandstone in the upper part, and north of Topeka channel sandstone, with a foot or two of moderately coarse conglomerate at the base, occurs below the middle of the White Cloud shale. These sandy and conglomeratic deposits are interpreted as the initial phase of the Happy Hollow cyclothem. Fossils are rare or absent at most outcrops of the White Cloud shale. Both marine invertebrates, chiefly mollusks, and land plant remains have been observed but further paleontologic studies are needed. The White Cloud shale is traceable from Iowa and Nebraska entirely across Kansas into Oklahoma.

HAPPY HOLLOW LIMESTONE, Condra, 1927

1895, †*Burlingame shale* (part), HAWORTH. (See under White Cloud shale.)

1898, †*Osage shale* (part), HAWORTH. (See under White Cloud shale.)

1908, *Scranton shale* (part), HAWORTH. (See under White Cloud shale.)

1927, **Happy Hollow limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 58. Applies name to limestone in the White Cloud shale member of the Scranton shale. —— 1930, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 53. Classes Happy Hollow as a member of the Scranton shale, restricting White Cloud to beds below this limestone. —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Same.

Type locality, Happy Hollow Creek, northeastern Doniphan county, Kansas.

The Happy Hollow limestone occurs next above the White Cloud shale and lies next below the Cedar Vale shale. It is the so-called "salmon bed," distinguished by a peculiar salmon-yellow or pinkish-brown color, noted by various geologists along the Missouri river in northwestern Missouri, northeastern Kansas and southeastern Nebraska. When Condra introduced the name Happy Hollow, he defined this limestone as a member of the Scranton shale, thinking it sufficiently distinctive and important to be worthy of at least local differentiation under a geographic name. It was not suspected, as has since been clearly determined, that the Happy Hollow limestone is traceable across Kansas and that it is identifiable in Oklahoma where it shows lithologic and faunal characters almost exactly like those seen in northeastern Kansas.

The Happy Hollow limestone consists typically of a single massive bed of pinkish-brown, somewhat impure limestone that tends to weather in rounded or irregularly porous surfaces. At some places it is very sandy and locally it is soft and somewhat shaly, so that its outcrop is difficult to trace. The presence of abundant robust *Triticites* is a common feature. Some sections show clearly an upper part of the limestone that lacks fusulinids and most other invertebrates but contains *Osagia* and other algal material. This part of the formation, which clearly represents the regressive algal-molluscan limestone phase (No. .7) of the cyclothem, appears to rest disconformably on the fusulinid-bearing limestone (No. .5), the contact being sharp and irregular. Locally there is a little shale between these two limestone phases. A dark bluish limestone containing mollusks, brachiopods and bryozoans (No. .3) has been observed a foot or two below the fusulinid limestone at some places. The thickness of the Happy Hollow limestone ranges from about 1 foot to 7 or 8 feet. It extends from Cass county, Nebraska, at least to southern Osage county, Oklahoma. Its distinctive lithologic and faunal characters make it a useful horizon marker.

CEDAR VALE SHALE, Condra, 1930

1895, †*Burlingame shale* (part), HAWORTH. (See under White Cloud shale.)

1898, †*Osage shale* (part), HAWORTH. (See under White Cloud shale.)

1908, *Scranton shale* (part), HAWORTH. (See under White Cloud shale.)

1930, **Cedar Vale shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 3, p. 53. Applies name to beds between the Happy Hollow limestone below and the Rulo limestone above. Classes it as a member of the Scranton shale. —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Same.

Type locality, near Cedar Vale, Chautauqua county, Kansas. Exposed in east bluff of Caney river, in sec. 12, T. 34 S., R. 8 E.

The Cedar Vale shale comprises the middle part of the interval formerly termed Scranton shale. The top of the Happy Hollow limestone forms its lower boundary and the base of the Rulo limestone its upper boundary. The Cedar Vale shale is bluish to yellowish brown, includes clayey and sandy beds and near the top contains the very persistent Elmo coal. At many places the few feet of beds underlying this coal consists of soft shaly sandstone or of hard fairly massive sandstone. The sandstone, sandy shale and coal in the upper part of the Cedar Vale represent the initial, terrestrial deposits of the Rulo cyclothem. Fossils are uncommon in most parts of the Cedar Vale shale. The topmost beds, between the Elmo coal and the base of the Rulo limestone, contain a mixed fauna of marine mollusks, brachiopods and bryozoans. The thickness of the Cedar Vale shale averages about 25 feet. The formation is traceable from southern Nebraska to northern Oklahoma.

RULO LIMESTONE, Condra and Bengston, 1915

1895, †*Burlingame shale* (part), HAWORTH. (See under White Cloud shale.)

1898, †*Osage shale* (part), HAWORTH. (See under White Cloud shale.)

1908, *Scranton shale* (part), HAWORTH. (See under White Cloud shale.)

1915, **Rulo limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 14. Refer to bed, 1.3 feet thick, next below the Burlingame limestone. Classed as lowermost member of the "Nemaha formation." —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 58. Applies name to limestone in the Scranton shale, next beneath the Silver Lake shale member. —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Same as last.

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A., Neb Acad. Sci., Publ., vol. 9, p. 14.

Type locality, about 2.5 miles north of Rulo, Richardson county, Nebraska.

The Rulo limestone overlies the Cedar Vale shale and underlies the Silver Lake shale. The limestone can be recognized by its lithologic characters and position just above the Elmo coal and between the Happy Hollow and Burlingame limestones. The Rulo limestone and Elmo coal were confused with the Howard limestone and Nodaway coal in some of the early geologic work, but there is no occasion for such confusion if attention is given to stratigraphic relationships and to lithologic characters of the limestones.

The Rulo limestone is a bluish-gray rock in fresh exposures and appears in some cases faintly mottled with irregular light-brownish areas. The limestone weathers brown or dark-gray. In general, it appears as a single massive bed that breaks along joints into fairly large rectangular blocks. A tendency to disintegrate in small chips is observed in some exposures, and locally the bed is distinctly shaly. Argillaceous, silty or sandy impurities are commonly present. Fossils are abundant in some outcrops but are few in others. Brachiopods and bryozoans are most common. Small fusulinids have been observed in a few places. The presence of a transgressive molluscan phase is indicated by occurrence of numerous pelecypods at the base in some exposures and a thin zone of algal limestone at the top locally marks the regressive algal-molluscan phase of the typical cycle. In general, however, the different calcareous elements of the cyclothem are not well differentiated in the Rulo limestone. The thickness of the Rulo averages about 2 feet. The bed is identified at many places from Nebraska to northern Oklahoma.

SILVER LAKE SHALE (Beede, 1898), Condra, 1927

1895, †*Burlingame shale* (part), HAWORTH. (See under White Cloud shale.)

1898, †*Osage shale* (part), HAWORTH. (See under White Cloud shale.)

1898, *Silver Lake shale,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. Name applied to beds between the top of the "Silver Lake" [Elmo] coal and the base of the "Stanton" [Burlingame] limestone; includes a thin limestone [Rulo] near base.

1908, *Scranton shale* (part), HAWORTH. (See under White Cloud shale.)

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 14.

1927, **Silver Lake shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 58. Restricts to apply to beds between top of Rulo limestone and base of Burlingame limestone. Classed as the uppermost member of the Scranton shale. —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Same.

Type locality, in vicinity of Silver Lake, Shawnee county, Kansas.

The Silver Lake shale includes the strata that lie between the Rulo limestone, below, and the Burlingame limestone, above. It is somewhat variable in lithologic character, in some places consisting chiefly of bluish-gray and yellowish clay shale, with or without platy impure beds of limestone, and in other places being composed largely of light yellowish-brown sandy shale and shaly sandstone. Locally a coal bed is found in the upper part of the shale. This shale includes the upper part of the Rulo cyclothem and the lower part of the Burlingame cyclothem. Some outcrops of the Silver Lake shale yield remains of land plants and some show fairly abundant marine mollusks, brachiopods, bryozoans and other invertebrates. These kinds of fossils reflect different phases in the sedimentary cycle that are unequally developed in various places. Two or more dissimilar fossil zones may be seen in a single exposure of the shale. The thickness of the Silver Lake shale averages about 25 feet. The formation may be traced practically continuously from Nebraska across Kansas into northern Oklahoma.

BURLINGAME LIMESTONE, Hall, 1896

1894, †*Wyckoff limestone,* HAWORTH, E., AND KIRK, M. Z., Kan. Univ. Quart., vol. 2, p. 111. Name preoccupied by Ordovician formation in Minnesota.

1896, **Burlingame limestone,* HALL, JOHN, Kan. Univ. Geol. Survey, vol. 1, p. 105. Applies name to brown, shelly limestone "8 feet thick, just west of Burlingame" next above shale "150 or 200 feet thick." —— 1902, PROSSER, C. S., Jour. Geol., vol. 10, p. 704. Probably in part includes Wakarusa limestone. —— 1908, HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 112. Same. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 106. Classes the Burlingame as a member of the Wabaunsee formation. —— MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 48. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 76. Classes Burlingame as part of the "Nemaha beds." —— 1929, BASS, N. W., Kan. Geol. Survey, Bull. 12, p. 40.

1898, †*Eureka limestone,* HAWORTH, E., Kan. Univ. Geol. Survey, vol. 3, p. 67. Name preoccupied by Ordovician formation in Nevada.

1902, †*Barclay limestone* (part), ADAMS, G. I., Mss., in Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 175. As used by Beede, the Barclay includes beds from the base of the Burlingame to the top of the Elmont ("Emporia"). —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 51.

1915, *Tarkio limestone,* HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 34. This name was erroneously used for beds in northwestern Missouri that were regarded as equivalent to the Burlingame.

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 14. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 76. Uses the term "Nemaha beds" for strata from base of Burlingame limestone to top of Tarkio limestone, but (p. 71) states that "the name Nemaha formation is dropped provisionally." —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Strata from the base of the Burlingame to the top of the Tarkio are called "Nemaha limestone." Moore was not consulted on this usage and has never adopted it.

Type locality, Burlingame, Kan. The limestone makes a fairly prominent escarpment that crosses the west part of Burlingame.

The Burlingame limestone occurs next above the Silver Lake shale and lies beneath shale that is called Soldier Creek. As here defined, the Burlingame limestone comprises the various types of calcareous deposits and interbedded shale beds that occur in the middle portion of the Burlingame cyclothem. Careful examination of the literature and studies in the field make reasonably certain the conclusion that the limestone now called Wakarusa and the Soldier Creek shale, which occurs between the Wakarusa and Burlingame, have been included by various writers in the Burlingame limestone at a number of places. This applies to descriptions of outcrops throughout much of central and southern Kansas where the Burlingame and Wakarusa are relatively close together and form what is essentially a single escarpment. Good reasons for restricting application of the term Burlingame to the lower of these two limestones lie in their persistent lithologic and faunal differences, but especially in the clearly defined evidence that they belong to different sedimentary cycles. Hall's original description of the Burlingame limestone seems to apply to the formation as here recognized, that is, without inclusion of shale and limestone that are now classed as Soldier Creek and Wakarusa, respectively. Apparently Hall did not see these beds above the brown Burlingame limestone "8 feet thick just west of Burlingame," but in any case it is believed that use of Burlingame should be restricted to beds below the Soldier Creek shale.

Prosser's[44] original definition of the "Wabaunsee formation" placed the base of this unit, now classed as a group, at the "Osage coal" [Nodaway (?)] but Haworth[45] later redefined this boundary, placing it at the base of the Burlingame limestone. The only apparent reason for this change is the topographic prominence of the Burlingame escarpment which makes it conveniently traceable across the state. This relationship to the long adopted definition of Wabaunsee has given to the Burlingame somewhat more prominence than it deserves. The distinctness of topographic expression just mentioned is quite as much due to the presence of resistant Wakarusa beds a little above the Burlingame, as it is to thickness and resistance of the Burlingame limestone. When this is noted, the Burlingame becomes neither more nor less important as a stratigraphic marker than other limestones in the Wabaunsee group.

The Burlingame limestone is perhaps chiefly distinguished by its strongly brown color and thick bedding, as seen in most outcrops. The rock is hard, medium-to fine-grained, and is commonly rather unfossiliferous. Many exposures show a peculiar mottled color and apparently brecciated structure, with irregularly shaped fragments of dense gray or light brownish limestone in a matrix that becomes very dark-brown on weathering. This type of rock is generally somewhat porous, and it may contain numerous fine cal-

44. Prosser, C. S., Jour. Geol., vol. 3, p. 688, 1895.
45. Haworth, E., Kan. Univ. Geol. Survey, vol. 3, p. 94, 1898.

cite veins and other markings. Some beds of the Burlingame are light-gray and rich in fossils, but the color of the weathered rock is brown.

Different kinds of limestone and different assemblages of fossils, which are recognizable as representatives of certain parts of the sedimentary cycle, are seen in the Burlingame formation, but the development of these various phases is very unequal from place to place along the outcrop. At the base of the formation locally is limestone that contains abundant pelecypods and a few brachiopods such as *Derbya* and *Juresania* but no fusulinids. This clearly represents the transgressive molluscan phase (No. .3) of the cyclothem. A few inches of shale overlies the molluscan limestone, or limestone with fusulinids occurs next without a shale parting. The fusulinids of the Burlingame are mostly small and may easily be overlooked. There are many outcrops of Burlingame, however, that lack fusulinid-bearing beds. A very important element of the formation as observed in most places is the limestone classed as the regressive, algal-molluscan (No. .7) phase of the cyclothem. This includes the massive apparently brecciated rock at many outcrops, beds that contain abundant *Osagia* and other algal material, thin-bedded, platy, very dense limestone that is unfossiliferous, molluscan limestone with well preserved fossils, and locally conglomeratic limestone. A number of gastropods are found in this part of the Burlingame. In northern Kansas there is a remarkable development of algal limestone of two or three sorts at this horizon. One of these consists of beds and local "reefs" of sponge-like bodies, subspherical or irregular in shape, and an inch to 4 or 5 inches in diameter. These bodies were interpreted by Beede as sponges and he applied to them the name *Somphospongia.* They are believed to be algal, however,

The thickness of the Burlingame limestone ranges from about 4 to 16 feet, the average being about 8 feet. The formation has been mapped from southern Nebraska across Kansas and has been identified 40 miles or more south of the Kansas-Oklahoma line.

SOLDIER CREEK SHALE (Beede, 1898), Condra, 1927

1898, *Soldier Creek shale,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. Applies name to shale "40 feet or less thick" above the "Stanton" [Burlingame] limestone and beneath the Wakarusa limestone.

1898, *Stanton limestone* (part), BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. As explained below (Condra, 1927) the shale now called Soldier Creek comprises the middle portion of Beede's "Stanton" [Burlingame] limestone.

1902, †*Barclay limestone* (part), ADAMS, G. I., in Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 175. —— 1903, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 51. Same (?). —— 1905, SMITH, A. J., Kan. Acad. Sci., Trans., vol. 19, p. 150. Same.

1908, *Burlingame limestone* (part ?), HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 8, p. 112. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 106. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 48. —— 1929, BASS, N. W., Kan. Geol. Survey, Bull. 12, p. 41.

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A. (See under Burlingame limestone, above.)

1927, **Soldier Creek shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 77. Applies Beede's name to shale between Burlingame and "Wakarusa" limestones and classes it as a member of the Humphrey shale. It appears from studies of Beede's sections that the limestone called Wakarusa by Condra is included in Beede's "Stanton" [Burlingame] and that the original application of Wakarusa was to the limestone that has subsequently been called lower Emporia by most writers. Because the beds called Wakarusa by Condra belong to a sedimentary cycle that is distinct from that of the Burlingame limestone, it is desirable to differentiate them from Burlingame, and because of consistent use of Wakarusa in this sense in describing many sections in recent literature, it is deemed advisable to follow Condra's unintentional transposition of stratigraphic terms. The name Soldier Creek shale, therefore, will be applied as by Condra to the next lower shale unit than that originally designated by this term. The sequence of the units is the same as given by Beede, but the application is modified.

1927, †*Humphrey shale* (Smith, 1905) (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 71. Classes Soldier Creek shale as the lowest member of Humphrey shale, but the writer concludes that the type Humphrey does not include Condra's Soldier Creek shale.

Type locality, not designated but presumably it is on "Big and Little Soldier creeks about 3 miles from Silver Lake," Shawnee county, Kansas.

The Soldier Creek shale overlies the Burlingame limestone and underlies the Wakarusa limestone. As noted in connection with references to the literature given above, it has seemed desirable to follow usage rather than priority in determining the present application of the term Soldier Creek. Beede introduced the name for the shale between the "Stanton" [Burlingame] and Wakarusa limestones, a definition which as regards stratigraphic sequence is here retained. Beede's original Wakarusa limestone, however, is identified as the unit here called Reading limestone, and the Wakarusa limestone as now defined by usage, mainly by Condra, was included in the upper part of Beede's "Stanton" [Burlingame] limestone. It is apparent, therefore, that application of Soldier Creek is transferred to a shale that lies below that originally signified.

The Soldier Creek shale is a bluish-gray to bluish, clayey to sandy or silty micaceous stratigraphic unit that locally contains a little sandstone. Locally, also, a thin coal bed occurs in the upper part of the shale, but in most places this is absent. Fossils are not common. In a few places there are marine invertebrates at the top of the shale just below the Wakarusa limestone. The Soldier Creek is 15 to 25 feet thick in southern Nebraska and part of northern Kansas, but near Kansas river and southward for many miles it is less than 6 feet thick. In southern Kansas this shale is 12 to 18 feet in thickness. The minimum observed thickness is about 2 feet. That the Soldier Creek shale may properly be differentiated as a formational unit according to principles applied in dividing the strata of the Wabaunsee group is indicated by the fact that the Burlingame and Wakarusa limestones belong to entirely separate cyclothems and by the persistence of the shale from southern Nebraska to northern Oklahoma.

WAKARUSA LIMESTONE (Beede, 1898), Condra, 1927

1898, *Wakarusa limestone,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. "A limestone 2 to 4 feet in thickness, very fossiliferous and a fine building stone" which is "40 feet or less" above the "Stanton" [Burlingame] limestone. This limestone is identified in the type locality as equivalent to the lower Emporia limestone of common usage.

1898, *Stanton limestone* (part), BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. The limestone now called Wakarusa comprises the upper part of Beede's "Stanton" [Burlingame] limestone.

1902, †*Barclay limestone* (part), ADAMS, G. I., etc. (See under Soldier Creek shale.)

1908, *Burlingame limestone* (part), HAWORTH, E., AND BENNETT, J., etc. (See under Soldier Creek shale.)

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A. (See under Burlingame limestone, above.)

1915, †*Fargo limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 14. Classed as a member of the †Nemaha formation.

1927, **Wakarusa limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 66. Applies name to limestone beds about 6 feet thick that occur about 25 feet above the Burlingame limestone in Nebraska. This usage seems to agree with Beede's original definition but when the limestone called Wakarusa by Condra is traced to southern Shawnee county, Kansas, it is found to comprise the upper member of Beede's "Stanton" limestone. It is desirable to differentiate this unit from the Burlingame limestone, and because Condra's use of Wakarusa is the only one since the original publication and because this name has been extensively employed recently with the application given by Condra, it is here retained with Condra's definition. This is a case where usage desirably takes precedence over priority of definition.

1927, *Humphrey shale* (SMITH, 1905) (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 71. Condra classes the Wakarusa limestone as the middle member of the Humphrey shale, but the writer concludes that the type Humphrey does not include Condra's Wakarusa limestone.

Type locality. The Wakarusa limestone of Beede was "named from the fine exposure of this rock on Wakarusa Creek immediately south of Auburn." The beds called Wakarusa by Condra and here designated by this name are present along Wakarusa Creek south of Auburn, but much better exposures are to be found on Kansas highway 10 west of Topeka in sec. 35, T. 11 S., R. 13 E., and along the creek north of the highway near this place.

The Wakarusa limestone comprises the first resistant unit above the Burlingame limestone. The shale beneath it is called Soldier Creek and that above it is the Auburn. The most persistent and distinctive element in the Wakarusa formation is a thick-bedded or massive dark bluish hard limestone that contains large fusulinids, *Ottonosia,* a robust *Dictyoclostus,* crinoid stem fragments, *Fistulipora,* and a varied assemblage of other brachiopods, bryozoans, and some additional groups of invertebrates. The limestone is vertically jointed as seen in most places. On weathering the Wakarusa becomes mottled gray and light-brown or the rock is changed entirely to brown. Both lithologic and faunal characters serve readily to distinguish the Wakarusa limestone from the underlying Burlingame and it can be differentiated from somewhat similar lithologic phases of the Reading and Elmont limestones by observation of stratigraphic position and faunal characters. The limestone just described represents the culminating or fusulinid phase of the Wakarusa cyclothem. Locally a molluscan limestone, or a limestone containing an assemblage of mollusks and brachiopods, occurs below the fusulinid-bearing limestone. Above this latter rock, also, there are algal-molluscan or fine-granular unfossiliferous sandy limestones that represent phase No. 7 of the ideal cyclothem. Where these additional limestone units are found the Wakarusa limestone includes two or more limestone beds and the shale that occurs between them. The thickness of the Wakarusa limestone ranges from about 2 feet to about 18 feet, the latter thickness including somewhat more shale than limestone. The formation is traceable from Nebraska into northern Oklahoma.

The so-called "Cryptozoon limestone" of Osage county, Oklahoma, which is a widely recognized datum in this part of the Pennsylvanian column in northern Oklahoma, is the fusulinid-bearing phase of the Wakarusa limestone.

AUBURN SHALE (Beede, 1898), Condra, 1927

1898, *Auburn shale,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. Applies name to shale "8 to 20 feet in thickness" between Wakarusa limestone below and Elmont limestone above. Since the Wakarusa of Beede is identified as equivalent to the lower Emporia and the Elmont to the upper Emporia of authors, the term Auburn was originally applied to the middle shale member of the Emporia limestone.

1898, *Soldier Creek shale,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. Present application of Auburn shale is synonymous with Beede's original Soldier Creek shale.

1902, †*Barclay limestone* (part), ADAMS, G. I., in Beede, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 175. Beede, using Adams' manuscript name, included under this term the beds from the base of the Burlingame to the top of the Elmont [upper Emporia].

1903, †*Olpe shale* (part), ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 52. This unit includes beds from the top of the †Barclay [Burlingame and Wakarusa] to the base of the Emporia.

1905, †*Humphrey shale* (part), SMITH, A. J., Kan. Acad. Sci., Trans., vol. 19, p. 150. Includes strata from the top of the †Barclay [Burlingame and Wakarusa] to the base of the Reading [lower Emporia]. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 71. Employs this term for beds between the Burlingame and Emporia limestones. —— 1929, BASS, N. W., Kan. Geol. Survey, Bull. 12, p. 41. Same.

1908, *Willard shale* (Beede, 1898) (part), HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 113. Erroneously applies this name to the beds between Burlingame [includes Wakarusa in part] and Emporia. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 106. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 48. Same.

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A. (See under Burlingame limestone, above.)

1927, **Auburn shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 78. Applies name to shale 10 to 25 feet thick between the Wakarusa and Emporia as identified by him. As indicated in the discussion of Wakarusa limestone, Condra has used this term for a lower bed than Beede's Wakarusa which corresponds to the lower member of Condra's Emporia. Therefore, application of the name Auburn shale is transposed to a lower unit that appears to be the same as Beede's original Soldier Creek shale. Because greater importance is attached to usage in recent literature than to the claims of priority of definition in the case of a term that had been unused except in the original rather obscure paper, we shall follow Condra's placement of the Auburn shale.

Type locality, not designated, but undoubtedly it is in the vicinity of Auburn, Shawnee county, Kansas. Good exposures of this shale occur along Wakarusa Creek (near NE. cor. sec. 26, T. 13 S., R. 14 E., southwest of Auburn.

The Auburn shale includes the strata between the top of the Wakarusa limestone, below, and the base of the Reading limestone, above. It is a more complex unit than most of the shale formations of the Wabaunsee group, for it includes not only the terminal clastic portion of the Wakarusa cyclothem and the initial clastic part of the Reading cyclothem, but in addition there are several identifiable phases of what appears to be a partially developed cyclothem belonging between the Wakarusa and Reading cyclothems. This intermediate incomplete cyclothem is named Auburn. Because of the complex nature of the Auburn shale, it is desirable to describe briefly the various recognized subdivisions. It should be borne in mind that variations along the strike of the shale make this attempt to generalize the description according to zones somewhat difficult.

The lowermost part of the Auburn, comprising the terminal part of the Wakarusa cyclothem, consists of yellowish-brown or gray sandy shale, mostly lacking in fossils. The upper limit of this zone is not clearly defined in most places, and where a definite sandstone or red zone that may be interpreted as marking the base of the Auburn cyclothem is absent, the sandy and silty beds up to the lower coal horizon of the Auburn shale may be grouped together.

The lower part of a cyclothem that belongs above the Wakarusa and that is distinct from the Reading cyclothem is clearly marked in many places by sandstone or red shale and locally by coal and underclay in the lower part of the Auburn shale. These nonmarine deposits are overlain by shale and thin even-textured fine-grained blue limestone beds that contain marine pelecypods and commonly the brachiopod *Linoproductus*. Other brachiopods, bryozoans and crinoid remains are fairly abundant in the shale at some exposures. A blocky, somewhat impure limestone about 0.4 to 0.5 feet thick, with very even top and bottom, is identified in this zone entirely across Kansas and in northern Oklahoma. It is underlain by a thin platy limestone that carries plant fragments and some pelecypods. The persistence and uniformity of characters of these thin layers for scores of miles along the outcrop is very striking and the horizon is a very useful stratigraphic marker.

No fusulinid-bearing limestone beds have been observed in the Auburn cyclothem but at least in Shawnee county there is a locally prominent No. .7 limestone phase with abundant molluscan and algal fossil remains. Near Kansas river this limestone is a resistant scarp-making limestone, 5 feet thick. It is coquinoid and in part conglomeratic and cross-bedded, as is the habit of many of the No. .7 phases of the cyclothem. Very dark, nearly black clay shale just beneath this limestone in some outcrops contains an interesting fauna of well preserved pectinoid and other pelecypods and a profusion of large ostracodes.

The upper part of the Auburn shale includes the terminal portion of the Auburn cyclothem, and the initial portion of the Reading cyclothem. The base of the latter cyclothem is clearly marked throughout southern Kansas by a persistent platy sandstone that can be recognized easily in numerous outcrops. This sandstone is 1 to 3 feet thick in most places but in northern Oklahoma it becomes thicker and somewhat less thin-bedded. The overlying shale contains remains of mollusks, chiefly pelecypods and some brachiopods, but in most places it is not very fossiliferous. A thin coal horizon belongs at the base of this zone.

The thickness of the Auburn shale ranges from about 20 to 70 feet. The formation is identified in Nebraska and is continuous southward across Kansas into Oklahoma.

READING LIMESTONE, Smith, 1905

1896, †*Emporia limestone* (part), Kirk, M. Z., Kan. Univ. Geol. Survey, vol. 1, p. 80. It is impossible to determine to which of three or more different limestones exposed near Emporia Kirk intended to apply this name. Judging from localities cited by him it appears that he considered as identical, beds that are actually 75 feet or more apart stratigraphically. —— 1902, Prosser, C. S., Jour. Geol., vol. 10, p. 706. Includes bed here called Reading and a higher 2-foot blue limestone separated by 4 feet of shale. —— 1908, Haworth, E., and Bennett, J., Kan. Univ. Geol. Survey, vol. 9, p. 113. Same. —— 1917, Moore, R. C., and Haynes, W. P., Kan. Geol. Survey, Bull. 3,

p. 106. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 48. Same. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 65. Same. —— 1929, BASS, N. W., Kan. Geol. Survey, Bull. 12, p. 42.

1903, *Emporia Blue limestone* (part), SMITH, A. J., Kan. Acad. Sci., Trans., vol. 18, p. 100.

1903, †*Olpe shale* (part), ADAMS, G. I., U. S. Geol. Survey, Bull. 211. This name was employed for beds between the top of the †Barclay (Wakarusa) limestone and the "Emporia limestone," the latter indicating beds more than 60 feet above the Reading [= lower Emporia of recent common usage].

1905, **Reading limestone,* SMITH, A. J., Kan. Acad. Sci., Trans., vol. 19, p. 150. Smith designated as "Reading blue limestone" the prominent dense blue bed that forms the lower member of the Emporia limestone as commonly recognized. Subject only to considerations of priority, Reading is a valid stratigraphic name, but the descriptive term "blue" is to be omitted (see Stratigraphic Code, Geol. Soc. Am., Bull., vol. 44, p. 434, art. 7j, 1933). Wakarusa limestone (Beede, 1898) has priority over Reading and if we are correct in concluding that Beede's term was applied to the same unit as later called Reading, the proper designation for this limestone is Wakarusa. Application of the latter term to another unit by Condra, however, and the desirability of retaining this usage as applied to many sections in recent papers, lead us to selection of Smith's term as the next one that is available.

1915, †*Preston limestone* (part), CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 16.

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A. (See under Burlingame limestone, above.)

Type locality, in the vicinity of Reading, Lyon county, Kansas. Excellent exposures in roadcut near NW. cor. sec. 33, T. 17 S., R. 13 E., one mile west and one mile north of Reading.

The Reading limestone includes one to three beds of limestone and the shale between these beds. The formation rests on the Auburn shale and is followed by the Harveyville shale. The Reading comprises the lower part of the beds that previously have been called Emporia limestone, or in northern Oklahoma, the Stonebreaker limestone. The term Emporia has been so variously applied to strata in the middle part of the Wabaunsee group that much confusion is encountered in the literature. Condra[46] discusses the subject of nomenclature of these beds and on the grounds of usage, primarily, applies the name Emporia to beds that are here termed Reading, Harveyville and Elmont, collectively. This accords with previous practice of the Kansas Geological Survey. Since in most

46. Condra, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 59-76, 1927.

sections, but not all, the Reading and Elmont limestones are closely associated, commonly forming a single escarpment, it may appear to some that it is undesirable to abandon Emporia as a stratigraphic term. Argument can be advanced that because the Harveyville shale is thin and accordingly the Reading and Elmont are close together, these units should be assigned rank as members of the Emporia formation. This is not done because it is perfectly clear that the Reading and Elmont represent different sedimentation cycles and because other limestone formations of the Wabaunsee group are made up of the calcareous phases of single cyclothems.

The most persistent subdivision of the Reading limestone is the fusulinid-bearing member which consists of one to three or four layers of rather dark-blue, fine-grained, dense, hard limestone that show prominent vertical joints. The weathered rock is light bluish-gray mottled or blotched with light brownish or lemon-yellow areas. In places the entire thickness of the fusulinid-bearing member is colored yellowish brown. Fossil fragments tend to weather in relief. Fusulinids are abundant in this part of the Reading limestone occurring with or without other types of invertebrates. Locally, the fusulinids are somewhat rare. A limestone bed containing numerous pelecypods and some brachiopods occurs in some outcrops below the fusulinid-bearing limestone. This represents phase No. .3 of the typical Wabaunsee cyclothem and it is the lowermost member of the Reading. Phase No. .7 of the cyclothem is represented in many exposures of the Reading limestone, especially in the southern part of Kansas. In some cases this is found in the upper part of the bed that contains fusulinids, but commonly it is a distinct bed separated by a few inches to several feet of shale from phase No. .5. The distinguishing feature of this uppermost member is the presence of *Osagia* or other algal remains accompanied in most instances by some mollusks. Fusulinids are absent. The shale beds that occur between limestones of the Reading formation are blue-gray and clayey to calcareous. In places marine fossils are found in the shales.

The thickness of the Reading limestone ranges from about 1.5 feet to 15 feet. The formation is continuous from southern Nebraska to northern Oklahoma, being represented in the latter region by the lower part of beds classed as the Stonebreaker limestone.

HARVEYVILLE SHALE, Moore, 1934

1896, †*Emporia limestone* (part), Kirk, and authors. (See under Reading limestone.)

1903, †*Olpe shale* (part), Adams. (See under Reading limestone.)

1915, †*Preston limestone* (part), Condra, G. E., and Bengston, N. A. (See under Reading limestone.)

1915, †*Nemaha formation* (part), Condra, G. E., and Bengston, N. A. (See under Burlingame limestone.)

1934, **Harveyville shale,* Moore, R. C., in stratigraphic section of Pennsylvanian and "Permian" rocks of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December. —— 1936, Moore, R. C., this paper, first formal description.

Type locality, near Harveyville, southeastern Wabaunsee county, Kansas. A good section is seen in sec. 25, T. 15 S., R. 13 E.

The Harveyville shale, which is first defined in this report, includes the beds that occur between the Reading limestone, below, and the Elmont limestone, above. It includes the clastic terminal part of the Reading cyclothem and the clastic and carbonaceous initial phases of the Elmont cyclothem. The shale is mostly bluish or yellowish-brown and clayey, but locally there is sandy shale and thin, platy sandstone. A coal bed occurs locally above the sandstone. Pelecypods and some other invertebrates are found between the coal horizon and the base of the Elmont limestone.

The thickness of the Harveyville shale ranges from less than a foot in a few places to an observed maximum of about 25 feet. The shale is identified at many places from Nebraska to Oklahoma and is undoubtedly continuous across Kansas.

ELMONT LIMESTONE, Beede, 1898

1896, †*Emporia limestone* (part), Kirk, M. Z., and authors. (See under Reading limestone.)

1898, **Elmont limestone,* Beede, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 30. A limestone "very fossiliferous, 1 to 2 feet in thickness . . . found on the tops of the hills near Elmont." According to Beede's section this limestone occurs between the Auburn shale below and the Willard shale above. It appears from study of the type sections that the Elmont is equivalent to "upper Emporia" of authors and that the Wakarusa limestone as originally used corresponds to the "lower Emporia."

1903, †*Olpe shale* (part), Adams, G. I. (See under Reading limestone.)

1915, †*Preston limestone* (part), Condra, G. E., and Bengston, N. A. (See under Reading limestone.)

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A: (See under Burlingame limestone.)

Type locality, Elmont, northern Shawnee county, Kansas.

The Elmont limestone comprises the upper part of the Emporia limestone as previously recognized by the Kansas Geological Survey. It lies between the Harveyville shale, just described, and the Willard shale. Exposures in the vicinity of Elmont show a strong development of phase No. .7 of the Elmont cyclothem but the fusulinid-bearing phase (No. .5) is poorly developed or absent. Elsewhere, especially in southern Kansas, the fusulinid limestone is prominent. It is a dense, hard, dark-blue rock, very much like the Reading limestone, but it commonly bears much more closely spaced vertical joints and it is typically a single massive bed that weathers light bluish. In southern Shawnee county the lowest member of the Elmont is a dense, very fine-grained unfossiliferous blue limestone that contains round pebbles of limestone slightly different in color and texture from the matrix. Elsewhere a limestone with mollusks and some brachiopods occurs in this position, or else there is no representative of phase No. .3 of the cyclothem. East of St. George, Pottawatomie county, the No. .3 and No. .5 phases of the Elmont cyclothem are joined to form a massive bed 2 to 4 feet thick that is locally strongly conglomeratic at the base. The upper member of the Elmont, representing phase No. .7, is a blue, fine-grained, fossiliferous or unfossiliferous limestone that ranges in thickness from less than an inch to 6 or 8 feet. Algal remains and mollusks are found commonly. A few miles north of Topeka this phase is represented by about 8 feet of light bluish-gray coquinoid limestone that is massive or shows fairly distinct cross-bedding. This thick development of the No. .7 phase of the cycle is very local.

The thickness of the Elmont limestone ranges from about 1 to 15 feet. The formation is traced from Nebraska across Kansas to northern Oklahoma where it has previously been included as the upper part of the Stonebreaker limestone.

WILLARD SHALE, Beede, 1898

1898, **Willard shale,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 31. This name is applied to the shale, about 55 feet thick, between the Elmont [upper Emporia of authors] and the "Chocolate" [Tarkio] limestones. —— 1902, BEEDE, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 176. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 69. Shale between Emporia and Tarkio limestones.

1903, †*Olpe shale* (part), ADAMS, G. I., U. S. Geol. Survey, Bull, 211, p. 52. This unit was defined to include beds between the †Barclay [Burlingame and ?Wakarusa] and "Emporia" limestone, the latter being the "Emporia system" of A. J. Smith (Kan. Acad. Sci., Trans., vol. 19, p. 150, 1905) which includes Maple Hill to Grandhaven of present classification. The "Emporia" of Adams and Smith thus belongs 60 feet or more above the Emporia as generally defined.

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J., Kan. Univ. Geol. Survey, vol. 9, p. 114. Erroneously place the Willard shale below the Emporia limestone and class beds between the Emporia and Americus limestones as Admire shale. —— 1917, MOORE, R. C., AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 106. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull. 6, pt. 2, p. 48. Same.

1908, Not *Willard shale,* HAWORTH, E., AND BENNETT, J., Survey, vol. 9, p. 113. See Auburn shale. Kan. Univ. Geol. —— 1917, MOORE, R. C. AND HAYNES, W. P., Kan. Geol. Survey, Bull. 3, p. 106. Same. —— 1920, MOORE, R. C., Kan. Geol. Survey, Bull 6, pt. 2, p. 48. Same.

1915, †*Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A. (See under Burlingame limestone.)

Type locality, Willard, western Shawnee county, Kansas.

The Willard shale is defined to include the beds lying between the top of the Elmont limestone, below, and the base of the Tarkio limestone, above. South of the point in Lyon county where the Tarkio limestone disappears, the Willard is overlain by the Pierson Point shale and the combined shale unit is designated as the Willard-Pierson Point shale. South of Emporia the Maple Hill limestone likewise disappears, so that there is a continuous shale and sandstone section from the base of the Willard to the top of the Table Creek shale. This combination of shales that are distinct in the north is called Willard-Table Creek shale in southern Kansas.

The Willard shale includes the upper part of the Elmont cyclothem and the lower part of the Tarkio cyclothem. The boundary between these cyclothems is marked in some sections by the contact between clayey or sandy shale in the lower part of the Willard and massive light-tan sandstone in the upper part. The sandstone is prominent at many places in northern Kansas and southern Nebraska but it thins and disappears toward the south. This is a departure from the general rule that sandy deposits become more prominent southward and that clastic units are thicker in the south than in the north. It is worthy of note that the thickness of the Willard-Table Creek shale in southern Kansas, about five feet, is only one fourth as thick as the Willard shale in parts of northern Kansas and less than one sixth the combined thickness of Willard, Tarkio, Pierson Point, Maple Hill and Table Creek in northern Kansas. The color of the Willard shale is mostly dark bluish and brown. Fossils are not common.

The thickness of the Willard shale ranges from about 30 to 60 feet in northern Kansas and southern Nebraska, maximum thickness being observed near Kansas river.

TARKIO LIMESTONE (Calvin, 1900), Condra and Bengston, 1915

1867, †*Chocolate limestone,* SWALLOW, G. C., Am. Ass'n Adv. Sci., Proc., vol. 15, p. 67. Applied name to "coarse, rough, porous gray and chocolate limestone, full of a very large, ventricose *Fusulina*" on Mill Creek, eastern Wabaunsee county and eastward. This is clearly the rock now called Tarkio limestone. The term "Chocolate limestone" is not available because it is not derived from a geographic name. —— 1868, SWALLOW, G. C., Kan. Geol. Survey, Prelim. Rept., p. 19. —— 1898, BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 27.

1900, Not *Tarkio limestone,* CALVIN, S., Iowa Geol. Survey, vol. 11, p. 397. Applied name to rocks on Tarkio Creek, north of Coin, Page county, Iowa. G. E. Condra, who has studied carefully the type exposures of the Tarkio concludes (1934) that the strata named Tarkio by Calvin are unquestionably equivalent to beds that have been called Emporia in Kansas.

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J. (See under Willard shale.)

1915, Not *Tarkio limestone,* HINDS, H., AND GREENE, F. C., Mo. Bur. Geol. and Mines, (2), vol. 13, p. 34. Erroneously designate the Burlingame limestone by this name.

1915, **Tarkio limestone,* CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 8. Apply this name to the topmost limestone of the "Nemaha formation." The next lower limestone is the †Preston [Reading-Elmont]. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 61-73, 79. Further defines and describes relations of limestone now called Tarkio. —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Shows Tarkio limestone as now generally defined, between Willard and Pierson Point shales. Classed as a member of the "Nemaha limestone," although Moore was not consulted and has never accepted use of this term.

1915, *Nemaha formation* (part), CONDRA, G. E., AND BENGSTON, N. A. (See under Burlingame limestone.)

Type locality. Since it appears that usage of the past 20 years has led to designation by the name Tarkio of a limestone that is not recognized at the locality on Tarkio Creek, north of Coin, Iowa, and since it is desirable to continue to use Tarkio in its currently understood sense, the exposures of the Tarkio on Mill Creek, southwest of Maplehill, Kansas, which were noted by Swallow in 1867 under the designation of "Chocolate limestone," may appropriately be chosen as a new "type locality." This procedure may at first seem anomalous, but it is theoretically and practically in accord with principles of good stratigraphy.

The Tarkio limestone is a distinctive formation that occurs next above the Willard shale and beneath the Pierson Point shale. As indicated by the name used by Swallow in 1867, "Chocolate limestone," the rock typically weathers to a very strong brown color, which, however, is somewhat more yellow in hue than chocolate. The limestone is moderately hard and in most outcrops appears as a single massive bed. It breaks down in irregularly shaped shelly slabs. Except locally the thickness and resistance of the formation are sufficient to produce a well defined escarpment. Aside from lithologic features, the most prominent character of the Tarkio liemestone is the presence almost everywhere of extremely abundant large ventricose fusulinids (*Triticites ventricosus*) which weather in relief, and because of their nearly white color, appear in strong contrast to the brown matrix. This feature is so striking and so unlike most other limestones in this part of the section that it is possible to identify exposures of Tarkio very easily. Some outcrops of this limestone show a gray color and these resemble in appearance certain exposures of the Dover limestone which also contains abundant large fusulinids. Observation of stratigraphic position establishes the identity of the formation in cases where there is any possible question on basis of other characters. Above the fusulinid-bearing limestone there is present in some outcrops a few inches to 4 or 5 feet of algal limestone that lacks fusulinids but contains mollusks and some brachiopods. This represents phase No. .7 of the cyclothem. It is not a persistent unit. Mollusk-bearing beds without fusulinids, corresponding to phase No. .3 of the cyclothem, are also seen locally at the base of the Tarkio.

The Tarkio limestone ranges in thickness from less than a foot in a few places to a maximum of about 10 feet, as seen in the vicinity of Maplehill in eastern Wabaunsee county, Kansas. The formation is traced from Nebraska southward to northern Lyon county, Kansas, but no outcrops identifiable as Tarkio have been found farther south.

Throughout the region in which it is developed, the Tarkio limestone is a very valuable horizon marker that is not easily confused with any other stratigraphic unit. Nevertheless, there has been confusion in the literature concerning it. Hinds and Greene (1915) called the Burlingame limestone of northwestern Missouri Tarkio. Condra and Bengston (1915) identified the beds now called Tarkio in Nebraska and Kansas with Calvin's Tarkio limestone in Iowa and thus extended use of the term into these states. It appears that the limestone of Nebraska and Kansas called Tarkio by Condra and Bengston and subsequently by Condra and various others had not previously been differentiated by any name, although it was miscorrelated by some geologists with other units. The latest conclusions of Condra, based on restudy of the Iowa type exposures and additional knowledge concerning Nebraska formations, are that the Tarkio limestone of Calvin is not the same as that of Condra and Bengston and of later authors. The type Tarkio is believed to be equivalent to beds here called Reading and Elmont, or at least to part of these units that were formerly grouped under the name Emporia limestone. It seems obviously unwise in this case to attempt to rearrange nomenclature on the basis of priority alone, especially since the Tarkio type locality as indicated by Calvin appears ill suited to characterization either of the Reading or Elmont limestones, which on grounds of cyclic development are to be recognized separately. Also, usage has firmly established application of Tarkio to the distinctive limestone with large fusulinids that occurs next above the Elmont limestone, and if this usage should not be continued the limestone above the Elmont would have no name. We follow the principle of usage in accepting Tarkio for the limestone designated by Condra and Bengston, and because this limestone is not recorded on Tarkio Creek, in Iowa, it seems desirable to indicate an alternative locality where the bed now called Tarkio is typically shown. This is on Mill Creek, southwest of Maplehill, Kan.

PIERSON POINT SHALE, Condra, 1927

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 80. Includes beds from top of Tarkio to base of Brownville.

1927, **Pierson Point shale,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 80. Includes beds between the Tarkio and Maple Hill limestones. Classed as a subdivision of the McKissick Grove shale member of the Wabaunsee formation. —— 1932, MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., classification chart.

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Corresponds to McKissick Grove shale as defined above. This classification and nomenclature has never been accepted by Moore, however.

Type locality, Pierson Point, on Missouri river a few miles southeast of Falls City, Neb.

The Pierson Point shale comprises beds lying between the Tarkio and Maple Hill limestones. It consists of bluish clay shale and yellowish-brown sandy, micaceous shale, the total thickness ranging from about 6 to 25 feet. Locally in the north the upper portion is nearly black. A persistent zone of shaly to thin-bedded tan or buff sandstone, 1 to 4 feet thick, appears in the upper middle part of the Pierson Point shale in Kansas. The sandstone marks the initial phase of the Maple Hill cyclothem. Above the sandstone, near the top of the shale, is a coal bed that in places attains a thickness of nearly a foot. It is observed at most outcrops between the Kansas and Cottonwood rivers in Kansas. Marine fossils, consisting of pelecypods, brachiopods and bryozoans chiefly, occur above the coal but other parts of the Pierson Point shale are mostly unfossiliferous. Some of the historically famous Nebraska City fossils, described in early writings by Geinitz and by Meek, come from the Pierson Point shale.

The Pierson Point shale is traced some distance northward from its type locality in Nebraska and extends continuously southward to Lyon county, Kansas. South of the point where the Tarkio limestone disappears the Pierson Point rests directly on the Willard shale and because it is not practicable to separate these contiguous, lithologically similar units, the shale between the Elmont and Maple Hill limestones, about 90 feet thick near Emporia, is termed Willard-Pierson Point shale. South of Emporia where the Maple

Hill limestone also disappears there is a continuous shale section from the Elmont limestone to the Dover limestone. This shale may be called Willard-Table Creek shale. It contains some sandstone beds, one of which is probably a continuation of the sandy zone in the Pierson Point shale, but it is not possible to differentiate the Pierson Point shale. The coal bed of the upper Pierson Point has not been observed south of northern Lyon county.

MAPLE HILL LIMESTONE, Condra, 1927

1903, †*Emporia limestone* (part, ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 52. Includes beds identified as equivalent to Maple Hill to Grandhaven, inclusive, in present classification.

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 80. Includes beds from top of Tarkio to base of Brownville.

1927, **Maple Hill limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 80. Classed as subdivision of the McKissick Grove shale. —— 1932, MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., Classification chart.

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

Type locality, on Mill Creek, south of Maplehill, eastern Wabaunsee county, Kansas.

The Maple Hill limestone consists in most places of a single bed of bluish-gray, somewhat sandy limestone, 1 to 4 feet thick. It is fairly hard and commonly forms a bench a little above the escarpment of the Tarkio limestone. The rock is intersected by two or more systems of rather widely spaced vertical joints and in some places there are large rectangular or rhomb-shaped blocks along the outcrop. The joints are locally much enlarged by solution. On weathering the Maple Hill limestone commonly appears reddish-brown but in some places it is rather a brownish-gray. Fossils are rare in some outcrops of the Maple Hill, but in others they are abundant. Small slender fusulinids are very common in the southern part of the outcrop area but not in the north. Crinoid stem fragments, several kinds of brachiopods and bryozoans and a few pelecypods and gastropods may be found at most exposures of this limestone.

The Maple Hill limestone extends from Emporia northward into Nebraska. Because the Pierson Point shale is much thinner, on the average, than the Table Creek shale, the outcrop of the Maple Hill is closer to that of the Tarkio than to the Dover escarpment. At Emporia, however, the Maple Hill limestone is less than 5 feet below the Dover limestone, and in Lyon county these limestones form a single escarpment. The Maple Hill bed is readily distinguished by lithologic and faunal characters from the Tarkio and Dover limestones.

TABLE CREEK SHALE, Condra, 1927

1903, †*Emporia limestone* (part), ADAMS, G. I. (See under Maple Hill limestone.)

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 80. Includes beds from top of Tarkio to base of Brownville.

1927, **Table Creek shale*, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 80. Includes beds between the Maple Hill and Dover limestones. Classed as subdivision of the McKissick Grove shale. —— 1932, MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 96.

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

Type locality, Table Creek at Nebraska City, Neb.

The Table Creek shale includes the strata that occur between the Maple Hill and Dover limestones. The shale is largely bluish-gray in color, and clayey to sandy in character. In many places the upper part of the Table Creek consists of tan or buff sandstone which is shaly, platy or fairly massive. This sandstone is the basal phase of the Dover cyclothem. The underlying shale contains marine fossils in many places and represents the terminal part of the Maple Hill cyclothem. This horizon furnished part of the famous Nebraska City fossil collections described by Geinitz in 1866 and by Meek in 1872. The fauna is by no means so varied or the specimens so abundant as in many other Pennsylvanian formations of Nebraska and Kansas. Near the top of the Table Creek shale is a widely persistent thin coal bed that is locally worked in Missouri and Iowa. It is known as the Nyman coal. The coal extends almost uninterruptedly across southeastern Nebraska and northern Kansas and is recognized locally in southern Kansas.

The Table Creek shale ranges in thickness from about 25 feet in southern Nebraska to 50 feet or more in Wabaunsee county, Kansas. Southward from this region the thickness gradually diminishes until at Emporia less than 5 feet of shale separates the Maple Hill and Dover limestones. South of Emporia the Table Creek is not separable from underlying shale that represents the Pierson Point and Willard shales of areas to the north. This combined shale section which is about 100 feet thick near Emporia thins southward to about 15 feet in parts of Chautauqua county, Kansas.

DOVER LIMESTONE, Beede, 1898

1898, **Dover limestone,* BEEDE, J. W., Kan. Acad. Sci., Trans., vol. 15, p. 31. Name applied to limestone about 4 feet thick near Dover, Shawnee county, Kansas, and to southwest. Occurs between "Dover shale and sandstone," about 85 feet thick, below, and "Rossville shale and sandstone," above. —— 1902, BEEDE, J. W., Kan. Univ. Sci. Bull., vol. 1, p. 177. Same. Occurs about 85 feet above the "Chocolate [Tarkio] limestone." —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 80. Classes as subdivision of †McKissick Grove shale. —— 1932, MOORE, R. C., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 94.

1903, †*Emporia limestone* (part), ADAMS, G. I. (See under Maple Hill limestone.)

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 80. Includes beds between top of Tarkio and base of Brownville.

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

Type locality, in vicinity of Dover, Shawnee county, Kansas.

The Dover limestone is an important although thin formation that is traced from Oklahoma across Kansas and southern Nebraska into Iowa. As observed at the type locality, a few miles southwest of Topeka, and at many other places in northern Kansas and Nebraska, the Dover most closely resembles the Tarkio limestone, perhaps mainly because both of these units contain an abundance of very large fusulinids. Very unlike the rich-brown color of the weathered Tarkio, however, the weathered Dover limestone is light-gray, and it is generally much softer than the Tarkio. Numerous large *Cryptozoon* growths, which are rare or absent in the Tarkio, are seen in most outcrops of the Dover. In much of northern Kansas only the fusulinid-bearing limestone is present, but south of Kansas River algal bed with abundant *Osagia,* and in places what appear to be other types of algal growths, occurs above the fusulinid bed. Extending southward from Greenwood county there is a dense, fine-grained blue limestone carrying a mixed fauna of mollusks, brachiopods and bryozoans, that appears a few feet below the fusulinid-bearing bed. This represents phase No. .3 of the Dover cyclothem, the fusulinid bed being phase No. .5 and the algal bed phase No. .7. The blue bed becomes thicker and harder southward, while the phase No. .5 bed decreases in thickness and the fusulinids disappear, although *Cryptozoon* growths are still abundant. The algal bed is very persistent and prominent in the southern area. The changes in the composition of the Dover limestone along the outcrop have been determined by detailed field work that includes mapping and the careful study of many sections.

The Dover limestone is about 2 to 4 feet thick in northern Kansas and Nebraska, but where the three limestone members are present in southern Kansas the formation is about 15 to 20 feet thick.

DRY SHALE, Moore, 1934

1903, †*Emporia limestone* (part), ADAMS, G. I. (See under Maple Hill limestone.)

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Willard shale.)

1934, **Dry shale*, MOORE, R. C., in stratigraphic section of Pennsylvanian and "Permian" rocks of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December. ———, 1936, MOORE, R. C., this paper. Defined to include beds between the Dover limestone, below, and the Grandhaven limestone, above.

Type locality, Dry Creek, southwest of Emporia, Kan., in sec. 5, T. 20 S., R. 11 E.

The term Dry shale is here applied to shaly beds, 5 to 20 feet or more thick, that separate the Dover limestone from the next higher limestone, which is called Grandhaven. The shale is bluish-gray and clayey for the most part, but sandy beds appear in places. A thin coal bed occurs near the top of the Dry shale in southern Kansas, the coal and sandy beds belonging to the Grandhaven cyclothem. The shale between the top of the coal and the base of the Grandhaven limestone is locally rich in marine fossils, calcareous brachiopods and bryozoans being dominant.

The Dry shale is a well defined stratigraphic unit from Shawnee county, Kansas, southward to the Oklahoma line, but northward it coalesces with the Friedrich shale above the Grandhaven limestone, for the Grandhaven disappears. It is possible—indeed, there is some explicit indication—that the Grandhaven beds grade laterally northward into shale, but it is not practicable to subdivide the shale section between the Dover and Jim Creek limestones. This may be designated, accordingly, as the Dry-Friedrich shale.

GRANDHAVEN LIMESTONE, Moore, 1935

1903, †*Emporia limestone* (part), ADAMS, G. I. (See under Maple Hill limestone.)

1908, *Admire shale* (part), HAWORTH, E., AND BENNETT, J. (For references see under Willard shale.)

1934, **Grandhaven limestone,* MOORE, R. C., in stratigraphic section of Pennsylvanian and "Permian" rocks of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December. ——— 1936, MOORE, R. C., this paper. Name applied to limestone between the Dover limestone, below, and the Jim Creek limestone, above.

Type locality, sec. 31, T. 13 S., R. 14 E., near Grandhaven, Shawnee county, Kansas.

The Grandhaven limestone overlies the Dry shale and underlies the Friedrich shale. It comprises the only persistent limestone beds that occur between the rather easily recognized Dover limestone, below, and the Jim Creek limestone, above. There are commonly two limestone members which are separated by a few feet of shale. The lower limestone is gray to bluish in color, and unlike the Dover, commonly weathers brown,—in some cases a strong reddish-brown. It contains numerous fusulinids and some other invertebrates in some exposures, but elsewhere fusulinids are sparse or absent. Toward the south this limestone is thinner and finer grained, weathers shelly, and in many ways resembles outcrops of the Maple Hill limestone. There are numerous brachiopods, but few or no fusulinids. The changes in faunal character along the strike of this member are similar to those observed in the No. 5 phase of the Dover limestone, in which northern outcrops show abundant fusulinids and *Cryptozoon,* but southern outcrops lack the fusulinids and retain numerous *Cryptozoon* remains. The upper limestone member of the Grandhaven formation is characterized by an abundance of algal deposits, mostly of the *Osagia* type. This bed so closely resembles some outcrops of the upper member of the Dover that it is easy to mistake one for the other unless attention is given to stratigraphic sequence. The algal bed of the Grandhaven limestone is very light-gray, weathering almost white, and in some exposures the prominent rounded algal growths give the rock a resemblance to conglomerate. The shale between the two limestones is mostly bluish-gray, and clayey to calcareous. Locally, as along the south side of Cottonwood River near Emporia, the upper Grandhaven is strongly cross-bedded and it contains an abundant brachiopod and bryozoan fauna, in which are included also some molluscans.

The thickness of the Grandhaven limestone averages about 10 feet. The lower limestone is 2 to 5 feet in the north, but only 0.5 foot in the south. The upper limestone is 1 to 2 feet thick in most places, but locally attains a thickness of 8 feet or more. The intermediate shale is 4 to 10 feet thick. The Grandhaven limestone is recognized from Shawnee county southward to Oklahoma, but is not seen north of Kansas river. The formation clearly belongs to a cycle of sedimentation distinct from that of the Dover limestone.

FRIEDRICH SHALE, Moore, 1934

1903, *Admire shale* (part), ADAMS, G. I., U. S. Geol. Survey, Bull. 211, p. 52. Includes beds between Grandhaven and Americus limestones of present classification. (For additional references see under Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 81.

1927, *Pony Creek shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), p. 80. Includes beds between top of Dover limestone and base of Brownville limestone.

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

1932, †*Frenck shale* (part), MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., classification chart. This term, derived from erroneous spelling of French Creek on maps, was applied to beds between the Dover limestone, below, and the Jim Creek [Nebraska City] limestone above. The Grandhaven limestone is not recognized north of Kansas river.

1934, **Friedrich shale,* MOORE, R. C., in stratigraphic section of Pennsylvanian and "Permain" rocks of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December. ———, 1936, MOORE, R. C., this paper. Defined to include beds between the Grandhaven limestone, below, and the Jim Creek limestone, above.

Type locality, Friedrich Creek, sec. 6, T. 22 S., R. 11 E., Greenwood county, Kansas.

The term Friedrich shale is here proposed to include clayey and sandy beds that lie between the Grandhaven and Jim Creek limestones. The unweathered shale is chiefly bluish-gray, but outcrops of weathered shale commonly appear yellowish or brownish. Locally there is sandstone in the upper part of this zone and at least in southern Greenwood county a thin coal bed appears a little below the Jim Creek limestone. *Myalina* and other pelecypods, and some brachiopods, bryozoans and other marine fossils appear near the top of the Friedrich shale, but in some outcrops fossils are rare or absent.

The thickness of the Friedrich shale averages about 15 feet. The unit is clearly identifiable throughout the region in which the Grandhaven limestone is developed, that is from Shawnee county, Kansas, southward, but farther north where the Grandhaven is not seen, the shale lying between the Dover and Jim Creek limestones may be called Dry-Friedrich shale.

JIM CREEK LIMESTONE, Moore, 1934

1903, *Admire shale* (part), ADAMS, G. I. (See under Friedrich shale and Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 81.

1927, *Pony Creek shale* (part), CONDRA, G. E. (See under Friedrich shale.)

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

1932, Not *Jim Creek limestone,* MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., classification chart. The name Jim Creek was erroneously applied to limestone north of Kansas river now recognized as equivalent to the Nebraska City limestone, which is here classed as lowermost member of the Caneyville limestone.

1932, †*Frenck shale* (part), MOORE, R. C., AND CONDRA, G. E., Kan. Soc., Guidebook, Sixth Ann. Field Conf., classification chart. The Jim Creek limestone, as now recognized, occurs in the middle part of the so-called Frenck shale of this reference.

1934, **Jim Creek limestone,* MOORE, R. C., in stratigraphic section of Pennsylvanian and "Permian" rocks of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December.
——— 1936, MOORE, R. C., this paper. Name applied to persistent limestone lying between Grandhaven or Dover limestone, below, and Caneyville limestone, above.

Type locality, on Jim Creek, sec. 29, T. 7 S., R. 11 E., Pottawatomie county, Kansas.

A thin but surprisingly persistent limestone that in many places carries slender fusulinids is here designated as the Jim Creek limestone, from a locality in Pottawatomie county, Kansas. The limestone is known to extend into Oklahoma and Nebraska, but nowhere is the observed thickness greater than 2 feet. The Jim Creek is a useful horizon marker and it belongs to a sedimentation cycle that is distinct from those containing the adjacent Grandhaven and Caneyville limestones. Hence it is desirable in spite of the thinness of the unit to differentiate it as an indepedent formation. The Jim

Creek limestone is fine-grained, hard and bluish-gray or bluish in fresh exposure. The weathered rock is commonly brown and gray and in most cases there are reddish or purplish tones. The bed appears as a single massive layer that is vertically jointed, but on prolonged weathering there is a tendency for the rock to break down in small shelly chips. A large variety of marine fossils, including especially brachiopods, bryozoans and pelecypods, is found in the Jim Creek limestone in some places.

The Jim Creek limestone has been traced from northern Oklahoma across Kansas into Nebraska.

FRENCH CREEK SHALE, Moore, 1934

1903, *Admire shale* (part), ADAMS, G. I. (See under Friedrich shale and Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 81.

1927, *Pony Creek shale* (part), CONDRA, G. E. (See under Friedrich shale.)

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

1932, †*Frenck shale* (part), MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., classification chart. The French Creek shale comprises the upper part of what was termed Frenck shale in this paper.

1934, **French Creek shale*, MOORE, R. C., in stratigraphic section of Pennsylvanian and "Permian" rocks of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December. ———, 1936, MOORE, R. C., this paper. Defined to include beds between the Jim Creek limestone, below, and the Caneyville limestone, above.

Type locality, French Creek, northeastern Pottawatomie county, Kansas.

The French Creek shale comprises the beds between the Jim Creek and Caneyville limestones. It is bluish-gray or yellowish-brown in color, and clayey to sandy in texture. The upper part commonly contains some light brownish or tan sandstone which may be fairly hard, thick and massive. There is much variation in this shale from place to place, but it is clear that the lower part represents the terminal part of the Jim Creek cyclothem and that the upper part, including the sandstone beds, belongs to the Caneyville cyclothem. Near the top of the French Creek shale is a thin but very persistent coal bed that has been termed by Condra the Lorton coal. This coal crops out at many places from Oklahoma to Nebraska and is one of the most widespread of the known Late Paleozoic coal beds of the northern Mid-Continent region. Above the coal and beneath the Nebraska City limestone member of the Caneyville formation there is dark-colored shale with an abundant marine fauna characterized especially by large *Myalina* shells, *Derbya* and some other forms.

The thickness of the French Creek shale averages about 30 feet. The formation is recognized across all of Kansas.

CANEYVILLE LIMESTONE, Moore, 1934

1903, *Admire shale* (part), ADAMS, G. I. (See under Friedrich shale and Willard shale.)

1918, *Grayhorse limestone,* BOWEN, C. F., U. S. Geol. Survey, Bull. 686, p. 138. This limestone is included in the present Caneyville limestone, comprising its uppermost member.

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 81.

1927, *Pony Creek shale* (part), CONDRA, G. E. (See under Friedrich shale.)

1927, *Nebraska City limestone,* CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 116. This limestone, classed by Condra as a subdivision of the Pony Creek shale, is here defined as the basal member of the Caneyville limestone.

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

1932, *Jim Creek limestone,* MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., classification chart. The so-called Jim Creek limestone of this reference is equivalent to the Nebraska City member of the Caneyville limestone.

1934, **Caneyville limestone,* MOORE, R. C., in stratigraphic section of Pennsylvanian and "Permian" rocks of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December. ———, 1936, MOORE, R. C., this paper. Defined to include beds from the base of the Nebraska City limestone to the top of the Grayhorse limestone.

Type locality, sec. 11, T. 32 S., R. 8 E. Named from Caneyville Township, Chautauqua county, Kansas.

The term Caneyville limestone is here proposed to include beds from the base of the limestone previously designated as Nebraska City to the top of the limestone called Grayhorse. Field studies have shown that the Nebraska City limestone is a molluscan bed that represents the No. .3 phase of a cyclothem for which no fusulinid-bearing, or No. .5 phase, was known until recently, when outcrops in Chautauqua county, Kansas, of this expected phase were discovered. Above the fusulinid-bearing limestone in Chautauqua county is a fragmental, algal and molluscan limestone, that clearly represents the No. .7 phase of this cyclothem. It is traced southward into the Grayhorse limestone of Osage county, Oklahoma, and it is thus determined that the Nebraska City and Grayhorse limestones are parts of a single cyclothem which includes the unnamed fusulinid-bearing limestone between them in southern Kansas. Neither Nebraska City nor Grayhorse is available as a name for the three limestones and the shales included between them. Hence, the new term Caneyville is introduced. No name is proposed for the fusulinid-bearing limestone member of the Caneyville, and it is thought that none is needed. If all of the persistent subdivisions of Wabaunsee formations were to be given names as members, there would be a wholly unwarranted addition of some scores of unnecessary new stratigraphic terms. Perhaps it is awkward to refer to "transgressive molluscan phase," "fusulinid phase" and "algal-molluscan phase" or to use numbers for the phases of the cyclothem, but this seems preferable to the alternative of burdening the literature with a multitude of additional stratigraphic names of doubtful value. The terms Nebraska City and Grayhorse happen to have been introduced and it is perhaps not necessary to kill them.

The Nebraska City member of the Caneyville limestone is a bluish or greenish-gray sandy limestone that weathers light-yellowish brown. It is rather soft and does not make a prominent outcrop in most places. Brachiopods, bryozoans and some mollusks are common in this bed. The stratigraphic position of the member with reference to the Jim Creek, Brownville, and other distinctive limestones in this part of the section, and the occurrence of a coal bed a few inches below the member, are the chief means of recognizing the Nebraska City limestone. This limestone ranges in thickness from less than 1 foot to about 5 feet, the average being about 1.5 feet.

The fusulinid-bearing limestones, which represents the No. .5 phase of the Caneyville cyclothem, is a bluish-gray, massive slightly arenaceous bed with vertical joints. Few fossils other than long slender specimens of *Triticites* occur. The thickness of this limestone averages about 1 foot, and the maximum observed thickness is about 1.5 feet. It occurs 5 to 10 feet above the Nebraska City limestone.

The Grayhorse member of the Caneyville limestone is very different in appearance from the other two limestone members. It is medium- to coarse-grained, appears fragmental or coquinoid, and is rather strongly ferruginous. Broken surfaces of the unweathered rock commonly show curved cleavage surfaces of iron or magnesium-bearing carbonate crystals. In some exposures the bed appears massive but commonly there is distinctly evident cross-bedding. Large specimens of *Myalina* of the *M. subquadrata* type are the most common type of fossil. The Grayhorse limestone ranges in thickness from about 0.5 to 5 or 6 feet, the average being about 1 foot. This member occurs 5 to 15 feet above the fusulinid-bearing limestones.

The average total thickness of the Caneyville limestone is 15 to 20 feet. The formation extends from northern Oklahoma across Kansas to southern Nebraska.

PONY CREEK SHALE (Condra, 1927), Moore, 1934

1903, *Admire shale* (part), ADAMS, G. I. (See under Friedrich shale and Willard shale.)

1927, †*McKissick Grove shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, pp. 74, 81.

1927, *Pony Creek shale* (part), CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 81. As defined by Condra the Pony Creek shale included the beds between the top of the Dover limestone and the base of the Brownville limestone. —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Same. Classed as a subdivision of the "McKissick shale." —— 1932, MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., classification chart. The term Pony Creek is applied in this paper to beds between the top of the "Jim Creek [Nebraska City] limestone" and base of the Brownville limestone.

1932, †*McKissick shale* (part), CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O. (See under Pierson Point shale.)

1934, **Pony Creek shale*, MOORE, R. C., in stratigraphic section of Pennsylvanian and "Permian" roads of Kansas river valley, by Moore, R. C., Elias, M. K., and Newell, N. D., Kan. Geol. Survey, issued December. ———, 1936, MOORE, R. C., this paper. Name restricted to include beds between top of Caneyville limestone and base of Brownville limestone.

Type locality, along Pony Creek between the Kansas-Nebraska boundary and 2 miles south of Falls City, Neb.

As first used, the term Pony Creek shale was applied to beds lying between the Dover limestone, below, and the Brownville limestone above. The Jim Creek and Nebraska City limestones are present in Nebraska but were regarded as rather unimportant subdivisions of the Pony Creek shale. Because of evidences of successive cyclothems that have been discovered in the Wabaunsee group, it has appeared desirable to recognize the Grandhaven, Jim Creek and

Caneyville limestones, and the shales between them as independent units of correlative rank, and the term Pony Creek is here restricted to the upper part of the original Pony Creek shale, that is, to beds lying between the Caneyville and Brownville limestones. Thus defined the Pony Creek shale comprises 5 to 20 feet of bluish and bluish-gray shale and locally some red clayey or sandy shale. The middle part locally contains some sandstone. The lower Pony Creek shale is mostly unfossiliferous, but the upper part commonly contains a variety of brachiopods and bryozoans, with *Marginifera wabashensis* and *Chonetes granulifer* among the most common species. A thin coal bed which belongs to the Brownville cyclothem appears in the upper middle part of the Pony Creek, just beneath the fossiliferous marine zone, in southern Kansas and northern Oklahoma. The Pony Creek shale extends entirely across Kansas and is well developed both in Nebraska and northern Oklahoma.

BROWNVILLE LIMESTONE, Condra and Bengston, 1915

1903, *Admire shale* (part), ADAMS, G. I. (See under Friedrich shale and Willard shale.)

1915, **Brownville limestone*, CONDRA, G. E., AND BENGSTON, N. A., Neb. Acad. Sci., Publ., vol. 9, p. 17. Name applied to limestone, 2.5 to 6 feet thick, in Missouri river bluffs, south of Brownville, and near Peru, Neb. —— 1927, CONDRA, G. E., Neb. Geol. Survey, (2), Bull. 1, p. 81. Classed as basal subdivision of the "Admire shale member" of the Wabaunsee formation. —— 1932, CONDRA, G. E., MOORE, R. C., AND DUNBAR, C. O., Neb. Geol. Survey, (2), Bull. 5, Table C, p. 18. Same as Condra, 1927. —— 1932, MOORE, R. C., AND CONDRA, G. E., Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., classification chart. Classed as a unit correlative in rank with †McKissick Grove shale and Admire shale, and lying between them.

Type locality, bluffs of Missouri river just south of Brownville, Nemaha county, Nebraska.

The Brownville limestone is a very widespread and distinctive formation that is here regarded as the uppermost stratigraphic division of the Wabaunsee group. At most places the Brownville consists of one or two beds of bluish-gray, hard limestones that weather yellowish or somewhat reddish brown. Some outcrops show rock that appears impure and sandy, but in most places the limestone is fairly pure, dense, massive and fine-grained. Commonly the Brownville limestone weathers in angular or rounded blocks or it disintegrates in irregularly shaped shelly fragments. The occurrence of abundant shells of *Marginifera wabashensis* characterizes most outcrops and in addition exposures in Kansas commonly show the presence of fairly numerous large fusulinids, the bryozoan *Meekopora,* the brachiopod *Chonetes granulifer* and crinoid stem fragments. Not infrequently these fossils occur in clusters or "nests" between which the rock contains only scattered fossils. A bed with algal and molluscan remains, classifiable as phase No. .7 of the typical cyclothems, occurs above the fusulinid-bearing (phase No. .5) bed in parts of Chautauqua county, Kansas.

The Brownville limestone was named from outcrops in southeastern Nebraska. It has been traced entirely across Kansas and is known to extend at least 50 miles southward into Oklahoma. The thickness of the formation ranges from about 2 to 8 feet.

Classification of the Pennsylvanian Rocks in Relation to the Carboniferous System

On pages 8, 13, 15 and elsewhere in this report the Pennsylvanian rocks are designated as a geologic system. This classification conforms to my long-established views inculcated by early training, and is in accord with usage employed by most American geologists of the present day. The Pennsylvanian is classed as a system in my textbook on historical geology,[1] as in the majority of other American textbooks in this field. Judgment that the Pennsylvanian rocks should be given systematic rank rests chiefly on the widespread, mostly well defined nature of the break which separates these rocks from underlying Mississippian deposits, and general distinctions in the lithologic character and fossils of these two stratigraphic divisions. Separation of the Pennsylvanian from Permian rocks is more difficult, especially in the Mid-Continent region, but because the Permian is recognized generally as a system in other parts of the world, corresponding treatment has been given commonly in this continent.

A different classification of the late Paleozoic rocks that has long been adopted by the United States Geological Survey designates all of the rocks between Devonian and Triassic as the Carboniferous system, and divides this system into three series that are named (in upward order) Mississippian, Pennsylvanian, and Permian. This usage of terms represents acceptance of the well established European name, Carboniferous, for rocks next younger than Devonian, but unlike the definitions of Carboniferous and Permian that are uniformly understood in Europe, the "Carboniferous" of this American classification is expanded to include Permian, which is reduced to subordinate rank. The evident basis for the lower rank assigned to Permian is the inconspicuous nature of the boundary between Pennsylvanian and Permian rocks in certain North American areas. Places are now known on this continent, however, where the base of Permian rocks is marked by a very important unconformity. In any case, it is very clearly undesirable to use the term Carboniferous to include Permian, both because the Permian rocks of the type region for the Carboniferous, in England, are

1. Moore, Raymond C., Historical Geology, 673 pp., McGraw-Hill, New York, 1933; see pp. 281-315, esp. p. 282.

definitely excluded in the original definition of this term,[2] and because Permian is uniformly excluded from Carboniferous in subsequent usage of Europe and other continents, excepting the classification here discussed. If Carboniferous is adopted as a systematic unit in North America, it should apply only to rocks that are equivalent to the European Carboniferous which is limited by the Devonian below and the Permian above. Since rocks of Permian age are definitely recognized on this continent and since Carboniferous is the only European systemic term of the entire geologic column that is not now commonly employed in North America as in other continents, it seems desirable to make our classification of late Paleozoic rocks conform to that of Europe. The geologic systems defined in Europe have come to be accepted as the standard divisions of the column, and the only valid basis for modification of this classification is general agreement that a different definition of certain divisions better suits European and world conditions. Probability of such agreement is exceedingly remote.

Study of almost any system reveals that no matter how clearly evident the defined boundaries may be designated type regions, there are many places where such clear definition of boundaries does not exist. The limits of a system in any given region must, therefore, be determined essentially by comparison with standard European sections, and if this were not done the so-called systematic units of different areas would surely not agree. This means that our geologic systems, established on the basis of conditions in one part of the world and to a large extent fixed by long usage, are divisions that fail ideally to fit conditions in all continents. They are inheritances which are serviceable to geologic science, but definition of boundaries of these inheritances is measurably arbitrary considering their application to the entire globe.

Examination of late Paleozoic sections in various parts of the United States indicates rather clearly that divisions of strata such as the Chester beds, Morrow beds, and the divisions described as series in this report (Des Moines, Missouri, Virgil), which are delimited by extensive unconformities below and above, are really the most significant stratigraphic elements of these sections. Each such division represents essentially uninterrupted sedimentation during a considerable length of geologic time, and it is characterized by distinguishing features of the paleontologic record as well as associated differences of lithology and structural relations. These unconform-

2. Conoybeare, W. D., and Phillips, W., Outlines of the Geology of England and Wales, pp. vii, 278, 320-364, 1822.

ity-bounded units are the essential "building blocks" of the geologic column, for they reflect the lowest order of major sea and land movements. Accordingly it seems that these divisions are properly classified as series. It is undoubtedly true that the boundaries between the Morrow and Des Moines series and between the Missouri and Virgil series are in some places very much more conspicuous than the lower or upper boundary of the Pennsylvanian rocks in some places.

Acceptance of the conclusion that divisions such as Des Moines, Missouri and Virgil are properly classed as series does not require abandonment of any grouping of these series that is convenient or useful. The rocks called Pennsylvanian, in fact, comprise such a group of series which for various reasons, including established custom, it is desirable to set apart from a lower group of series that is collectively termed Mississippian. Neither Pennsylvanian nor Mississippian is represented by subdivisions of the European Carboniferous that are equivalent in span, the Pennsylvanian corresponding to Stephanian, Westphalian and upper Namurian, and the Mississippian to lower Namurian, Viséan and Tournaisian. The Upper Carboniferous of Europe includes Stephanian, Westphalian, and Namurian. The lower Carboniferous comprises Viséan and Tournaisian.

It aapears desirable to recognize the Carboniferous system and the Permian system in North America, with definition of boundaries as in Europe. The Pensylvanian and Mississippian may be classed as subsystemic divisions of Carboniferous. The Carboniferous system is represented in Kansas by the Waverly series of the Mississippian subsystem, and by the Des Moines, Missouri and Virgil series of the Pennsylvanian subsystem. The Permian system in Kansas contains the Big Blue and Cimarron series. The boundary between the Virgil and Big Blue series seems well defined, but it is recognized that certain questions of definition of Permian depend on clarification of boundaries in Russian sections.

August 15, 1936. RAYMOND C. MOORE.

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(Abandoned or unrecognized terms in italics. Page numbers in italics indicate chief reference.)

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