KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 59-6

STRATIGRAPHY OF THE HOWARD LIMESTONE (VIRGILIAN) BETWEEN THE KANSAS RIVER AND NEOSHO RIVER VALLEYS, KANSAS

By

H. A. Mendoza

Kansas Geological Survey
1930 Constant Avenue
University of Kansas
Lawrence, KS 66047-3726

Kansas Geological Survey
Open-file Report

Disclaimer

STRATIGRAPHY OF THE HOWARD LIMESTONE (VIRGILIAN) BETWEEN THE KANSAS RIVER AND NEOSHO RIVER VALLEYS, KANSAS

by

Herbert A. Mendoza
B. S., University of Illinois, 1957

Submitted to the Department of Geology and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of Master of Science.

Instructor in Charge

May, 1959

For the Department

TABLE OF CONTENTS

Page

Page

Page

LIST OF ILLUSTRATIONS

Page

Page

Page

LIST OF TABLES

Table

ABSTRACT

The Howard Limestone is a formation in the lower Wabaunsee Group of the upper Pennsylvanian rocks of Kansas. In the northern area it comprises two limestones and two shales, whereas, in the southern area three limestones and two shales are distinguishable, with a less persistent thin limestone also present. A black platy shale, and a coal Nodaway) were found with persistence throughout the area in the Aarde shale member, and a persistent fusulinid-bearing limestone in the Utopia limestone member.

The Howard Limestone beds are extremely fossiliferous, especially the lower Utopia limestone; algae and arenaceous foraminifers being the most persistent elements of the biota.

Analysis of field and laboratory data obtained from the Howard Limestone beds formed the basis for the determination of the environments of deposition and nature of the cyclic units. Concluding that the Howard sedimentary cycle resembles more the Shawnee Group megacyclothems than the Wabaunsee Group simple cyclothems. The Howard Megacyclothem is assigned the letter "W", comprising from the base of the Severy Shale to the channel sandstone in the White Cloud shale. This megacyclothem comprises five incomplete cyclothems designated with the roman numerals I, II, III, IV, and V. The Howard Limestone beds were presumably deposited chiefly in shallow marine environment, of trangressive and regressive seas.

INTRODUCTION

Purpose of Investigation

The purpose of this report is to study the stratigraphy and cyclic sedimentation of the Howard Limestone, and adjacent beds of Upper Pennsylvanian age in Kansas. Such a report involves the detailed study of the lithology and paleontology of these units. It has been reported that certain features of the Howard strata suggest transition in characteristics of sedimentation between megacyclothems of the Shawnee Group and more simple cyclothems of the Wabaunsee Group, in which no grouping of minor cycles into megacyclothems seem evident. An attempt is made to analyze and interpret any features of deposition in order to determine evidences of cyclic sedimentation.

Location of Area

The Howard Limestone crops out in the states of Iowa, Nebraska, Kansas, and Oklahoma. This report includes the study of exposures between Kansas River and Neosho River valleys in Kansas (Shawnee, Osage, northeastern Coffey, and eastern Lyon Counties). The elevation of the Howard outcrop belt is approximately 950 feet in the northern area, whereas, in the southern area is about 1,000 feet. Figure 1 is an index map showing location of the Howard sections that were measured and studied.

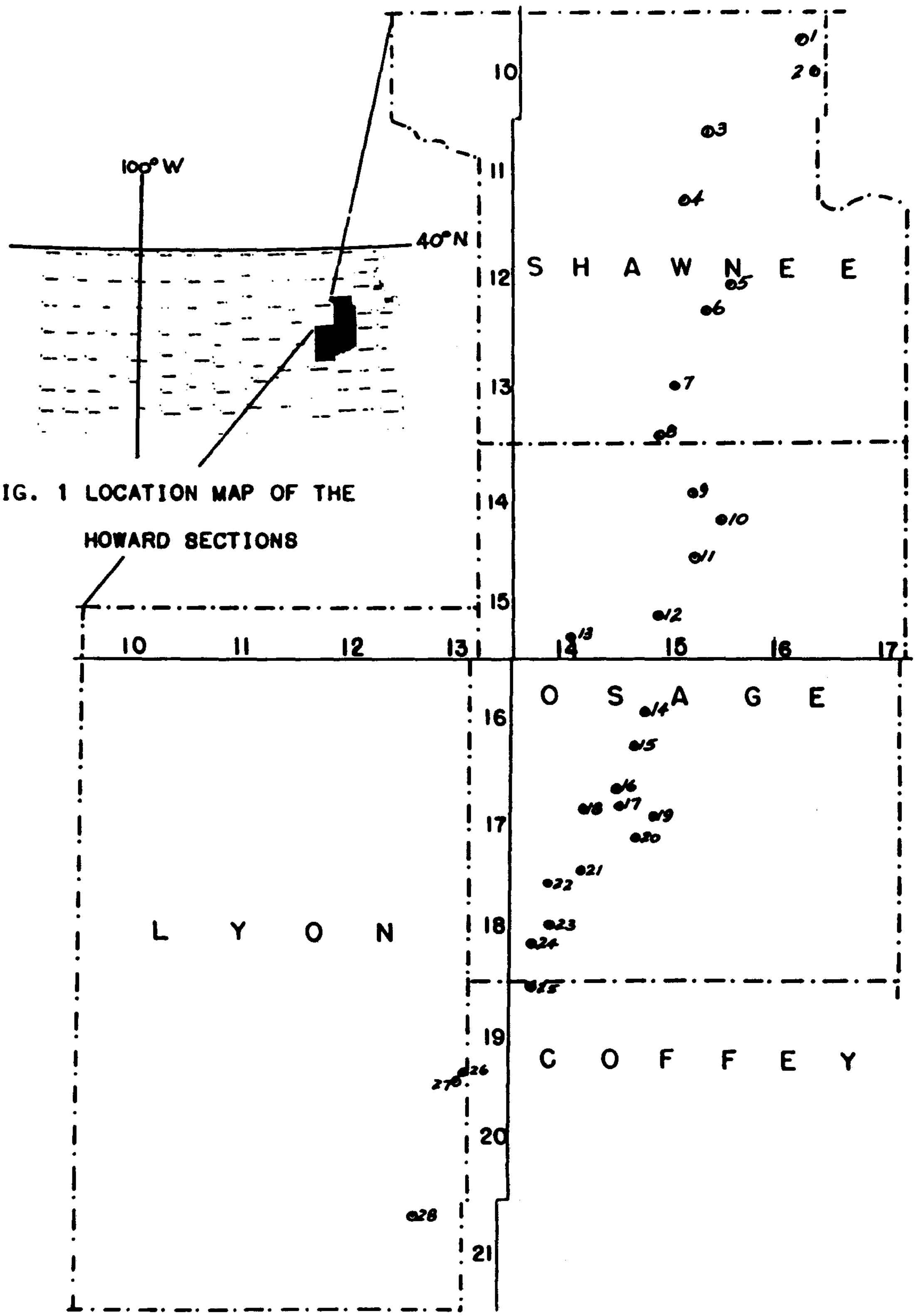


FIG. 1 LOCATION MAP OF THE HOWARD SECTIONS

Previous Work

The Howard Limestone was not known as such in the early days of geologic exploration in eastern Kansas. The first report published on the Carboniferous rocks of Kansas was by Swallow and Hawn (1858). A few years later Swallow (1866, p. 21) while reporting on the Upper Coal Measures of eastern Kansas, gave the first account of the Howard Limestone. He referred to this limestone as bed "No. 162"; his description follows: "Spring Rock; is a hard blueish-gray and brown limestone, 2 feet 8 inches to 4 feet. Locality, Beaver Creek, Marais des Cygnes, and Johnson's coal-bed, west of Topeka, and Lecompton." This name was later invalidated by Adams (1898, pp. 65-67) because it is not a geographic name. Swallow was confused in regard to the Howard Limestone and other beds that are lower in the section. The name Spring Rock was later used by Beede (1898, p. 30), describing the Howard as "Here we have two strata of limestone separated by a layer of shale. Of these the lower is the more important, the upper being as a rule very thin and somewhat argillaceous."

Hall (1896, p. 104) redefined the unit as Osage City limestone (shales, coal, and limestone). This name later was used to include only the Severy Shale, Beede (1902, p. 172).

The first person to publish on rocks to which the name Howard was applied was Haworth (1898, p. 67) from geologic field work done in Chautauqua, Elk, and Greenwood Counties by George I. Adams, who gave the following description, "Above the Severy Shales is a thin limestone, persistent from near Eureka to the south line of the state, but which nowhere is more than 3 to 6 or 8 feet in thickness..." The name as taken from outcrops near the town of Howard, Elk County, Kansas. The Howard Limestone was then regarded as being part of the "Remaining Formations" above the "Lecompton Shales".

The same year Gallaher (1898, p. 54) while working for the Geological Survey of Missouri, redefined what had been called Howard as Quitman limestone. The Kansas name, however, was readopted as the term Quitman was preoccupied for Cretaceous rocks of Texas.

Beede (1902, p. 171) included the Howard as a member of the Shawnee Formation, and enumerated the numerous fossils found near Carbondale in the two limestone beds of this member. The following year Adams (1903, p. 50) made a similar study and description of the Howard fauna, adding "This limestone is of interest since it indicates the general line of outcrop of the Osage coal."

A few years later Haworth and Benett (1908, p. 111) described the thickness and areal extent of the Howard Limestone as being "...from 2 to 7 feet thick, and in places form two beds separated by 1 or 2 feet of shale (forming an) ... escarpment somewhat persistent from Valley Falls, in

Jefferson County, to the south end of the state." Hinds and Greene (1915, p. 33) retained the member rank that previous workers had applied to the Howard Limestone.

Moore and Haynes (1917, p. 105) and Moore (1920, p. 45) reported for the first time that the Howard Limestone was recorded in subsurface logs as a single limestone bed.

An important contribution to knowledge of the stratigraphy of the Howard Limestone was supplied by Condra (1927, pp. 54-56) who studied the rocks of the Shawnee Formation in southeastern Nebraska, and adjacent areas of Kansas, Iowa, and Missouri. He correlated the Howard across these states, and assigned the name Church to the lower limestone, from a type locality which is near the town of Dubois, Nebraska.

Moore (1932, p. 94) redefined the boundaries of the Wabaunsee Group to include the beds from the top of the Topeka Limestone to the base of the Americus Limestone. In this new reclassification of the Pennsylvanian rocks of Kansas, he assigned to the Howard Limestone the rank of formation. At the same time, he proposed the following names to the different members within the Howard from the base upward: Bachelor Creek limestone, Aarde shale (containing the Nodaway coal), Church limestone, Winzeler shale, and Utopia limestone members. The same author (1935, pp. 204-208) described the Howard Limestone and the composing members in more detail than previously, following the new revised classification proposed by him in 1932.

The most recent description of this formation is made by Moore, Frye, Jewtt, Lee, and O'Connor (1951, pp. 61-63), and is the same as that of Moore (1935) mentioned above.

Wahrhaftig (1952, pp. 31-36) studied the insoluble residues of the limestones of the Wabaunsee Group, including the Church and Utopia limestone members of the Howard.

McMillan (1956) studied the Petrology of the Nodaway underclay.

Ireland (1956, pp. 831-868) described arenaceous foraminifers of the Upper Pennsylvanian rocks from Kansas, including all the Howard.

Other geologists have mentioned the Howard Limestone in connection with county reports of the state, but no published or unpublished report has described the rocks in the detail undertaken here.

Outcrops

Characteristically, the Howard Limestone is a ledge-former throughout its outcrop area, which is marked by a fairly distinct escarpment. However, this escarpment is not as prominent as the ones formed by the underlying Topeka Limestone, to the east, or the overlying Burlingame Limestone to the west. One of the main reasons for the ledge-forming character of the Howard, is the contrast in resistance to the thick sequence of Severy shales which underlies it.

Several of the sections studied for this report were measured along cuts in section-line roads and in creek banks. The best and most complete exposures were found in coal strip-pits, where the Nodaway coal, occurring in the Aarde shale member of the Howard, is actively mined in many places (Fig. 2). In the vicinity of Topeka, outcrops are almost non-existing because the area is largely covered by urban dwellings.

Fig. 2. Typical Howard Limestone exposure in coal strip-pits. Locality 10, Osage County.

Acknowledgements

The writer whishes to thank Dr. J. M. Jewett of the State Geological Survey of Kansas, for supervision and aid in the preparation of this report. Special thanks are given to Dr. H. A. Ireland of the Department of Geology, University of Kansas, for his assistance in the preparation of the insoluble residues and critical reading of the manuscript. Thanks are also given to Dr. W. K. Hamblin for his useful ideas and suggestions for this report; to the State Geological Survey of Kansas for assisting with the costs of transportation, and for access to important stratigraphic data; to Dr. W. H. Schoewe for the loan of amphibian footprint casts and pictures; to Stanton Ball for his cooperation and assistance in the field in the location of outcrops; to W. H. Johnson Jr. and Howard O'Connor, who have studied the Howard and other rocks in the same places in which my studies were made.

TECHNIQUES

Laboratory Techniques

Different laboratory techniques were followed to study the limestone and shale beds.

Limestone units.- One of the techniques used in the study of the limestone was making use of acetate peels. For the preparation of acetate peels the hand specimens were:

(1) sawed along the north direction, normal to the bedding; (2) sawed parallel to the bedding, taking proper care to label all samples cut in that way. A piece of each specimen was saved for further use in the preparation of the insoluble residues. Then, (3) each face selected for peels was ground on the coarse lap (150 abrasive powder), to smooth out any irregularities left by the saw. Efficient washing was necessary to remove all coarse abrasive. The specimens, then, (4) were finished on the medium lap (500 abrasive powder). Specimens were left to dry prior to etching. The next step (5) consisted in etching the specimen by immersing it in a pan containing 10 percent hydrochloric acid and left for 15 to 25 seconds, depending upon the density of the limestone and freshness of the acid. Specimens were washed and left to dry. These were later (6) immersed in commercial acetone, and placed on previously cut acetate paper. Different types of acetate paper were tried, but it was found that the .003 frosted acetate yielded the best results. The acetone softens the acetate so that an impression of the relief on the etched surface is retained on the acetate paper. The peels were left to harden for at least one hour before removal from the rock to avoid wrinkling. Peels were, then, (7) trimmed and mounted between glass slides to be used as negatives photographically.

Thin section.- These were few and made from selected specimens. They proved to be useful in the study of fusulinids, arenaceous material, and algae, especially *Osagia*.

Insoluble residues.- The procedure followed for the preparation of the insoluble residues was somewhat modified from that of Perkins (1952, pp. 12-33). The general procedure was as follows: (1) the limestone specimens were finely crushed, 20 grams weighed, and placed in labeled 250 cc beakers. The next operation (2) was done under the acid hood where 20 percent hydrochloric acid was added to the beakers, very slowly until initial rapid effervecence was completed. At least three acid applications were necessary to remove all carbonate material. Limonite was removed by boiling the sample in acid for at least 10 minutes. The fine fraction was then, separated by stirring the preparation and pouring the unsettled particles into large beakers. The coarse residue remaining was then, washed, dried, weighed, and placed in small vials for further study. The decanted fine fraction was allowed to settle, most of the water siphoned out, then filtered, dried, and weighed. Only the weight of the fine fraction was of interest and the fraction was disposed of, as the study was concentrated on the coarse fraction. Record of the results obtained is found in Appendix B.

Acid-etched blocks.- The preparation of etched blocks for investigation involved the same procedure used in making acetate peels. In some instances, these same polished faces were used for observation, but frequently the etched sides did not showed enough relief or in some cases relief had been reduced while making peels. These blocks were again smoothed on the lap, then immersed in 10 percent hydrochloric acid for 30 seconds to give sufficient relief. Care must be taken to place the side being etched in a horizontal position to avoid undesirable furrowing made by carbon dioxide bubbles.

Shale units.- When studying shales first was necessary to soak a small amount of fresh sample (100 grams) in water, breaking it by hand as much as possible; boiling for about 15 minutes, decanting the turbid water and sieving the disaggregated shale. After the samples were dryed, they were put in separately labeled envelops for study.

Field Techniques

A total of about six weeks were spent in the field locating and measuring outcrops. Many of the locations measured for this report were obtained from the stratigraphic files of the State Geological Survey of Kansas. Unfortunately some of the exposures had been measured and described as far back as 1929, and are now highly weathered and largely covered. Several other sections were found by following the Howard outcrop belt shown in the county maps published by the Geological Survey. Others, were found in recently opened coal strip-pits, which have been mining the Nodaway coal.

Fresh limestone samples were collected from all localities. Thicker limestones were sampled from near the top and bottom. These were properly numbered and oriented with arrows for vertical and north directions.

STRATIGRAPHY

General Stratigraphy of the Wabaunsee Group

The Wabaunsee Group of rocks comprises the uppermost group of Pennsylvanian strata in Kansas. As classified by the State Geological Survey of Kansas, it belongs to the Virgilian Series and includes five limestones, six shales, and one formation.

The Wabaunsee Group was named from Wabaunsee County, (west of Topeka) Kansas, where a number of Wabaunsee formations are well exposed.

Previous work.- The Wabaunsee Group, originally was defined as Wabaunsee formation by Prosser (1895, p. 689), who stated: "I have considered the base of this formation as defined by the top of the Osage coal horizon and the top by the base of the massive limestone known locally as the Cottonwood, Alma, and Manhattan limestones." The Osage coal mentioned here refers to the Nodaway coal in the Howard Limestone.

Haworth (1898, p. 94) redefined the base, excluding beds below the Burlingame Limestone.

Later Fath (1921, pp. 39-43) designated rocks, formerly assigned to the Wabaunsee Formation, the Wabaunsee Group.

Moore (1935, p. 200) redefined the boundaries of the Wabaunsee Group as follows "... 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 making the boundary between rocks classed as Pennsylvanian and "Permian" in the northern Mid-Continent region." Recent studies indicate that the contact between Towle shale and Wabaunsee rocks in general is conformable.

Currently Moore (1949, p. 165) changed the boundaries of the Wabaunsee Group as to include those beds between the top of the Topeka Limestone and the horizon that is regarded as the Pennsylvanian-Permian boundary.

Lithology and thickness.- The Wabaunsee Group consists of a sequence of shales, limestones, and sandstones. The shale units are predominant in this group than in adjoining parts of the geologic section, with several very persistent thin limestones, and some less persistent sandstones or sandy shales.

One of the characteristic features of this group is the nature of the repetition of strata, consisting of an alternating sequence of nonmarine and marine depoeits, showing evidences of cyclic sedimentation, "...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." Moore (1949, p. 169).

The Wabaunsee Group outcrop belt in Kansas begins in western Chautauqua County, and extends to eastern Brown and western Doniphan Counties, in northeastern Kansas (Fig. 3). Outcrops are more numerous and better exposed in the area south of the Kansas River, because the country north of the river is covered by glacial drift.

The Wabaunsee Group is divided into three subgroups, from the base upward, the Sacfox, Nemaha, and Richardson subgroups. The Sacfox subgroup in turn is subdivided into three formations: the Severy Shale at the base, the Howard Limestone, and the Scranton Shale at the top.

The thickness of the Wabaunsee Group is about 500 feet. Figure 4 shows a generalized section of the Sacfox subgroup in the lower part of the Wabaunsee Group and the stratigraphic sections of the Howard Limestone.

Severy Shale

The Severy Shale, which is the basal formation of the Wabaunsee Group, was named by Haworth (1898, p. 66) from exposures in the town of Severy, Greenwood County, Kansas.

Lithology and thickness.- In the area studied the Severy Shale was found to be of rather uniform lithologic character: an olive-gray to yellowish-gray sandy shale, micaceous, and in places clayey. In locality 6, numerous pyrite nodules were present near the top, these being about 2 inches in diameter. In this locality the shale is interbedded with hard, limonitic, sandy shale. In the same locality a hard, massive,

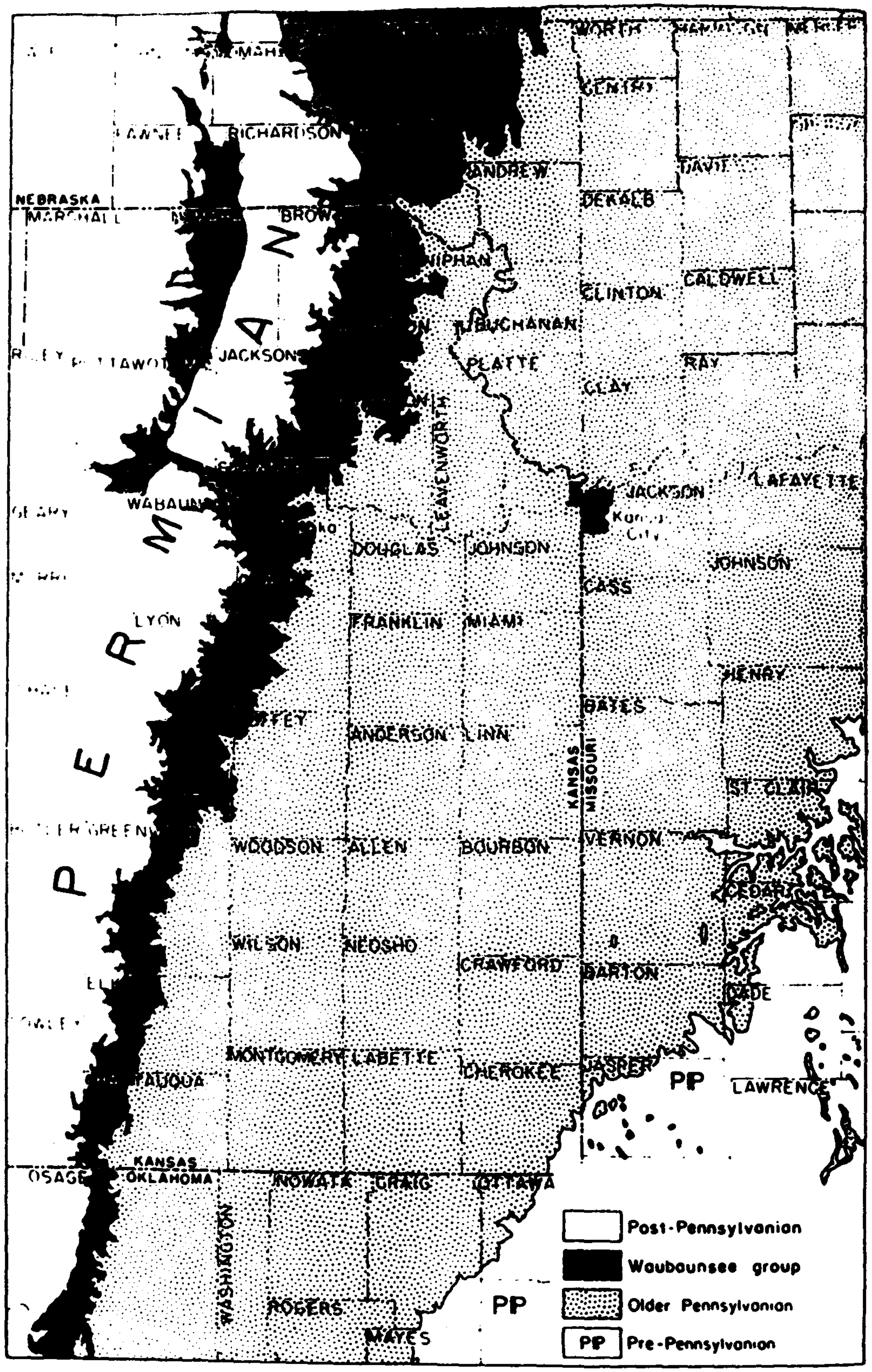


Figure 13. Distribution of outcrops of the Wabaunsee group in Kansas and parts of adjoining States. The belt forms the westernmost subdivision of the Pennsylvanian outcrop area.

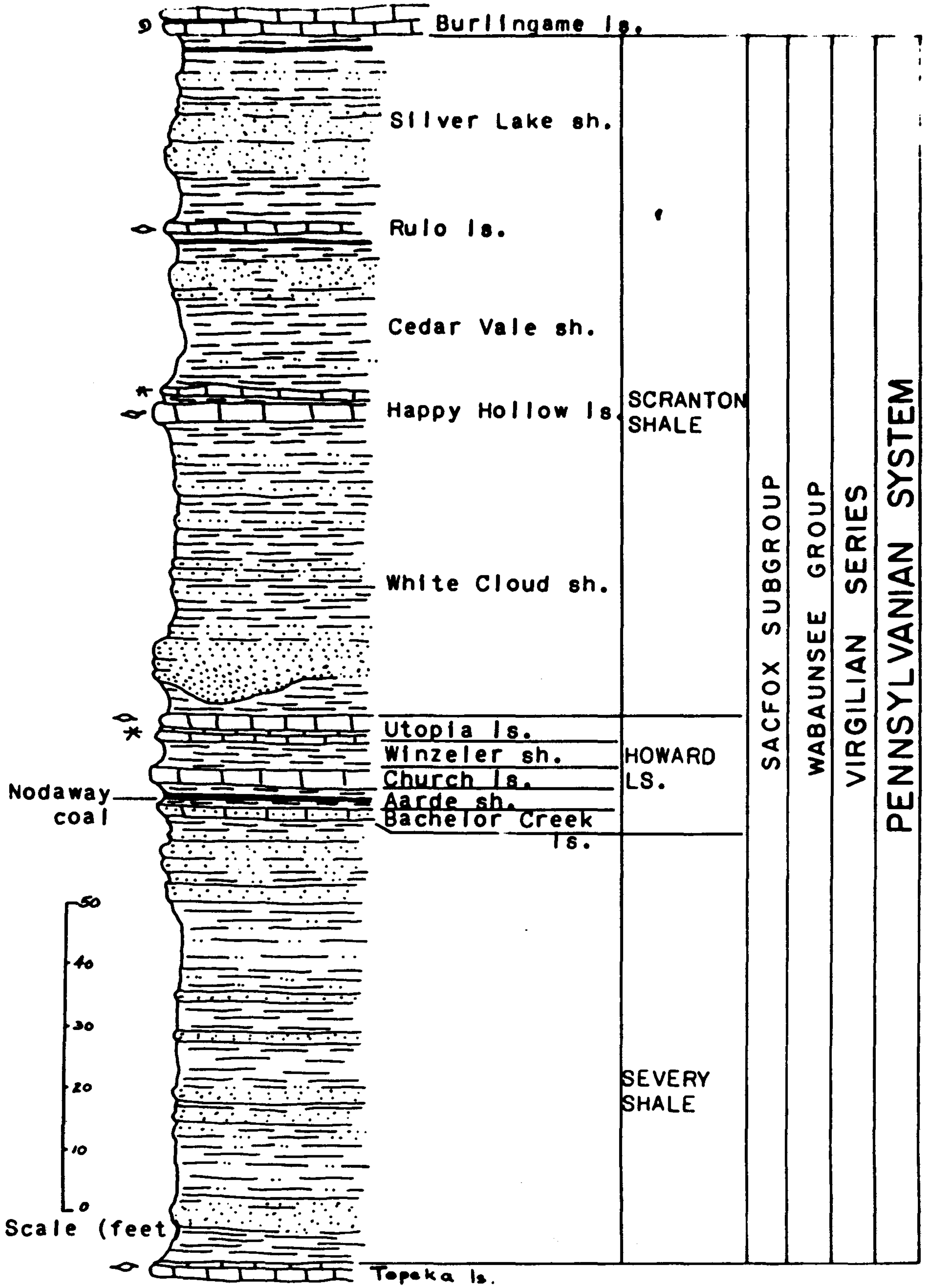


Figure 4. Generalized columnar section of rocks belonging to the Sacfox subgroup, lower Wabaunsee, Kansas. (Modified from Moore, 1949)

irregularly-bedded sandstone was found about 30 feet below the Howard Limestone.

In localities 1 and 4, a thin, buff sandstone appears about 5 feet from the top. The sandstone is micaceous, fine-grained, and finely laminated.

The total thickness of the Severy Shale is said to be between 70 to 80 feet, but the best exposure measured for this report showed a maximum of 35 feet, because the base was not exposed.

Paleontology.- The Severy Shale contains plant remains in various horizons. Megafossils were found sparsely near the top, except for locality 11 where numerous brachiopods and pelecypods were present in a sandy limestone, about 6 feet below the Nodaway coal horizon. Among the productid brachiopods found were *Juresania*, *Dictyoclostus*, and there were several unidentified clams.

Figures 5 and 6 show exposures of the Severy Shale.

Howard Limestone

The Howard Limestone was named by Haworth (1898, p. 67) from well developed outcrops near the town of Howard, Elk County, Kansas.

From Osage County southwards (NW¼, Sec. 7, T. 17 S., R. 15 E.), the Howard attains complete development and it comprises three limestones and two shale members. Named from the base upward these members are: the Bachelor Creek lime-

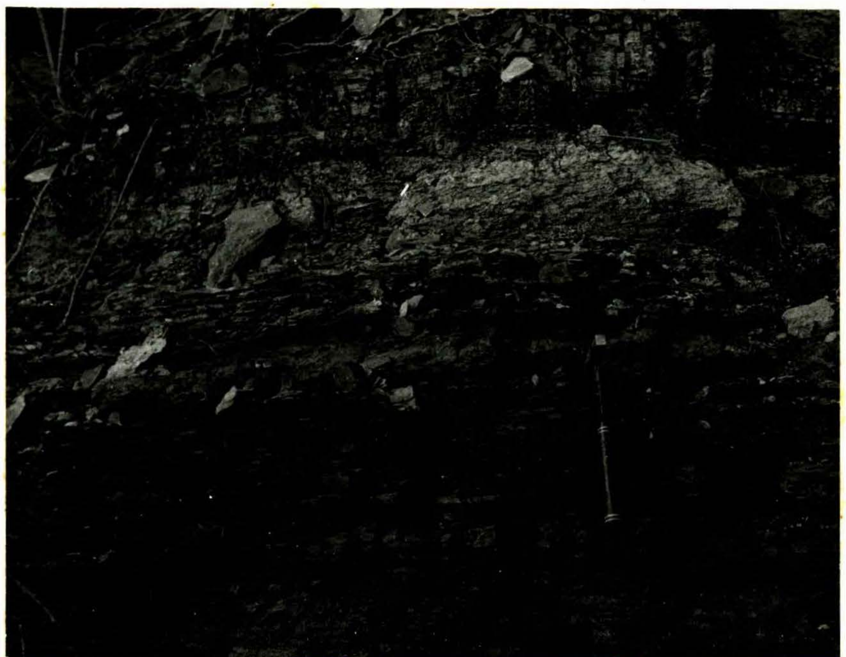


Fig. 5. Contact between Severy Shale and Howard Limestone in the northern area. Locality 4, near Kansas River, Shawnee County.

Fig. 6. Contact between Severy Shale and Howard Limestone in the southern area. Locality 28, Lyon County.

stone, the Aarde shale (containing the Nodaway coal and "Wauneta" limestone bed), the Church limestone, the Winzeler shale, and the Utopia limestone members. These members are discussed further in this order.

The lower boundary of the Howard Limestone in the southern part of the area overlies comformably the Severy Shale, and is defined as at the base of the Bachelor Creek limestone member. The upper boundary is sharp and comformable with the overlying White Cloud shale. In northern Osage County and farther north the Bachelor Creek member is absent, and the lower boundary of the Howard is regarded to be at the base of the Nodaway coal, which is the basal unit of the Aarde shale member in the northern part of the area. The upper boundary is unchanged in the whole area and is at the top of Utopia limestone member. Although the contacts between the Severy Shale and the Howard Limestone are usually sharp in the area where the Bachelor Creek limestone is absent, it appears to be rather gradational in places where this member is present. The presence, in some outcrops, of a calcareous shale with numerous Chonetes, seems to delineate boundaries between these two formations.

The Howard Limestone is not difficult to identify in the field, inasmuch as its members show certain characteristics which make them easily recognized and differentiated from adjacent beds.

During detailed field work a shaly limestone was found to have certain persistence below the Church limestone member and to be separated from the Church by thin shales. This argillaceous limestone unit is called "Wauneta". In this report the "Wauneta" bed is described and studied as a unit within the Aarde shale member.

The Howard Limestone has a variable thickness in the area under study. It ranges from a minimum of 13 feet in locality 4 to a maximum of 37 feet in locality 22. In general thickens towards the south.

The lithology and faunal characters of the Howard for the most part are fairly uniform, except in the Utopia limestone member. The characteristics of each individual member are discussed later.

The Howard is traced north into Nebraska under the same name; however, in this area the lower boundary is drawn at the base of the Church Limestone. Southward in Oklahoma, the Bird Creek Limestone is equivalent to the Church limestone member. In that area the rest of the Howard is not identified.

Figures 7 to 12 show Howard Limestone outcrops at different localities.

Fig. 7. Howard Limestone in the northern area. Locality 3, north of the Kansas River, Shawnee County.

Fig. 8. Howard Limestone and Severy Shale in the southernmost outcrop. Locality 28, Lyon County.

Fig. 9. Howard Limestone and upper part of Severy Shale. Locality 4, Shawnee County.

Fig. 10. Close-up of figure 9.

Fig. 11. Howard Limestone along the Kansas Turnpike. Note presence of extra limestone bed in the Winzeler Shale. Locality 6, Shawnee County.

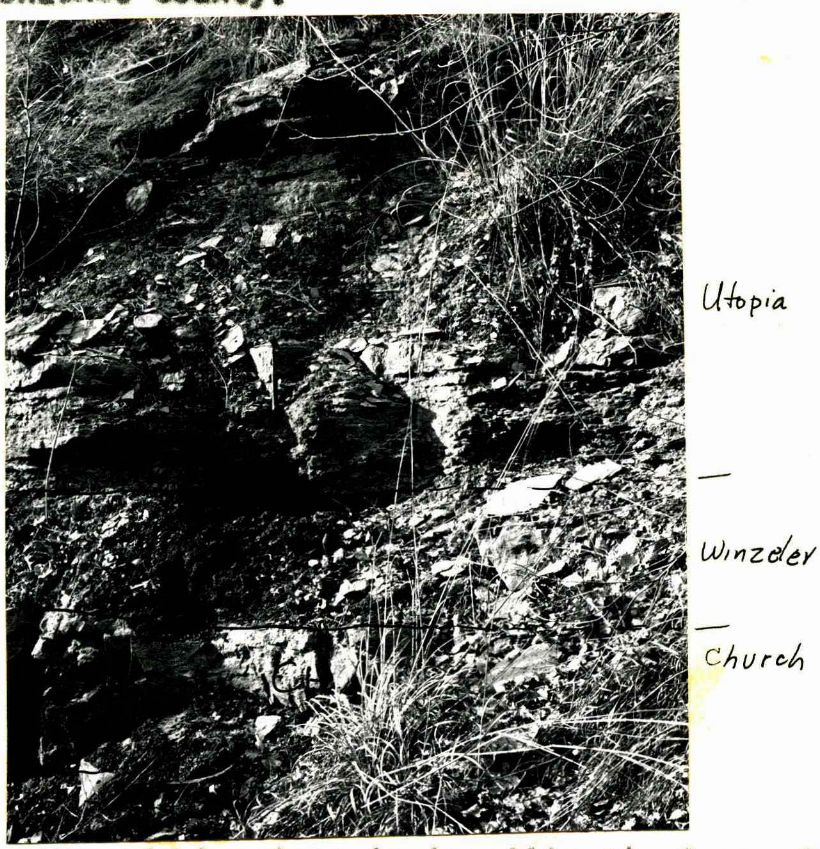


Fig. 12. Howard Limestone in locality 14, Osage County.

Bachelor Creek Limestone Member

The Bachelor Creek was named by Moore (1932, p. 94) from the type locality on Bachelor Creek, 5 miles east of Eureka, Greenwood County, Kansas. This limestone is the basal member of the Howard from Osage County (NW¼, Sec. 7, T. 17 S., R. 15 E.,) southwards.

Lithology, thickness, and contacts.- The Bachelor Creek in all localities was found to show fairly uniform lithology. It is a light olive-gray limestone, which weathers a pale brown, impure, and arenaceous. It is massive and upon weathering breaks into thin irregular shelly beds, with rounded surfaces resembling weathered sandstone. Locally the Bachelor Creek is dark blue to bluish gray, with a pseudolitic texture, and rare quartz grains.

The Bachelor Creek has a constant thickness of about 4 feet, with rare exceptions. It is interesting to note that in locality 23 it was found to be 15.5 feet. This is an unusual thickness and not heretofore reported.

In all localities, except 28 where both upper and lower boundaries are sharp, the lower contact of the Bachelor Creek and the underlying Severy Shale is gradational. It passes from a non-calcareous, non-fossiliferous shale, to one that is slightly calcareous and contains numerous specimens of *Chonetes*. The upper contact with the overlying Aarde shale is sharp.

Paleontology.- In most localities the larger part of the Bachelor Creek was found to be only sparsely fossiliferous. Among the fossils collected from this limestone were crinoid stems, some fenestrate bryozoans, echinoid spines, and few brachiopods. An exception occurs in locality 20 (Fig. 13), where numerous brachiopods are present; among them are _Juresania_, _Dictyoclostus_, _Chonetes_, _Enteletes_, spiriferids, and towards the very top pelecypods of the genus _Myalina_ are abundant.

Near the base of the Bachelor Creek in locality 23 _Chonetes_ were found associated with few _Dictyoclostus_, _Myalina_, sparse _Composita_, and a few _Aviculopinna_; the rest of the bed is only sparsely fossiliferous, except towards the top where one finds _Orthomyalina_, _Juresania_, fenestrate bryozoans, and spired gastropods.

In locality 28 the faunal content of the Bachelor Creek was found to be unusually different; there _Osagia_ constitute the bulk of the fossils in this bed, giving it a pseudoolitic appearance. In this same locality the limestone contains also _Crurithyris_, _Composita_, _Myalina_, crinoid stems, and fenestrate bryozoans.

Figures 13 and 14 shows Bachelor Creek limestone outcrops.

Fig. 13. Bachelor Creek limestone member. Locality 20, Osage County.

Fig. 14. Bachelor Creek limestone in locality 28, Lyon County.

Aarde Shale Member

The Aarde shale overlies the Bachelor Creek limestone, wherever this bed is present, and below the Church limestone member. It was named and described by Moore (1932, p. 94) from the type locality near Aarde farm (Sec. T. 26 S., R. 11 E.), Greenwood County, Kansas.

Lithology and thickness.- In general the Aarde member is a bluish-gray to yellowish-gray, clayey, sandy shale. The average thickness ranges from 2.5 to 7 feet, although, it was found to be as much as 24 feet thick in locality 10 (Fig. 17). Locally this shale shows an unusual thicknening, as in locality 5 (Fig. 16). Generally, the Aarde thickens southwards.

The Aarde shale comprises numerous units that are well differentiated in some outcrops in the southern area. Named from the base upwards are as follows: (a) shaly sandstone to sandy shale, (b) clayey gray shale, or (c) underclay, (d) coal (Nodaway), (e) impure silty gray shale, (f) calcareous gray shale, (g) bluish-gray argillaceous limestone ("Wauneta"), (h) black platy shale, and (i) light-gray to pale-brown shale.

The above sequence is obvious in the southern area, in some outcrops, however, the sequence of units is somewhat different, and in the northern area where units b or c, d, e, h, and i can only be identified.

Paleontology.- The lower two units were observable at localities 21, 22, 27, and 28, and contain only plant impressions. The underclay, unit c, and unit d, coal, are devoid of fossils. Unit e, which rests on Nodaway coal, contains numerous carbonaceous fragments and plant impressions. In most sections this shale was found to be crumbly, impure, and poorly consolidated. Unit e grades into f, which contains crinoid stems. The "Wauneta" limestone or unit g is highly fossiliferous bed, which is discussed later. Unit h is characterized by numerous phosphatic shells of the inarticulate brachiopods Orbiculoidea and Lingula, few Dunbarella, and unidentified shell fragments. Unit i is highly calcareous and contains abundant crinoid stems and brachiopods.

"Wauneta" Limestone Bed

The name "Wauneta" was applied by Moore (personal communication) from outcrops exposed near the small town of Wauneta, Chautauqua County, Kansas. This limestone becomes more persistent in the southern part of the state, from Greenwood County southwards. In this area it is bluish-gray in color, and is characterized by the presence of numerous fusulinids, Chonetes, Hustedia, Composita, and few Dictyoclostus.

In most outcrops, the "Wauneta" is about 1 or 2 feet below the Church limestone, and is regarded as part of the Aarde shale.

Lithology, thickness, and paleontology.- In most places where found, the "Wauneta" is a gray, highly argillaceous limestone. Usually is medium hard and coarse-grained. The thickness ranges from 0.3 to 0.5 foot. In places where this clayey limestone is absent, a limy shale commonly is present. It contains numerous fossils, among them *Crurithyris*, *Juresania*, *Cancranella*, *Dunbarella*, large crinoid stems, ostracods, and unidentified brachiopods.

Figures 15 to 18 show the Aarde shale and "Wauneta" limestone.

Church Limestone Member

The Church limestone was named by Condra (1927, p. 54) from outcrops in Church farm, near the town of Dubois, Pawnee County, Nebraska.

The Church was used as a datum reference plane for correlation in this report, because it is invariably found in every Howard outcrop. It is a very persistent limestone and has been traced from Oklahoma, across Kansas, and into Nebraska and Iowa.

Lithology and thickness.- The Church limestone member has rather uniform lithology and thickness throughout its outcrop area. It is dark blue to bluish-gray, and when weathered has a dark chocolate brown color. The Church is commonly a single massive bed, very hard, and dense. A sledge hammer was often used to break this hard limestone, and when broken it shows a subconchoidal fracture. Commonly, the

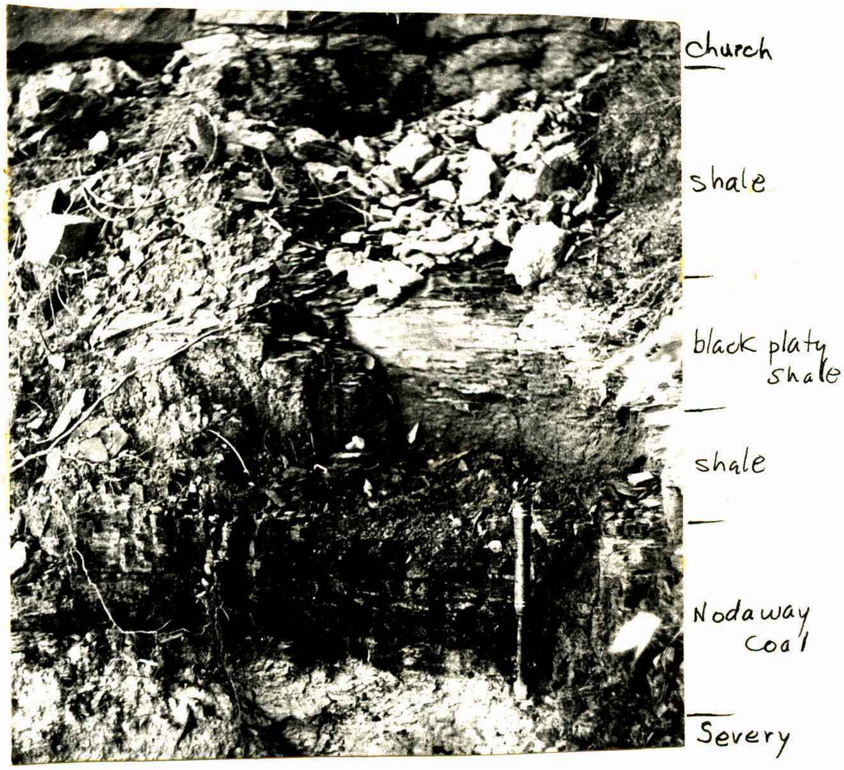


Fig. 14. Units in the Aarde shale member in the northern area. In this area the contact between the Howard Limestone and Severy Shale is at the base of Nodaway coal. Locality 4, Shawnee County.

Fig. 16. Aarde shale member along the Kansas Turnpike. Note different thicknesses of the shale. Locality 5, Shawnee County.

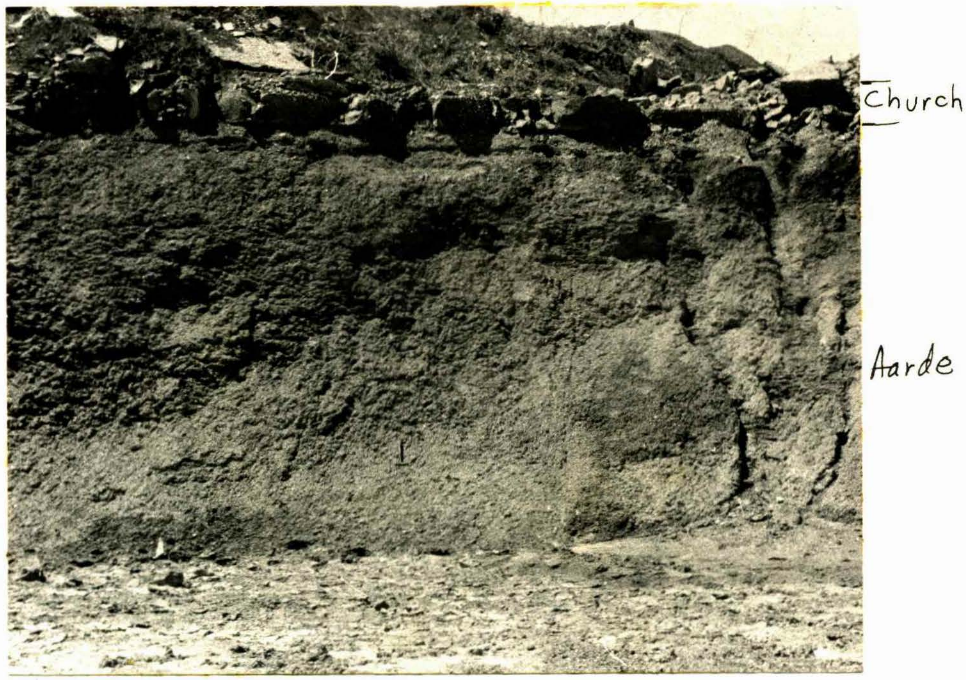


Fig. 17. Unusual thickness (24 feet) of the Aarde shale member in an open strip-pit. Locality 10, Osage County.

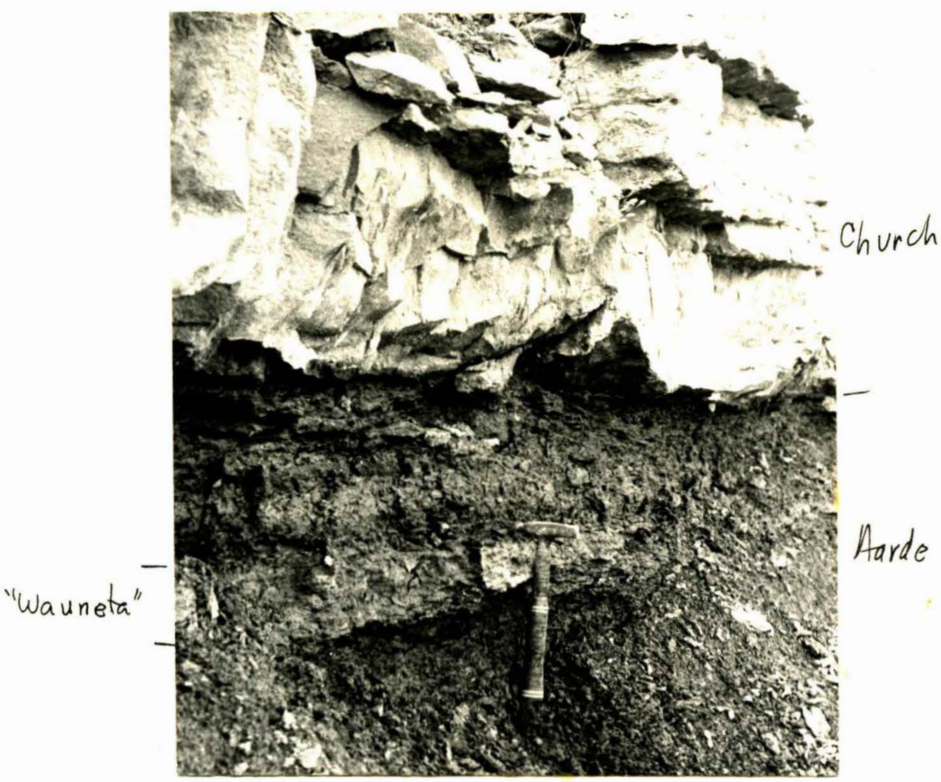


Fig. 18. "Wauneta" limestone bed in the Aarde shale, and below the Church limestone. Locality 10, Shawnee County.

Church breaks into rectangular blocks. The thickness of the Church constantly is a 2 feet, varying only an inch or two in a few places.

The uppermost 1 or 2 inches are shelly, and form a thin crust at the top of the massive Church member. This shelly top in many places is absent, especially where the Church has been exposed to weathering.

Paleontology.- The faunal character of the Church is fairly uniform in the area under study. It contains abundant *Ottonosia* towards the top, which are a distinguishing feature of this bed. These algae upon weathering stand out in relief, as shown in figure 19. Commonly, these algae are found encrusting other fossils. The representative fauna of this bed are: *Dictyoclostus*, *Enteletes*, *Composita*, *Marginifera*, *Lophophyllidium*, *Naticopsis*, *Echinoconchus*, *Punctospirifer*, spirriferids, spired gastropods, crinoid stems, and others.

The Church limestone, in the area under study, lacks fusulinids which are abundantly present in the southern part of the state.

The thin shelly crust at the top of the Church contains numerous *Chonetes*, some *Punctospirifer*, numerous ramose bryozoans like *Rhombopora* and *Streblotrypa*, and some fenestrate bryozoans.

Contacts.- The Church overlies conformably the Aarde shale member, and in turn is overlain by the Winzeler shale except in locality 10, where the Utopia limestone member rests directly upon Church. This is shown in Figure 22. This bed is separated from adjacent units by sharp contacts.

Figures 20 and 21 show the Church limestone at different localities.

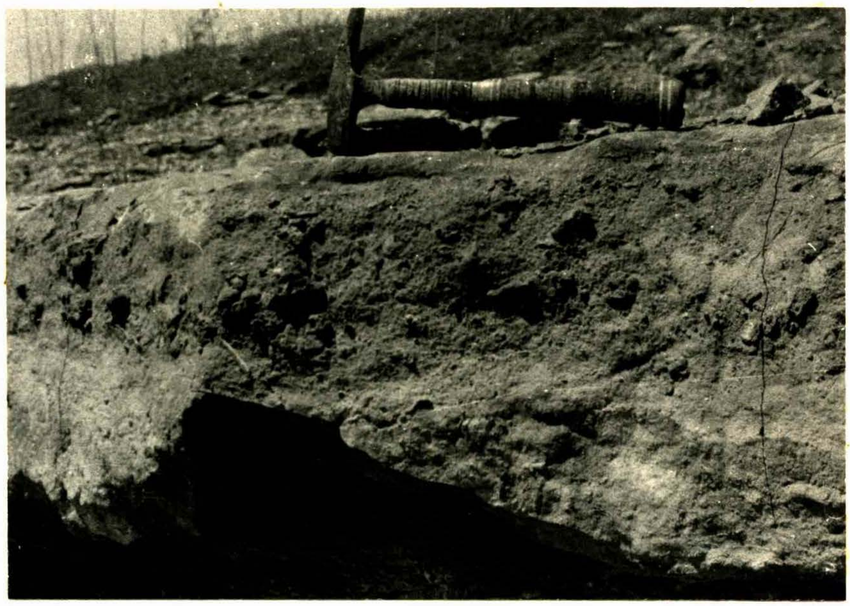


Fig. 19. Ottonosia in the upper part of the Church Limestone. Locality 10, Shawnee County.

Fig. 20. Sharp and even contact between Church Limestone and Aarde shale. Locality 4, Shawnee County.

Fig. 21. Church, Winzeler, and Utopia members. Note thinning of Winzeler shale and thin to medium bedding in the Church limestone. Locality 9, Osage County.

Winzeler Shale Member

The Winzeler shale was named by Moore (1932, p. 94) from outcrops near the Winzeler farm (Sec. 4, T. 26 S., R. 11 E.), Greenwood County, Kansas.

Lithology and thickness.- The Winzeler shale is usually medium gray to pale brown, clayey, and calcareous. The thickness ranges from 2.5 to 10 feet.

The Winzeler shale is a persistent member that has been traced from Oklahoma, northwards into Nebraska and Iowa. It has a uniform lithological character. However, locally in Osage County the member was found to be absent for 6 miles along the outcrop. The picture (Fig. 21) of the exposure in locality 9, Osage County, shows the Winzeler shale reduced in thickness to as little as 0.3 of a foot.

The Winzeler is missing in localities 10, 11, and 12, where the Utopia limestone directly overlies the Church (Fig. 22). In locality 14 it reappears normally developed and containing its typical fauna. One of the most noticeable features of the Winzeler shale is the lack of persistence of the limestone beds, which it contains locally. These limestone beds are dissimilar in lithology from place to place.

The condition mentioned above is shown in locality 6 (Fig. 23), where a thin argillaceous limestone occurs near the base of the Winzeler, and is separated from the Church by a thin fossiliferous shale. In locality 8, a 3-foot "limestone" is found resting on the Church, and which here is regarded as part of the Winzeler. The "limestone" in this locality contains numerous grooved nodules that give the appearance of sedimentary columnals (Fig. 24).

In locality 24, there is a thin limestone only 0.5 inch thick, and in locality 25 a "punky" limestone is present in the Winzeler member about 5 feet from its base. This in places occurs as limestone septarian concretions of various and irregular shapes.

Paleontology.- The presence of lacy bryozoans of the genera *Fenestrellina* are a diagnostic feature of the lower part, and in places the upper part, of the Winzeler. The ramose bryozoans *Rhombopora*, rare *Neospirifer*, pelecypods, and other brachiopods also are present in some outcrops. In locality 24, the thin encrinal limestone present in the Winzeler contains fairly well preserved cups, plates, and spines of the crinoid *Delocrinus verus*, the brachiopod *Cancranella*, and numerous minute spired gastropods.

Utopia Limestone Member

The Utopia was named by Moore (1932, p. 94) from exposures near the village of Utopia, Greenwood County, Kansas.

The Utopia limestone is the uppermost member of the Howard Limestone. It comprises those beds above the Winzeler shale, and below the White Cloud shale member of the Scranton Formation. The Utopia limestone is lithologically and faunal-

Fig. 22. Utopia limestone resting on Church limestone, with absence of Winzeler shale. Locality 10, Osage County.

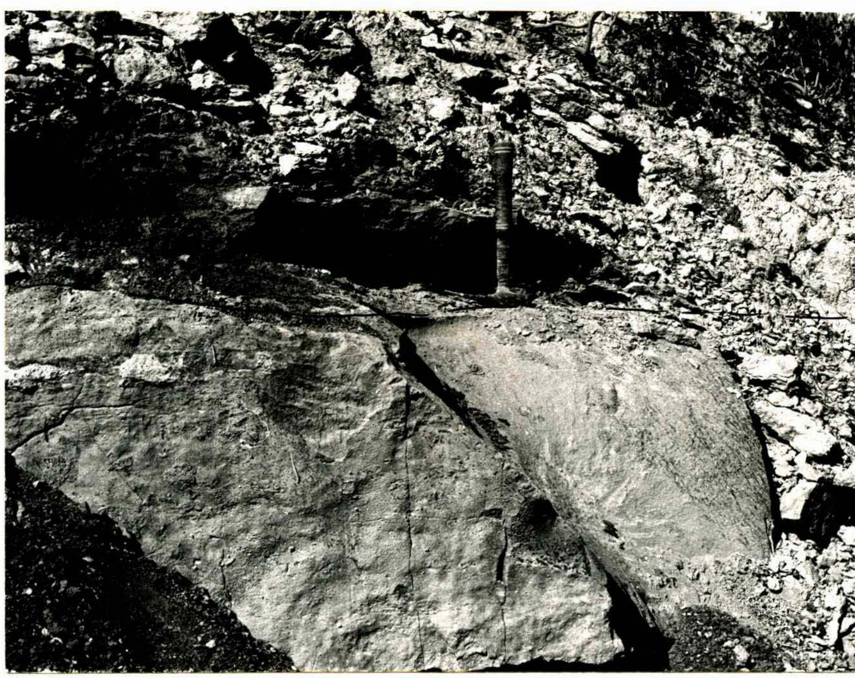


Fig. 23. Winzeler shale member along the Kansas Turnpike showing an extra limestone unit separated by a thin shale interval. Locality 6, Shawnee County.

Fig. 24. "Limestone" containing grooved nodules in the lower part of Winzeler shale. Nodules contain abundant sponge spicules. Locality 8, Shawnee County.

ly [and faunally] different from other members of the Howard.

<u>Lithology and thickness</u>.- The Utopia member is a bluish-gray to medium-gray limestone, hard, and medium- to coarse-grained. From Shawnee County northward the Utopia contains several thin shale units, one of which is black and fissile. Whereas, to the south it is mostly composed of thin limestone units.

The Utopia limestone ranges in thickness from 2 to 14 feet.

On the basis of lithology and faunal content the Utopia limestone member has two different parts: the lower part which is composed of thin units, and an upper part which is is commonly one single medium to massive bed. These parts will be treated, for convenience, as the lower Utopia and the fusulinid-bearing Utopia.

Paleontology.- The lower Utopia for the most part is highly fossiliferous (Fig. 25). Some thin units are differentiated because they are almost entirely composed of a particular fossil. For example we find beds with *Pernopecten*, *Myalina*, *Goniasma*, ostracods, and *Pleurophorus*. Still more common, are the numerous thin osagite beds that contain abundant *Osagia* algae, which on weathering stand out in relief giving the appearance of "oatmeal" texture. Among other fossils recognized and found to be abundantly present in the lower Utopia are: *Marginifera*, *Aviculopecten*, *Composita*, *Chonetes*, *Derbyia*, *Dictyoclostus*, *Lophophyllidium*, *Dielasma*, rare *Linoproductus*, common *Fenestrellina*, *Juresania*, *Polypora*, *Tabulipora*, *Punctospirifer*, *Cancrinella*, *Crurithyris*, *Fistulipora*, *Rhombopora*, *Orthomyalina*, *Bellerophon*, *Euphemites*, *Pharkidonotus*, crinoid stems, spiriferids, and unidentified mollusks. Ostracods are abundantly found in locality 10, in thinly-laminated limestone layers.

The fusulinid-bearing Utopia is almost entirely composed of fusulinids of the genus *Triticites*, along with rare *Lophophyllidium*, rare *Osagia*, *Fenestrellina*, echinoid spines, small brachiopods, mollusks, and crinoid stems.

The upper part of the lower Utopia limestone in locality 18 (Figs. 29-33), contains abundant well preserved fossil footprints. These are casts of amphibians of the specie _Limnopus vagus_, Marsh (Schoewe, 1956, pp. 389-405).

Contacts.- The Utopia overlies conformably with sharp contact the Winzeler shale. The White Cloud shale member of the Scranton Shale overlies the fusulinid-bearing Utopia with a sharp contact. West of Topeka, the Utopia limestone is deeply eroded by a channel sandstone that is regarded as part of the White Cloud shale.

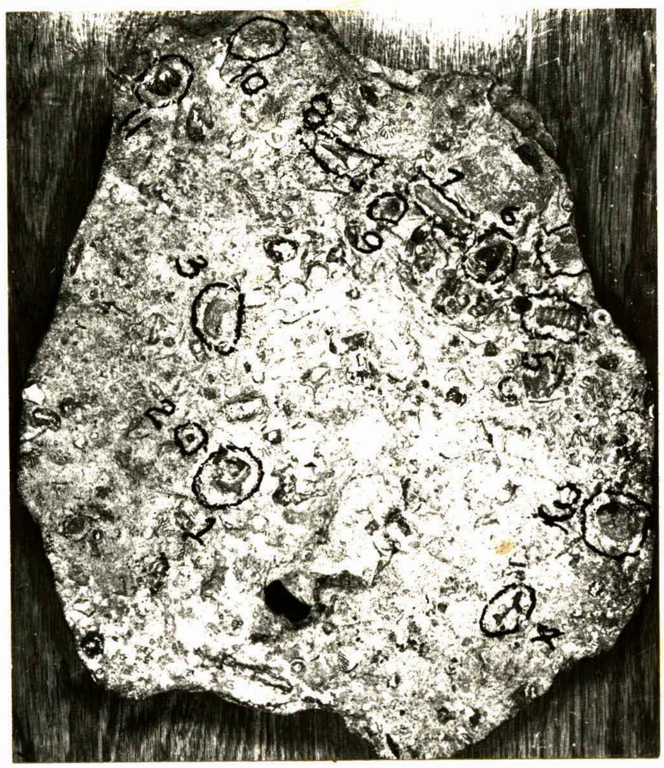


Fig. 25. Slab from the lower Utopia limestone showing the abundance of mixed fauna. Locality 8, Shawnee County.

Fig. 26. Thin limestone and shale units in the lower Utopia limestone of the northern area. Locality 4, Shawnee Co.

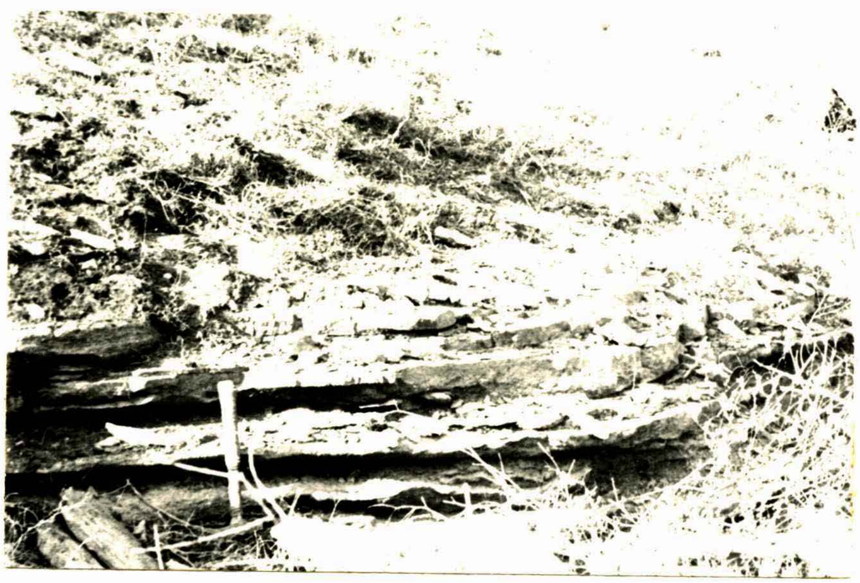


Fig. 27. Characteristic thin-bedding of lower Utopia limestone. Locality 10, Osage County.

Fig. 28. Lower Utopia limestone consisting of thin limestones and shales containing land plants and ostracods in the northern area. Locality 14, Osage County.

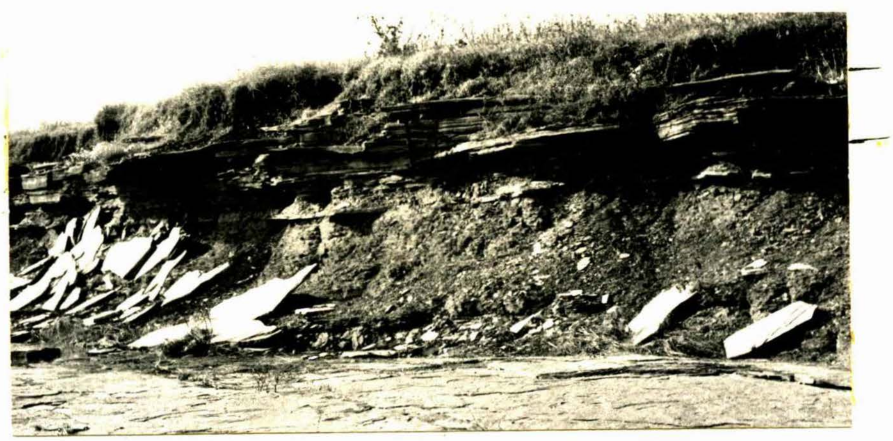


Fig. 29. Flaggy limestone in the lower Utopia unit containing fossil amphibian footprints. Locality 18. Sec. 14 and 15, T. 17 S., R. 14 E., Osage County.

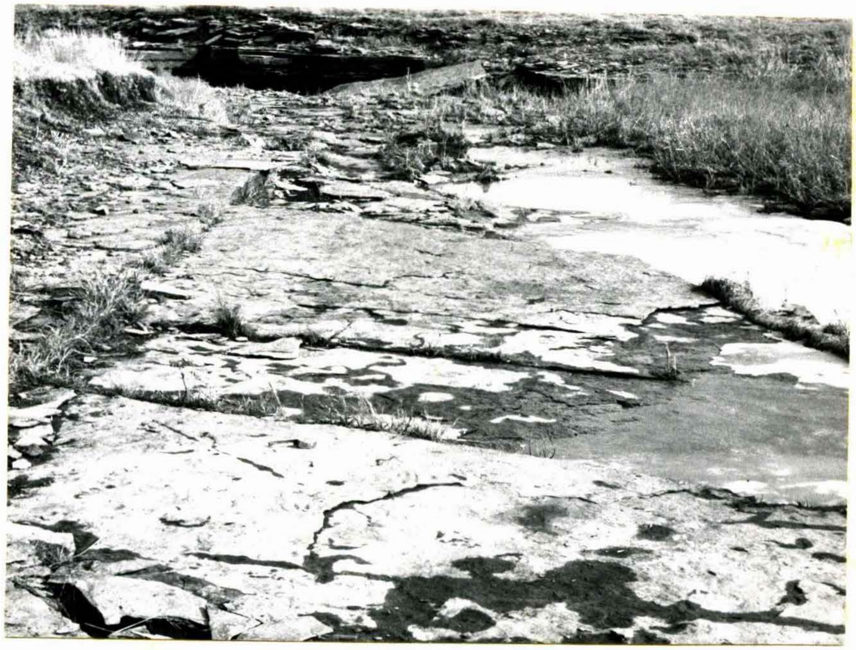


Fig. 30. Lower Utopia limestone containing casts of amphibian footprints. Locality 18, Osage County.

Fig. 31. Close-up of figure 30.

Fig. 32. Amphibian footprints of Limnopus vagus, Marsh. Locality 18, Osage County.

Fig. 33. Close-up of figure 32.

Scranton Shale

White Cloud Shale Member

The White Cloud shale was named by Condra (1927, p. 58; 1939, p. 53) from outcrops near the town of White Cloud, Doniphan County, in northeastern Kansas.

The White Cloud includes those beds between the top of the Howard Limestone and the base of the Happy Hollow Limestone.

Lithology and thickness.- The White Cloud is chiefly composed of olive-gray or yellowish-brown clayey to silty shale. The sandstone found in the White Cloud is pale brown, fine-grained and thinly laminated.

The thickness of the White Cloud ranges from 30 to 80 feet. It was found only in two localities 3 and 4; the maximum thickness is 37 feet.

Contacts.- In the two outcrops where the White Cloud was measured, it was observed to have a sharp contact with the underlying Howard Limestone. In locality 4, a channel sandstone occurs in the White Cloud shale (Fig. 34). Inasmuch as this channel is an interesting feature in this locality, it is described with some detail in the following part of this paper.

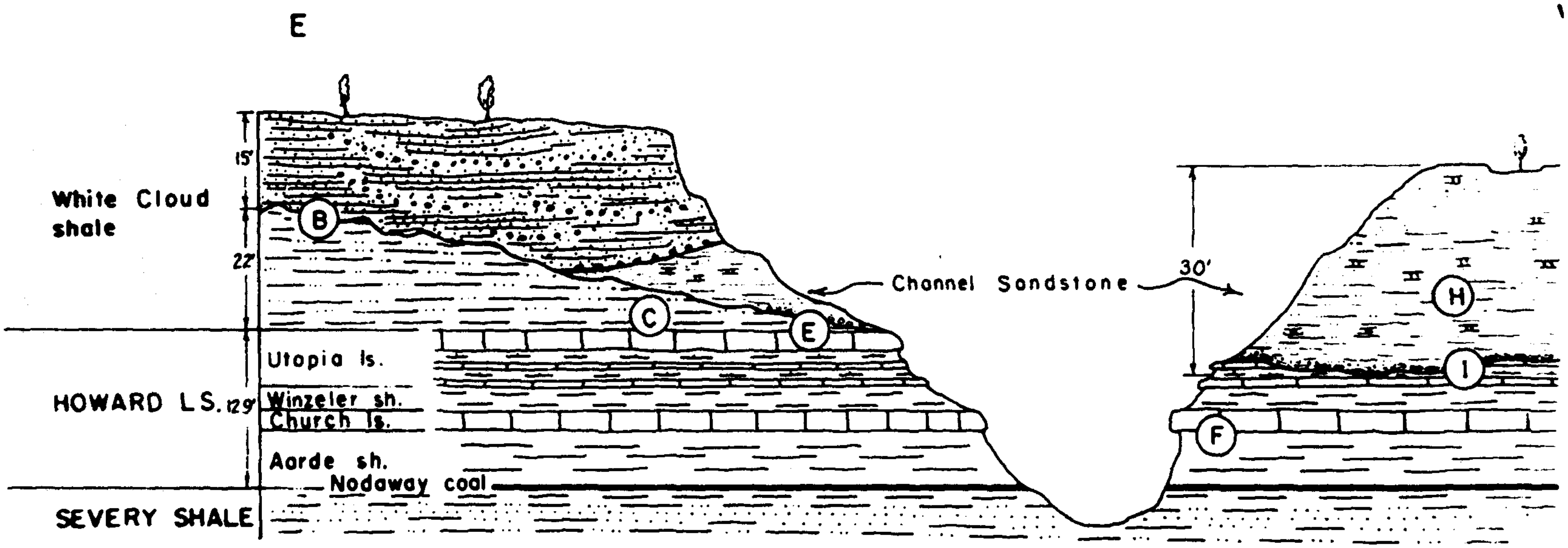


FIG. 34. SCHEMATIC DIAGRAM SHOWING THE WHITE CLOUD CHANNEL SANDSTONE, AND ITS RELATION TO ADJACENT BEDS. Letters indicate location of text figures. No horizontal scale, vertical thicknesses as indicated.

White Cloud Channel Sandstone

Location.- The White Cloud channel sandstone is exposed for about 400 yards in the NW¼, NW¼, Sec. 27, T. 11 S., R. 11 E., about 0.3 of a mile west of a new bridge over Kansas River on State Highway 4, about 3 miles west of Topeka.

Previous work.- The channel sanstone has been mentioned by Moore (1935, p. 210; 1949, p. 175) stating that "...these sandy and conglomeratic deposits are interpreted as the initial phase of the [of the] Happy Hollow cyclothem." The purpose of this part of the report is to describe this channel in more detail than has been done previously. An attempt will be made to interpret the possible age of the channel, and its relation to affected adjacent beds.

Lithology and thickness.- The White Cloud channel sandstone is composed chiefly of shales and sandstones. Four units are lithologically differentiated; from the base upward they are: (1) a well indurated basal conglomerate 0.5 to 1 foot in thickness composed chiefly of flat subrounded limestone pebbles, round limonite concretions, and pyrite nodules. The fine matrix is composed of numerous fossil shell fragments and fusulinids. Pyrite, glauconite, quartz sand, clay particles, carbonaceous material, and limonite are abundant. (2) Above the basal conglomerate is about 15 feet of light olive-gray, silty, and micaceous shale. It is laminated, and contains plant impressions; it contains calcareous sandstone stringers. (3) Near the center of the channel, just above the shale mentioned, is about 5 feet of limy sandstone, which is olive gray, laminated, and micaceous. The insoluble residues of this calcareous sandstone showed 35 percent calcium carbonate. The coarse residue fraction gave the following constituents:

82% quartz sand, subrounded, clear to frosted
7% sphalerite, subhedral, up to 0.1 mm in diameter
5% pyrite, amorphous
3% mica flakes
2% carbonaceous material, black
1% apatite, green

(4) The top unit is an olive-gray, micaceous, shale interbedded with thin limy sandstone. This shale is about 10 feet thick.

The possible sequence of events associated with the White Cloud channel sandstone are discussed:

Deposition of Howard Limestone and of lower shale in the White Cloud shale.

Erosion followed by deposition of channel sands. Clear evidence that the channel sandstone occurred later than the deposition of both the lower part of White Cloud shale and Howard Limestone is shown by the scouring, entrenchment, and erosional effects produced on those beds. In the eastern part of the section studied, shale in the White Cloud is deeply eroded as shown in Figures 36-39, and the shale is reduced in thickness from 22 feet, as seen nearby, to a fraction of an inch. Remnants of lithologically similar rocks to those in the channel sandstone are shown in Figures 38 and 39. In the western part of the channel, conglomeratic deposits rest directly upon the Utopia limestone member, which has been eroded from the original 5.3 feet to 1 foot.

Deposition of sandstone of the upper part of the White Cloud shale followed the erosion discussed above. Numerous thin conglomerates at different horizons are present in this sandstone. Deposition of younger Virgilian and other beds followed.

Recent erosion has partially obliterated the east side of the channel sandstone, and cut deeply into the Howard Limestone and Severy Shale (Fig. 34).

Study of the channel sandstone leads to the conclusions that: (1) Deposition of the channel sandstone occurred prior to the deposition of the upper sandstone of the White Cloud shale and subsequent to the deposition of the Howard Limestone and lower shale of the White Cloud. (2) The general attitude of the strata forming the channel is flat-lying and lacks cross-bedding. This presumes that these fine sediments were laid down in a sluggish stream with low competency and high capacity (Figs. 41 and 42).

A

Fig. 35. Eastern part of the channel sandstone in the White Cloud shale. Locality 4, Sec. 27, T. 11 S., R. 11 E., Shawnee County.

B

Howard

Fig. 36. Contact between the Howard Limestone and White Cloud shale. Note thickness of lower shale in the White Cloud (sh. W. C.)
Letters B, C, E, F, H, and I indicate parts in the graphic section (Fig. 34).

C

Fig. 37. Remnants of the lower shale in the White Cloud (sh. W. C.)

D

Fig. 38. A few yards west from above picture, lower shale has been reduced to about 1 foot.

E

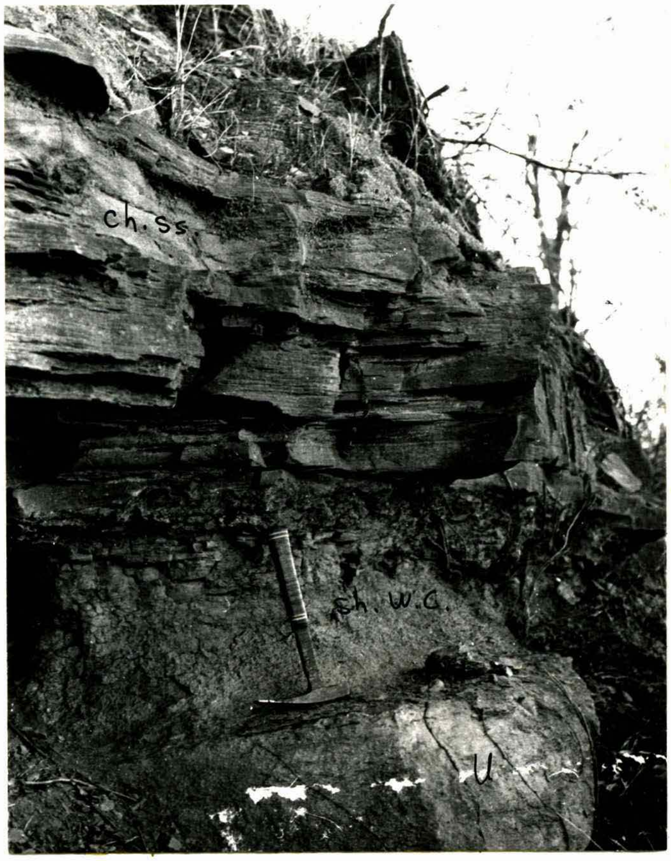


Fig. 39. Channel sandstone (ch. ss.) resting upon remnants of lower shale of White Cloud (sh. W. C.) and overlying Utopia limestone (U).

F

Fig. 40. Channel sandstone resting upon Howard Limestone.

G

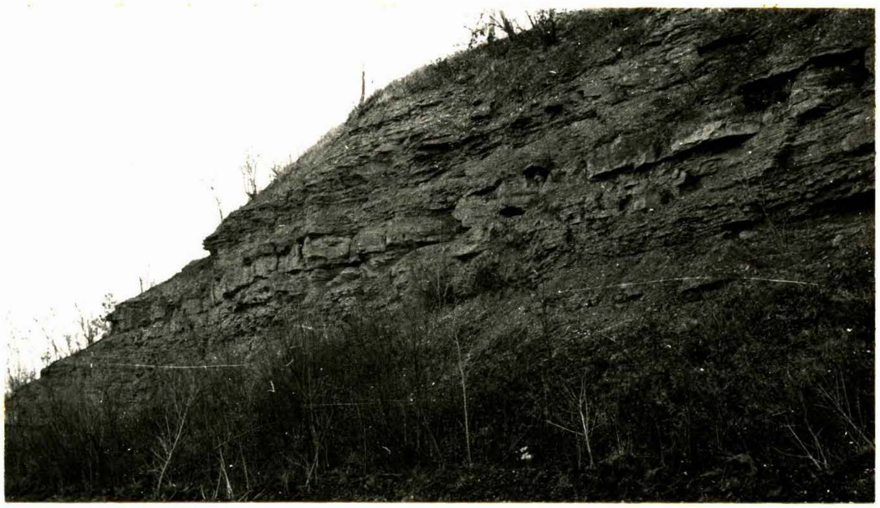


Fig. 41. Another view of the channel sandstone resting upon Howard Limestone.

H

Fig. 42. Flat-lying sediments composing the channel sandstone.

I

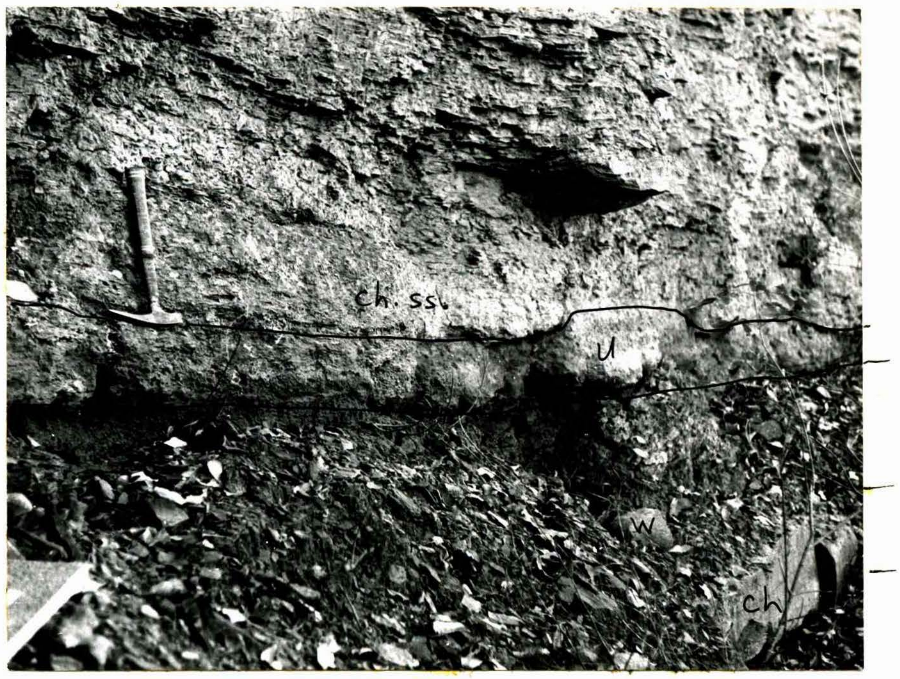


Fig. 43. Relation between White Cloud channel sandstone and beds of Howard Limestone. Church limestone (Ch), Winzeler shale (W), and Utopia limestone (U). Basal conglomerate in the channel sandstone (ch. ss.).

J

Fig. 44. Peel-print of the basal conglomerate in the channel sandstone fill.

SEDIMENTARY ANALYSIS

Insoluble Residues

An insoluble residue, is defined by Ireland (1951, p. 40): "...material remaining after rock fragments have been digested in acid. Hydrochloric acid is generally used, but acetic acid is occasionally used..." This definition applies to the insoluble residue material from the limestone beds of the Howard Limestone.

The insoluble residues of the Church and Utopia limestone members of the Howard received preliminary study by Wahrhaftig (1952).

As previously explained under Laboratory Techniques, two insoluble residue fractions were obtained, the fine and the coarse. The fine-fraction was not studied, because it did not show anything diagnostic. Hence only the coarse-fraction was studied for this report.

Table 1 is a classification of insoluble residues of the Howard Limestone based on the outline by Ireland (1936). Each type will be discussed under its proper heading. Appendix B gives the residue weights and corresponding percentages for each member and unit of the Howard Limestone.

A detailed description of the samples will be found in Appendix C. The terminology followed is that of Ireland, et. al. (1947).

Table 1. Classification of insoluble residues of the units and members of the Howard Limestone.

I. Allogenic - Constituents derived from previous sediments

   1. Quartz sand grains and silt aggregates
   2. Argillaceous material
   3. Mica flakes

II. Authigenic - Constituents formed contemporaneously with or subsequently to the deposition of the sediments.

   A. Syngenetic - Contemporaneous constituents
      1. Fossils
      2. Glauconite
      3. Carbonaceous material

   B. Epigenetic - Subsequent constituents
      1. Silicified fossils
      2. Interstitial silica
      3. Secondary quartz

   C. Syngenetic or Epigenetic
      1. Chert
      2. Pyrite
      3. Limonite

Allogenic

Quartz sand and silt aggregates.- Quartz sand grains are a common coarse-fraction in the Howard Limestone, and along with silt and silty aggregates constitute the greater percentage of the total residue. The quartz sand appears as loose, clear to slightly frosted grains, most commonly anhedral to subhedral, rarely euhedral. It makes up from 80 to 93 percent of the residue in the Bachelor Creek limestone member. In the Church and Utopia limestones, the percent of quartz is quite variable from a trace to 50 percent, with an average of 12 percent.

The Howard Limestone beds that are low in quartz sand were found to contain larger amounts of silt aggregates. These aggregates seemingly are stained by limonite; they are micaceous, and are usually poorly consolidated. The amount of silt aggregates varies from a trace to as much as 85 percent, with an average of 40 percent.

Argillaceous material.- This was found in a few sections as lumps of flocculated clay material, light-green to pale-brown, spongy, micaceous, and poorly consolidated aggregates. The amount of these aggregates ranged from 2 to 58 percent; the average, however, was less than 10 percent.

Mica flakes.- Mica is rather common, but makes up only a fraction of the total residue. It occurs as loose, clear flakes, that are irregular in outline; and commonly constitutes from 1 to 3 percent of the residue. This amount possibly be more in the residues that contain silt and clay aggregates, as mica flakes form part of the fine cementing material. The residues from the Bachelor Creek member contain an average of 10 percent of mica flakes.

Syngenetic

Fossils.- Arenaceous foraminifer tests and fragments are the most abundant fossils observed in the residues of the Howard. These consist of aggregates of fine quartz silt-size grains. They range in color from white to light gray. The abundance of arenaceous foraminifers varies with the different members. The Church limestone contains from 30 to 60 percent, with as much as 80 percent in locality 14. The amount of these foraminifers in the Utopia member is variable, ranging from only a trace to as much as 90 percent, locality 22. The Bachelor Creek, in most localities, contains only traces of these foraminifers. The "Wauneta" bed also contains abundant forams, with amounts ranging from a low of 12 percent in locality 22, to a high of 82 percent in locality 25. Foraminifers present are shown in Table 2.

Sponge spicules were found to be abundant, but restricted only to locality 8. These are composed of white finely granular or clear silica, and in the form of monaxons, triaxons, and desmas. The amount of spicules in this locality ranged from 15 to 30 percent.

Table 2. Arenaceous Foraminifera present in the Utopia and Church members of the Howard Limestone (taken from Ireland, 1956, pp. 831-864).

Species described:	Utopia	Church
Ammodiscella virgilensis Ireland	a*	a
Ammodiscus annularis (Brady)	a	a
Ammodiscus semiconstrictus Waters	a	a
Ammovertella inclusa (Cushman and Waters)	vc	
Ammovertella labyrintha Ireland	vc	
Ammovertella primoparva Ireland	c	
Ammovertella prodigalis Ireland	c	
Glomospira articulosa Plummer	a	a
Glomospira pusilla (Geinetz)	a	a
Glomospira simplex Harlton	a	c
Glomospira umbiculata (Cushman and Waters)	vc	
Hyperammina glabra (Cushman and Waters)		c
Psammosphaera gracilis Ireland		c
Thurammina lawrencensis Ireland		c
Thurammina diforamens Ireland		p

*Note:

p - present

c - common

vc - very common

a - abundant

ranged from 15 to 30 percent.

Glauconite.- Glauconite is abundant locally in some beds of the Howard. This occurs as light green, amorphous, soft masses. It is sparsely present in the Utopia limestone, except in locality 10, where in the unit below the fusulinid-bearing bed glauconite makes up for 50 percent of the residue. The uppermost shelly part of the Church limestone member contains glauconite in amounts ranging from 25 to 40 percent, and only scattered grains are present in the massive Church proper.

Carbonaceous material.- This was found to be an extremely minor constituent in the coarse fraction of the Howard. Only scattered small fragments were found, except in the Bachelor Creek which contains from 3 to 5 percent of carbonaceous material in all localities.

Epigenetic

Silicified fossils.- Fossils, replaced by silica, were found in abundance only in locality 8. In amounts these fossils range from 5 to 40 percent. Among the silicified fossils present are Punctospirifer, Hustedia, Crurithyris, fenestrate bryozoans, productid spines, ostracods, spired gastropods, and unidentified shell fragments. The Church limestone in locality 10 was found to contain about 15 percent silicified fossils.

The silica is generally white, clear to opaque, chalcedonic, with a granular to smooth texture.

Interstitial silica.- Interstitial silica was found to be restricted to locality 8. It is composed of clear to opaque, dolomoidic silica, and quartz in irregular masses. It is interesting to note that the only place where interstitial silica is found, and it is the place where silicified fossils occur. The amount of interstitial silica in this locality was found to be about 18 percent.

Secondary quartz.- Secondary quartz is a minor constituent in the residues of the Howard Limestone. It is found to be clear subhedral to anhedral, and distributed throughout the area from a trace to 2 percent.

Syngenetic or Epigenetic

Chert.- Chert occurs in various amounts in the Howard Limestone. This is found to be chalcedonic, white, granular, ordinary to lacy, and it was present only in localities 7, 8, and 18, with amounts ranging 10, 40, and 2 percent respectively.

Pyrite.- Pyrite commonly occurs in the coarse-fraction of the Howard Limestone as striated cubes, octahedrons, amorpheous aggregates, and partially or entirely replacing fossils such as *Rhombopora*, *Cancranella*, productid spines, and shell fragments. Pyrite is present in the Church member in all localities ranging from a trace to as much as 80 percent in locality 11, the average, however, is rather a constantly 35 percent. The pyritized fossils mentioned above, are found only in this bed.

The amount of pyrite in the fusulinid-bearing Utopia is negligible in most localities, except in locality 3, where it amounted to 57 percent.

The "Wauneta" limestone bed as an average of 14 percent of amorphous pyrite.

In all localities the Bachelor Creek contains only rare amounts of pyrite. The amounts of pyrite in the rest of the Howard are variable ranging from a trace to 75 percent.

Limonite.- Limonite is common constituent in almost every residue of the Howard beds. It shows as an amorphous, spongy masses, and makes up about 5 percent of the total residue. It was found that some samples of the Church limestone contain as much as 40 percent.

Acetate peels, Thin-sections, and Etched-blocks

Acetate peels along with thin-sections and etched-blocks were useful tools in studying the microstructures, microlithologies, and textures of the Howard Limestone. Fossils, especially *Osagia*, are shown conspicuously in peel-prints. Best results were obtained by studying the peels, prints, and etched-blocks together. Mineral determination, however, cannot easily be made from any of these methods, and was done from the insoluble residues, and has been discussed previously.

A series of peel-prints is shown at the end of this section (Figs. 47-79) as illustrations of different diagnostic features among the members of the Howard Limestone. The information gained from these different methods is discussed below. This discussion is arranged by members from the base upwards. All peel-prints have been enlarged 4 times, unless indicated otherwise.

Bachelor Creek Limestone Member

The Bachelor Creek generally has aphanitic texture throughout the area, and it appears to be highly arenaceous and impure. Insoluble residues showed a high percentage of quartz sand-grains. These are easily seen as standing in relief in the etched blocks. The only exception is locality 28, where this member contains many Osagia, in this same place arenaceous foraminifers are very abundant (Fig. 50). Locally this member is quite fossiliferous, as in locality 20, and it has an aphanitic matrix. The fossils are mostly Myalina and productid brachiopods (Fig. 48). In other places, only the upper portion is fossiliferous as in locality 19 (Fig. 47). While in other places, it is devoid of fossils as in locality 23 (Fig. 49).

"Wauneta" Limestone Bed

The "Wauneta" bed, wherever found, shows numerous fossils, including crinoids, in an aphanitic matrix, composed mainly of argillaceous material (Fig. 51).

Church Limestone Member

The Church was found to exhibit the same lithologic character throughout the area studied. It is commonly aphanitic in texture. Fossils in the form of crinoid stems, fenestrate bryozoans fragments are abundant; corals are rare. Some of these fossils in many places are encrusted by Ottonosia algae. These algae are rather diagnostic of the upper part of the Church, and when not encrusting other fossils they are found as amorphous algal masses. Pyrite and arenaceous foraminifers outlines are observed in the peels and etched-blocks of this bed (Figs. 52-57, and 75).

Overlying the Church, at locality 8, there is an extra "limestone" bed, described previously as be part of the Winzeler shale member. This "limestone" bed contains numerous grooved limestone nodules which in peels show an aphanitic texture in argillaceous material and siliceous microorganisms. Sponge spicules easily seen in etched-blocks make the bulk of these grooved nodules(Fig. 60). Other peel-prints of the limestones found in the Winzeler shale are shown in Figures 58 and 59.

Utopia Limestone Member

The Utopia member exhibits the most varied and distinctive lithology of the several members of the Howard Limestone. For purposes of easier description, the member, will be discussed in two parts, the lower and fusulinid-bearing bed. These thin beds are by no means possibly correlated either unit by unit or from section to section. However, as a whole these strata have a conspicuous feature which is remarkably well shown in peels, thin-sections, and etched-blocks made from specimens from each locality. This is the presence of the algae Osagia and less commonly "Marksia". These algal growths are not confined to any particular horizon. Figures 61-74 show the different types of fauna and microlithologies found in the lower Utopia limestone unit.

The Winzeler shale member is absent in locality 10, and the Church limestone is overlain directly by an "algal" bed comprised within the lower Utopia. Figure 64 shows clearly a peel-print of this mottled limestone, that is lithologically different from any other observed in the Howard formation. In this same locality a well developed cone-in-cone limestone was found (Fig. 66).

The fusulinid-bearing Utopia unit shows a persistent fauna and a marked lithologic character. The fusulinids of the genera Triticites are present abundantly throughout the area. Silt-clay particles constitute the aphanitic matrix of this bed in places as disseminated aggregates, and in others constituting a large portion of the matrix.

Summary

Fusulinid-bearing Utopia Limestone Unit

Quartz sand content ranges considerably from 3 to 75 percent;changes are not diagnostic in any way throughout the area.

The presence of arenaceous foraminifers and silt aggregates was found to be interrelated; where arenaceous forams were abundant, silt aggregates diminished in same proportion (Fig. 45).

Pyrite, clay material, and mica flakes were not diagnostic in the unit.

Lower Utopia Limestone Unit

Quartz sand is an abundant constituent found in all localities, with rare exceptions. This residue is a diagnostic feature of the unit. In Shawnee County, quartz is about 40 percent of the coarse residues. This amount diminishes in Osage County, and again steadily grows larger towards Lyon County.

Pyrite is present in almost every locality ranging from a trace to about 25 percent.

Flocculated clay aggregates are present from 8 to 25 percent in Shawnee County, absent in Osage County, and again present in Lyon County from 10 to 25 percent.

Arenaceous foraminifers were the most significant constituents in the lower Utopia. Except for one location, they are abundantly present from 3 to 93 percent, averaging about 40percent. Increasing abundance is noticed in Osage County.

Church Limestone Member

Quartz sand is usually present in small amounts.

Pyrite is a diagnostic constituent, and found to be present in every locality from 3 to 83 percent, however, the average was only about 35 percent.

Arenaceous foraminifers were abundantly present in almost every locality, ranging from 10 to 85 percent, averaging about 40 percent. They seem to be more abundant throughout Osage County.

Glauconite was present in few localities, but when present was abundant (Fig. 46).

Bachelor Creek Limestone Member

Quartz sand is present throughout the area in amounts over 90 percent. This amount diminishes in the last two southern localities, but the presence of quartz sand is diagnostic feature of the member.

Arenaceous foraminifers are present in very small amounts in the area, and they appear broken, however, in the southernmost locality the Bachelor Creek is full of *Osagia*, and contains about 30 percent of arenaceous foraminifers.

Mica flakes and carbonaceous material, are present in every locality in small amounts.

The diagrams in figures 45 and 46 show a graphical representation of percentages of the insoluble residues and the areal variation in percent of coarse- and fine-fraction content of the Howard Limestone beds.

Shale Study

The purpose of the shale study was primarily to determine the amount of carbonate, argillaceous material, mineral content, and fauna present. In general the shales comprised within the Howard Limestone range from slightly to extremely calcareous. The only exceptions are some of the shales in the lower part of the Aarde shale member. The black fissile shales were found to be only slightly calcareous. Difficulties were encountered in dispersing them because they were highly phosphatic and indurated. Hence the laboratory study consisted only in microscopic examination of the undispersed samples. The shales are discussed from the base upward.

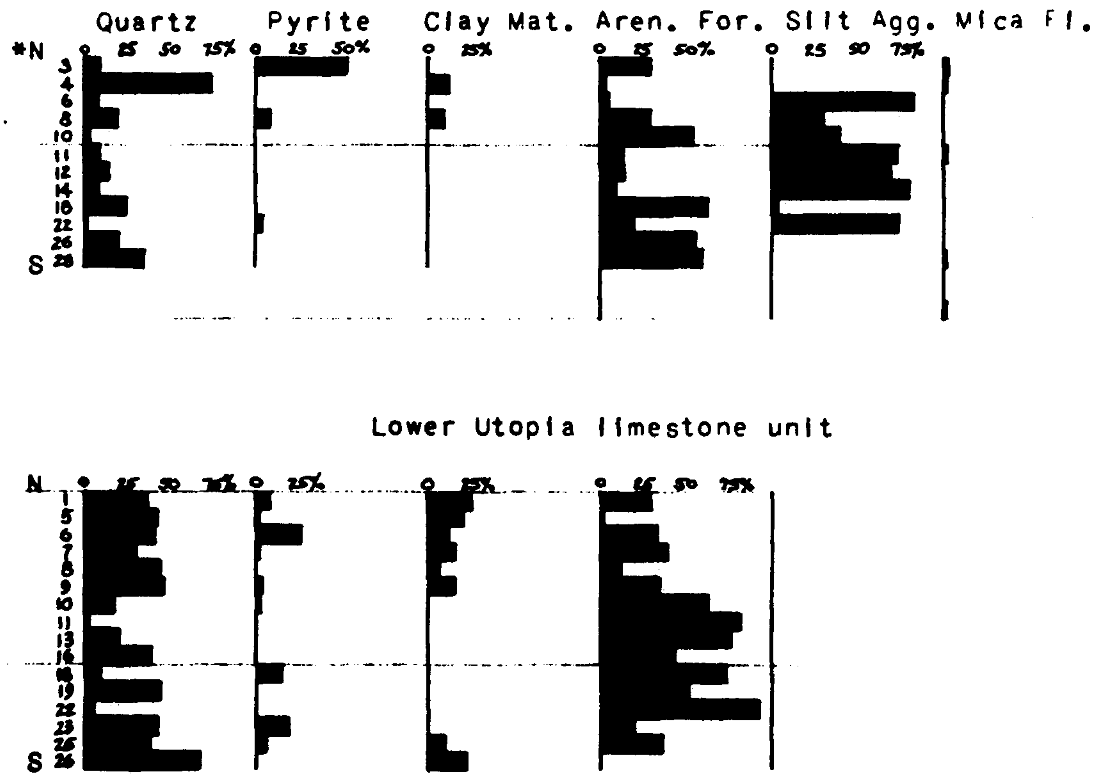
Aarde Shale Member

This will be discussed just in the southern area where the Bachelor Creek limestone member is present, and later in the northern area, where the Bachelor Creek is absent.

In the southern area (Osage and Lyon Counties) as a

FIG. 45. PERCENTAGE DIAGRAM OF THE INSOLUBLE RESIDUE CONTENT OF THE HOWARD LIMESTONE MEMBERS

Fusulinid Utopia limestone unit

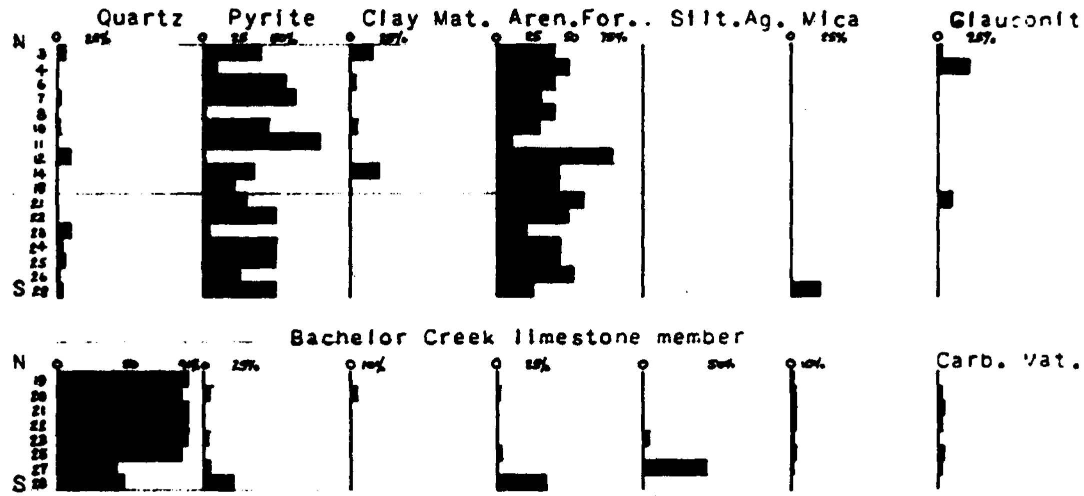


NOTE: N-S indicate North to South locations.
Each square represents 10% residue.
Number at left of bar indicates location.

FIG. 46. PERCENTAGE DIAGRAM OF THE INSOLUBLE RESIDUE CONTENT OF [THE]

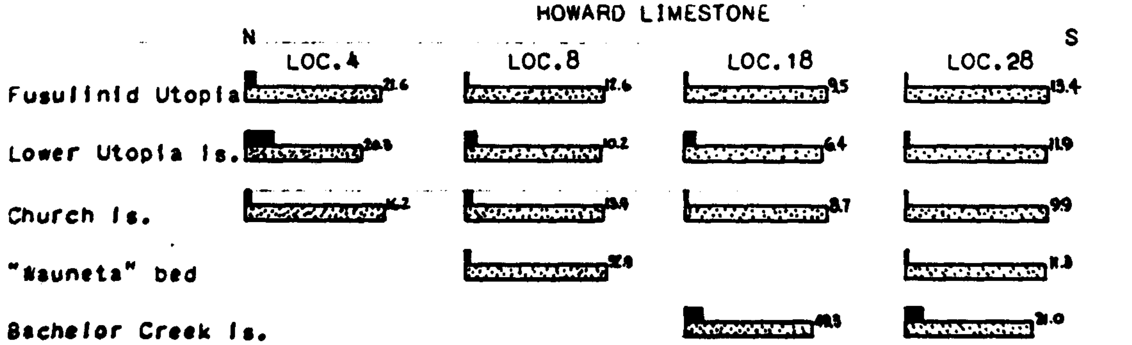
HOWARD LIMESTONE MEMBERS

Church limestone member



AREAL VARIATION IN PERCENT OF COARSE AND FINE RESIDUE CONTENT,

HOWARD LIMESTONE



NOTE: Number at right of bar indicates percent total residue
■ - coarse ; ▨ - fine fraction

general rule, the shale units underlying the Nodaway coal are devoid of fossils and are non-calcareous. Locally these shales are highly sandy to silty and contain abundant mica flakes, limonite, and carbonaceous material. The only biota found in these units were plant impressions.

In the southern area the shale between the Nodaway coal and below the "Wauneta" limestone bed, is commonly differentiated into two parts. The part overlying the coal which is silty, devoid of fauna, and non-calcareous, containing abundant plant impressions, mica flakes, and quartz sand. In locality 25, this shale seems to be varved, is slightly calcareous, and contains some small pelecypods of the genus Dunbarella. Overlying the above there is a bed of shale whose base is about 2 feet below the "Wauneta" bed. This shale is usually calcareous and in places contains crinoid stems, clams, and numerous shell fragments. Among the minerals white grains of gibbsite (hydrous aluminum oxide) are present as scattered aggregates in the shale; other minerals present are pyrite, magnetite, and limonite.

Overlying the "Wauneta" bed in the southern area, are at least three shale units that are well differentiated both in the field and in the laboratory. From the top of the "Wauneta" upward are as follows: (1) gray shale, flaky, only slightly calcareous, and sparsely fossiliferous; (2) black, fissile, phosphatic shale with abundant small inarticulate brachiopods of the genera Orbiculoidea and Lingula, the brachiiopod *Crurithyris*, and the pelecypod *Dunbarella*, which are diagnostic fauna of this shale in all localities. The mineral content of this shale include small phosphatic nodules and finely divided pyrite. Next above (3) follows a pale-brown shale, highly calcareous, and that is saccharoidal under the microscope. Fossils usually are present in the form of crinoid stems, common *Punctospirifer*, rare *Chonetes*, and rare *Dunbarella*. The mineral pyrite, selenite gypsum, magnetite, limonite, mica flakes, and others are usually present.

In the northern area, the Aarde shale member consists of three shale units, which are similar to those above the "Wauneta" in the southern area. Some exceptions will be noted.

These shale units are as follows from the base upward: (1) pale-brown to medium-gray shale, impure, and poorly consolidated. Abundant gypsum selenite crystals and kaolinite (?), mica flakes, quartz sand, and carbonaceous material are present. Next above (2) is a persistent black, fissile to platy shale which has the same mineral and faunal characteristics as number 2 in the southern area. Next immediately (3) and underlying the Church limestone member is a pale-brown to buff shale, with numerous crinoid stems, common *Hustedia*, *Chonetes*, *Marginifera*, and ramose bryozoans. The mineral content of this uppermost part includes pyrite, limonite, mica flakes, quartz sand; locally this shale is profusely fossiliferous containing abundant *Hustedia*, *Crurithyris*, *Juresania*, *Chonetes*, *Dictyoclostus*, ramose and fenestrate bryozoans, and crinoid stems.

The Aarde shale member is developed differently in locality 10 than elsewhere; there it attains a thickness of 24.2 feet. Overlying the Nodaway coal in this locality is a black fissile shale with inarticulate brachiopods. It in turn is overlain by 21 feet of medium-gray shale. This latter shale unit contains abundant plant and spore fossils, and common Dunbarella. Quartz sand grains, pyrite, limonite, carbonaceous material, and mica flakes are abundant. This shale, at a horizon about 0.5 foot from the top, changes to light-gray and calcareous, with abundant crinoid stems, fenestrate bryozoans, and common Chonetes. Above the "Wauneta" in this locality, two shale units may be distinguished: a black, fissile shale with Orbiculoidea and Lingula at the base, and a light-brown calcareous shale above. Minerals in these shales are quartz sand, mica flakes, pyrite, and gypsum.

Winzeler Shale Member

This shale is characterized by similar lithology throughout the area studied. Commonly it is medium gray, blocky to flaky, and clayey to calcareous. The common fauna present in this shale comprise well preserved lacy bryozoans of the genus Fenestrellina, and ramose bryozoans of the genus Rhombopora. Other fossils also are present in minor quantities, among them are Neospirifer, Dunbarella, Cancrinella, Bellerophon. The mineral content includes silt and quartz sand, abundant biotite and muscovite flakes, pyrite aggregates, light-green glauconite, carbonaceous material, magnetite, selenite gypsum, chalk or kaolinite (?), carbonaceous material. Sponge spicules are present in the shale in minor amounts at locality 10.

Utopia Limestone Member

The Utopia contains one or more thin shale units. One of the thin shales, in Shawnee County, was found to be very persistent. In this area this shale unit is black, papery to fissile, and only slightly calcareous. The abundance of ostracods is a diagnostic feature of the unit. The mineral content was not observable, due to the fact that these phosphatic shales did not disperse in water or detergent.

In Osage and Lyon Counties, these shales become pale-brown, laminated, calcareous, and silty. They contain abundant ostracods, as in the northern area, and plant impressions. However, in locality 10, Osage County, the shale is absent, nevertheless, the ostracods are present in thinly-laminated limestone layers. In this area the shale contains abundant quartz sand grains, limonite, pyrite, selenite gypsum, and mica flakes.

Fig. 47. Bachelor Creek limestone in locality 10. Note sparseness of fauna and aphanitic texture.

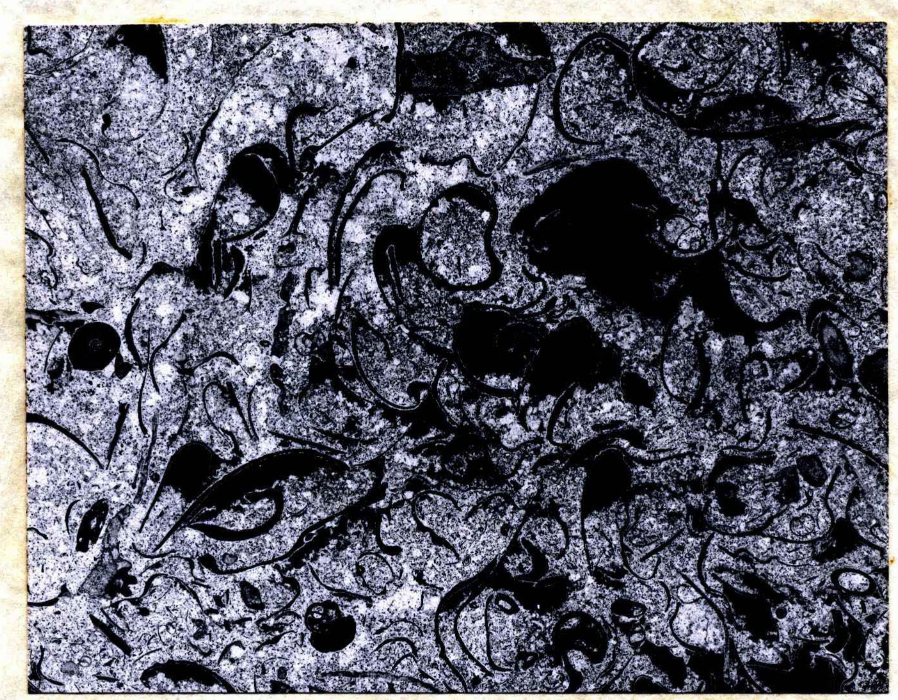


Fig. 48. Bachelor Crek limestone in locality 20. Note abundant mollusks and texture. (Peel-print X3)

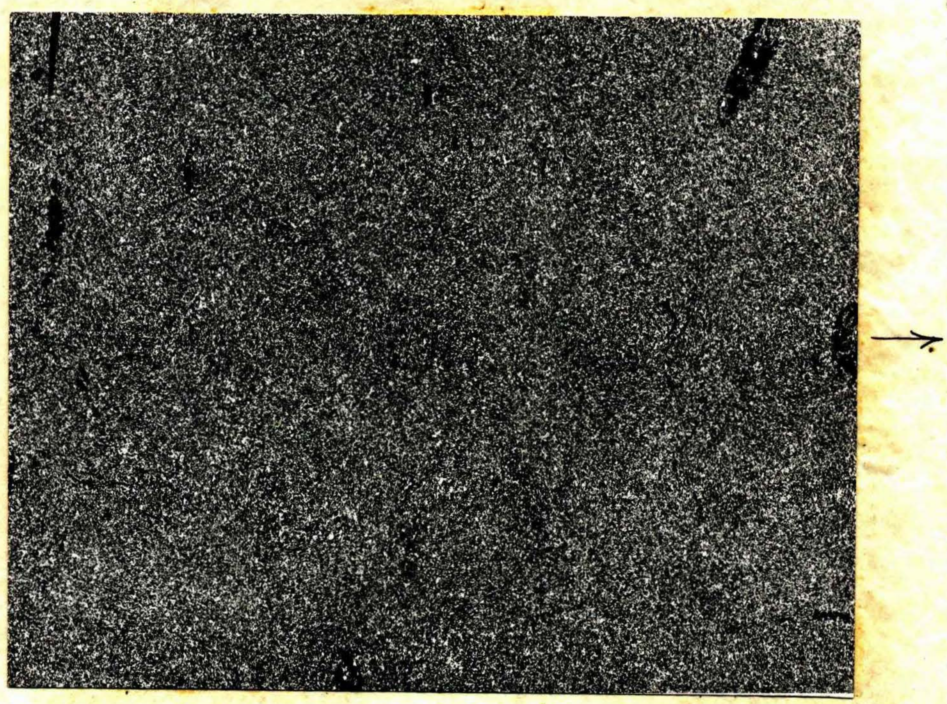


Fig. 49. Bachelor Creek limestone in locality 23. Note sandy texture and absence of fauna.

Fig. 50. Bachelor Creek limestone in locality 28. Note abundance of Osagia and arenaceous forams.

Fig. 51. "Wauneta" limestone bed in locality 10. Note fossil fragments and aphanitic texture.

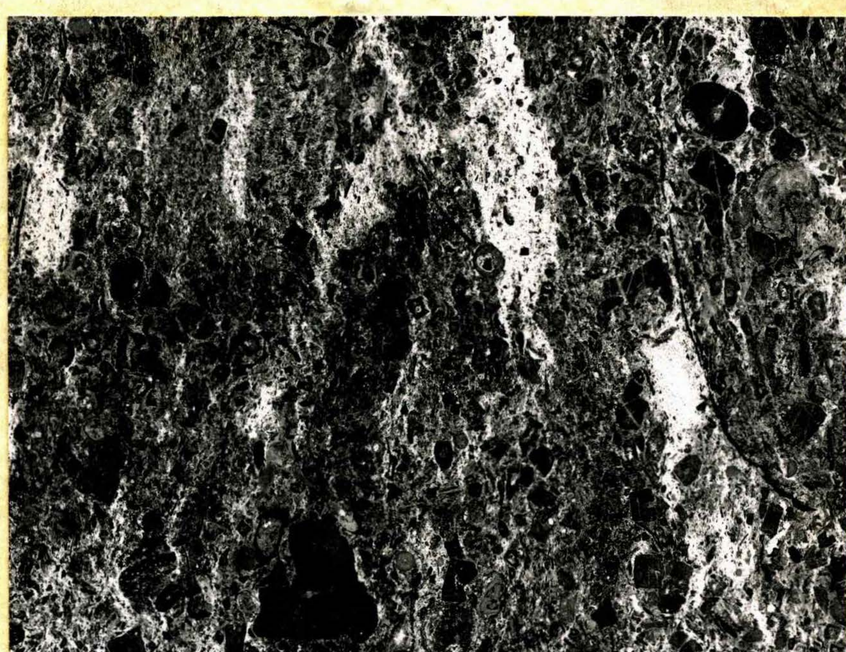


Fig. 52. Church limestone member in locality 2. Note fine-grained texture and fossil fragments.

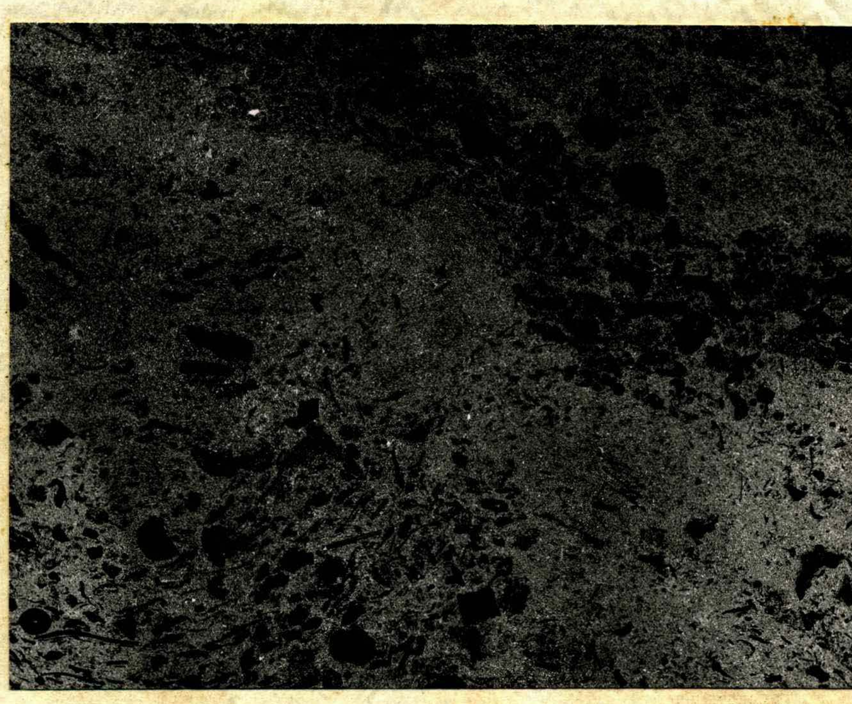


Fig. 53. Church limestone in locality 4. Arrow indicates up.

Fig. 54. Church limestone in locality 10.

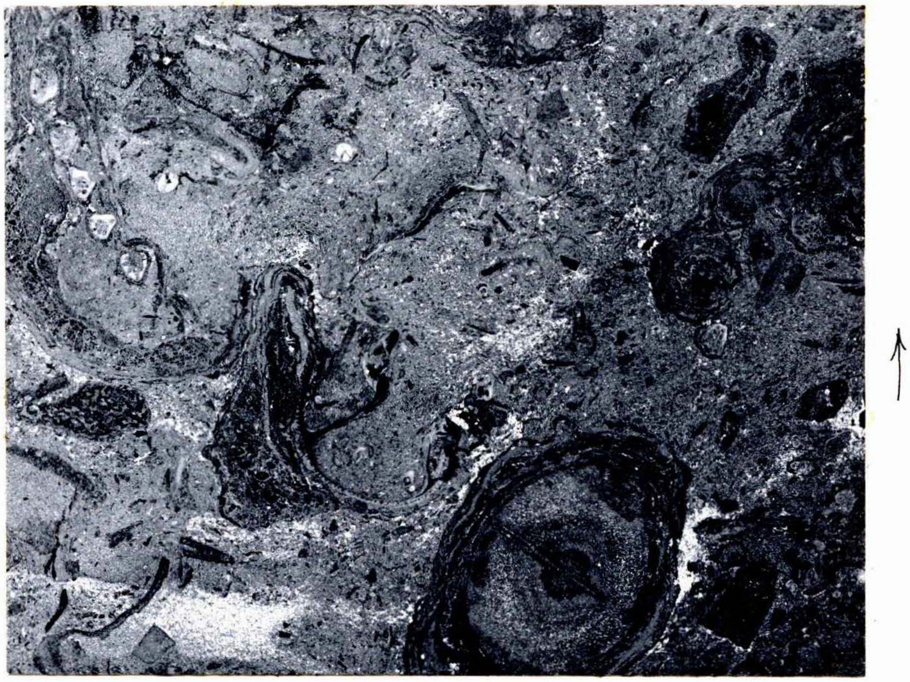


Fig. 55. Church limestone in locality 12. Note fossils encrusted by Ottonosia algae.

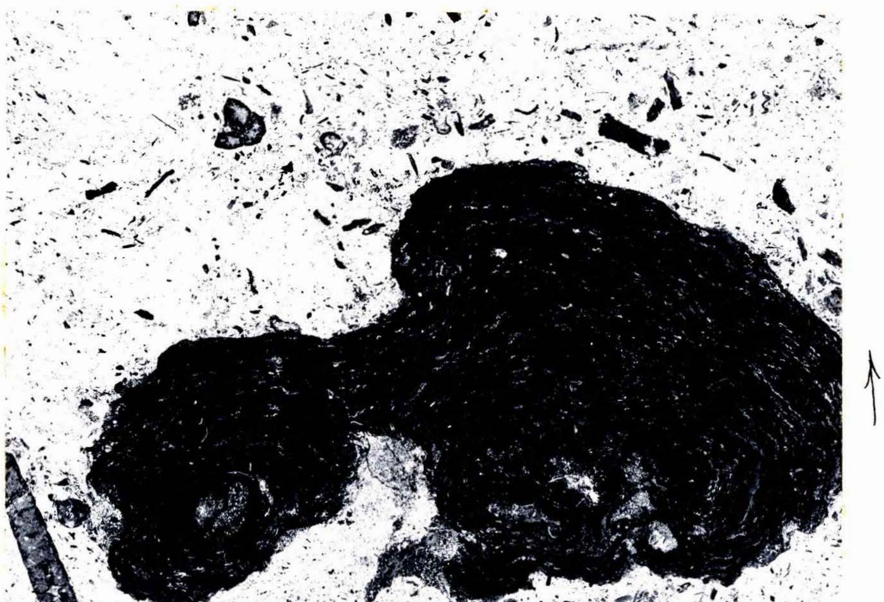


Fig. 56. Church limestone in locality 14. Note Ottonosia algae in fine-grained matrix.

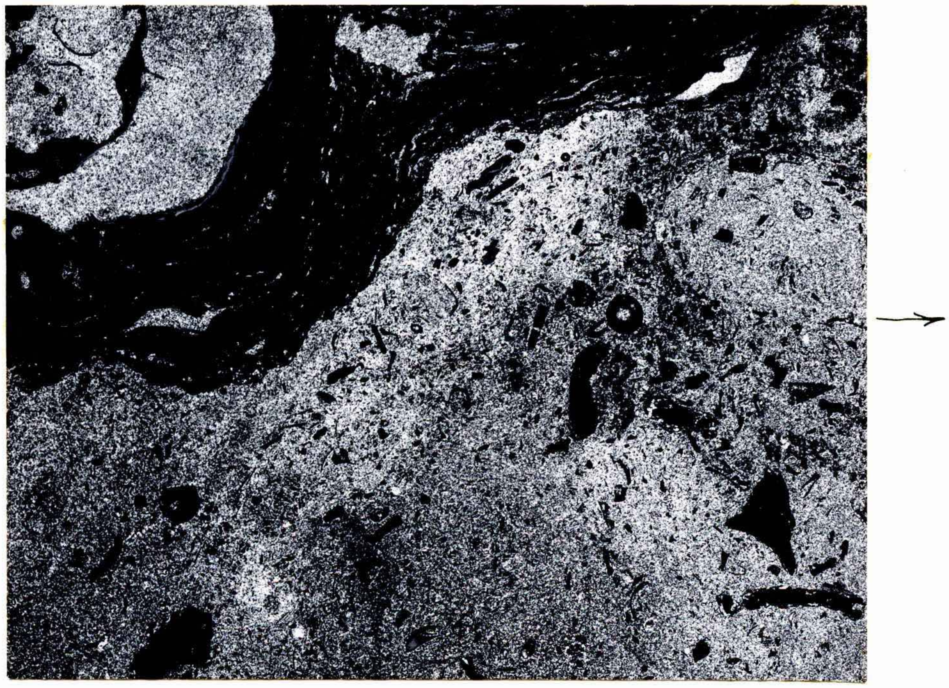


Fig. 57. Church limestone in locality 24. Note <u>Ottonosia</u> and abundant fossil fragments.

Fig. 58. Cone-in-cone in Winzeler shale. Locality 4.

→

Fig. 59. Peel-print of thin limestone in Winzeler shale. Locality 6.

→

Fig. 60. Peel-print of grooved nodule in lower part of Winzeler shale. Locality 8. Note abundant sponge spicules.

Fig. 61. Lower Utopia limestone in locality 3. Note abundance of "Marksia" and fine-grained matrix.

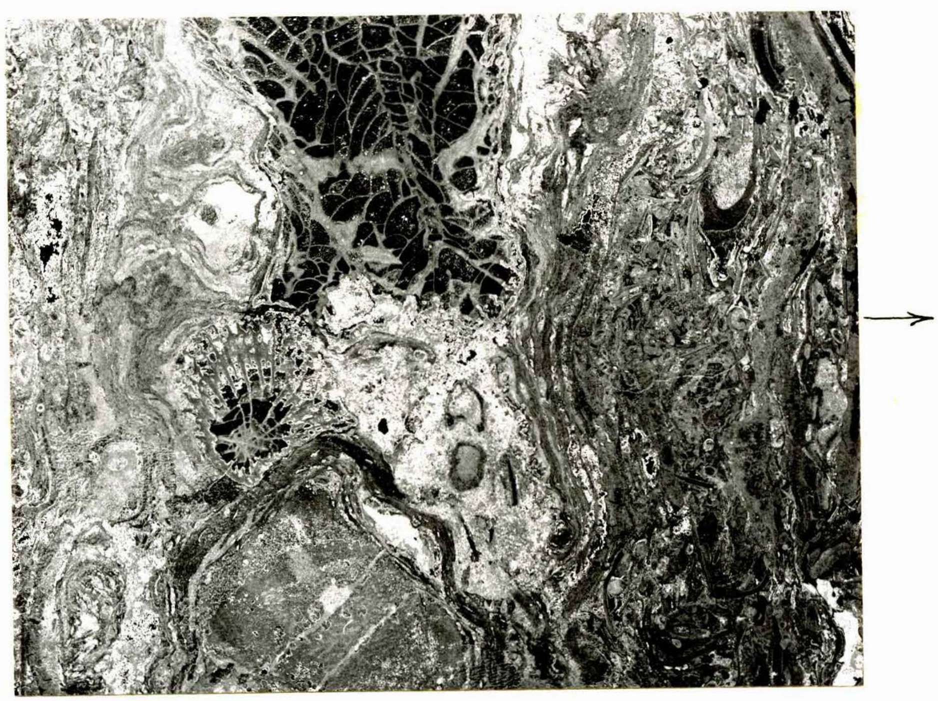


Fig. 62. Lower Utopia limestone in locality 8. Note pyrite nodule with Ottonosia.

Fig. 63. Lower Utopia limestone in locality 8. Abundant Osagia, minute gastropods, and arenaceous forams are noteworthy.

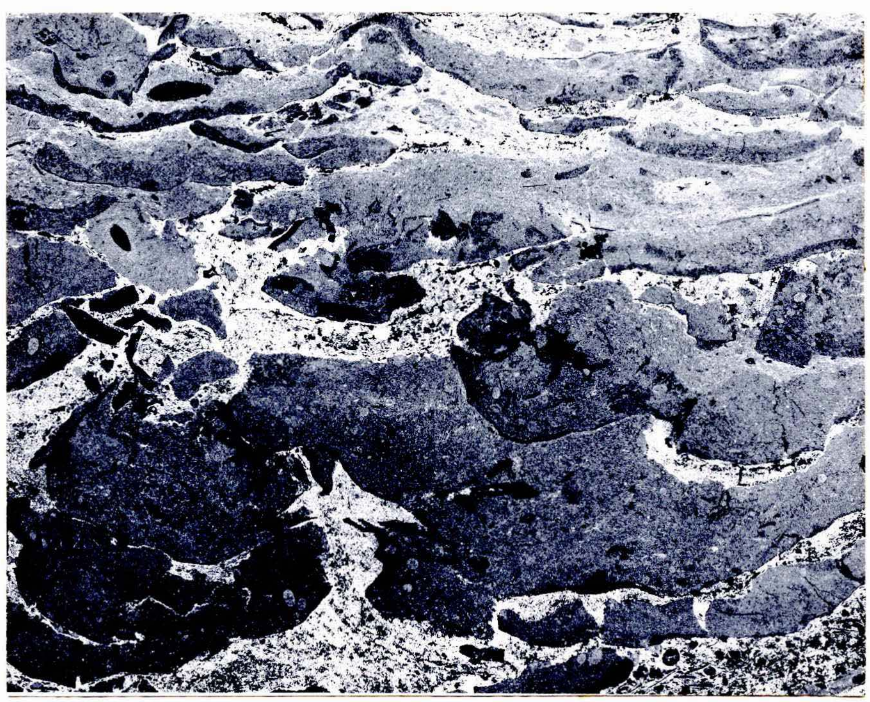


Fig. 64. Mottled limestone in lower Utopia. Locality 10. (Peel-print X3).

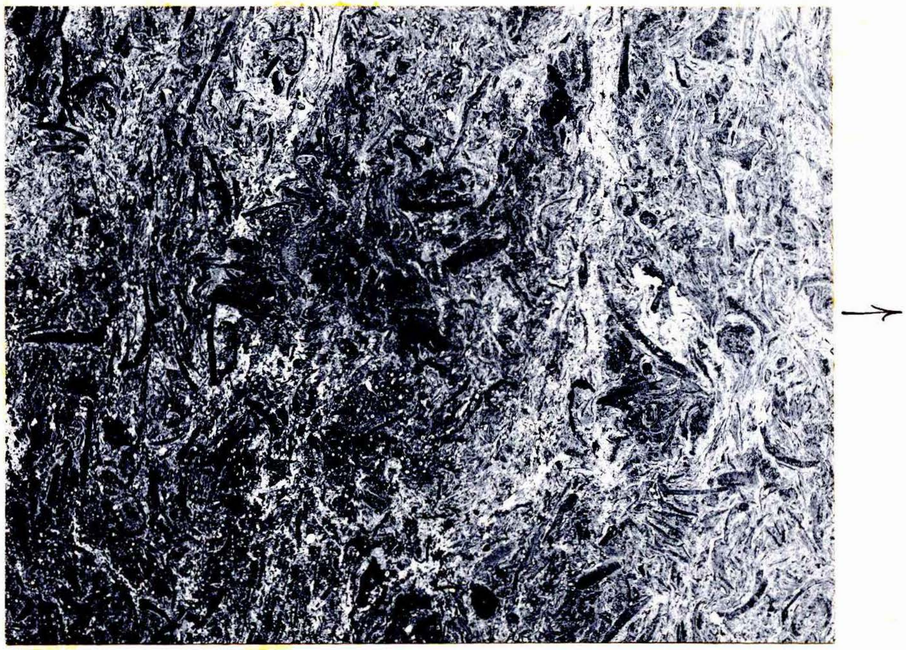


Fig. 65. Lower Utopia limestone in locality 10. Note poor sorting and algae(?).

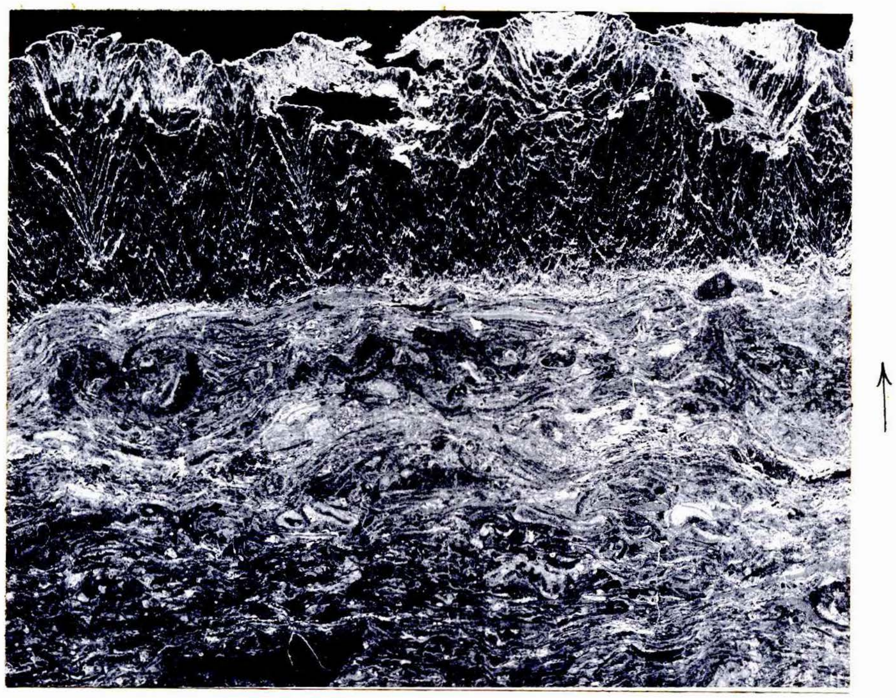


Fig. 66. Cone-in-cone in the lower Utopia limestone. Locality 10.

Fig. 67. Lower Utopia limestone in locality 11.

Fig. 68. "Marksia" in lower Utopia limestone in locality 12.

Fig. 71. Lower Utopia limestone in locality 26. Note pseudolitic texture.

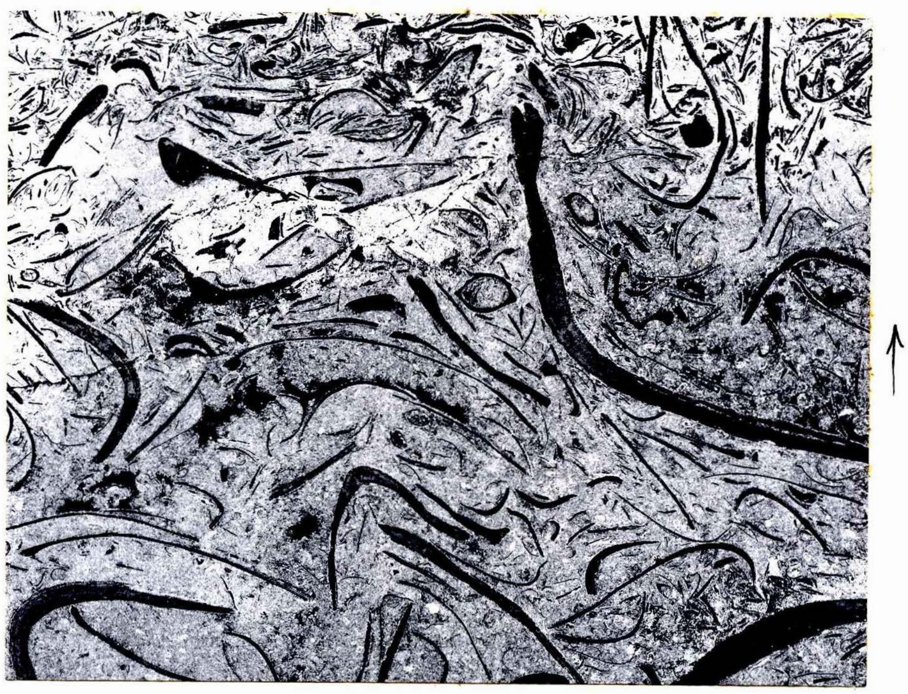


Fig. 72. Lower Utopia limestone in locality 26. Note abundant Myalina.

Fig. 69. Peel-print of thin limestone in lower Utopia in locality 14

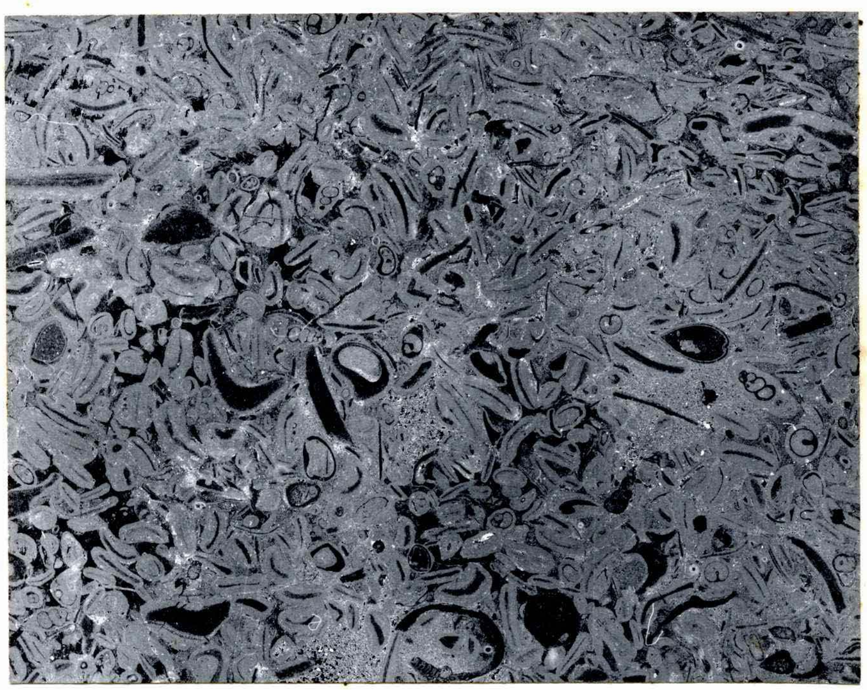


Fig. 70. Abundant Osagia in lower Utopia limestone. Locality 18. (horizontal peel)

Fig. 73. Lower Utopia limestone in locality 28. Note abundance of "Marksia".

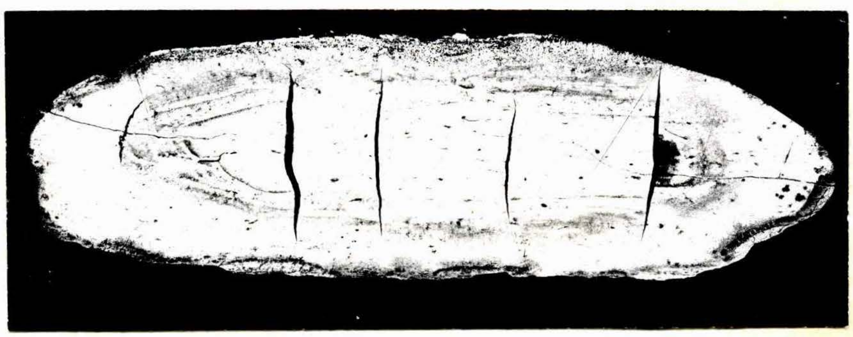


Fig. 74. Limy concretion in shale of lower Utopia limestone. Locality 18.

Fig. 75. Upper part of Church limestone in locality 5. Note Ottonosia encrusting crinoid columnal and bryozoan. (Peel-print X5).

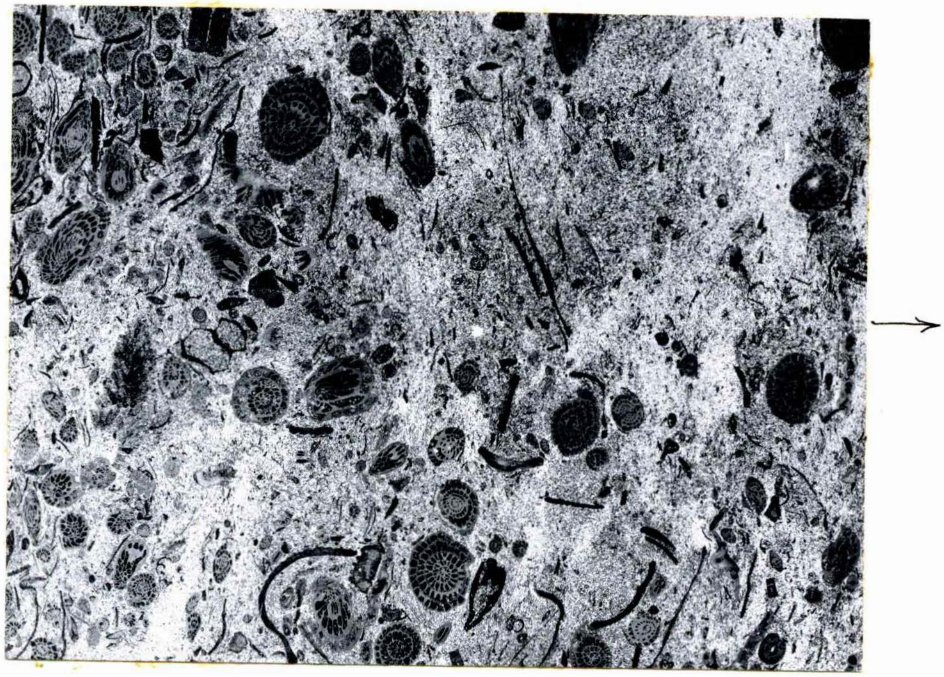


Fig. 76. Upper Utopia limestone in locality 3. Note abundance of fusulinids, sparseness of other fauna, and fine-grained texture.

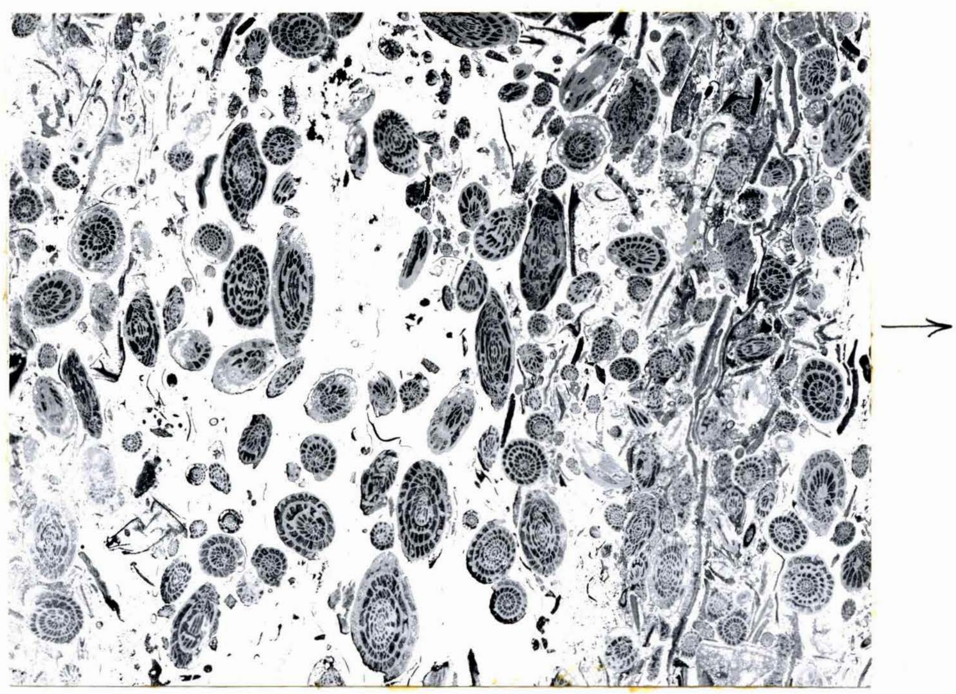


Fig. 77. Upper Utopia limestone in locality 10. Note abundance of argillaceous material (light).

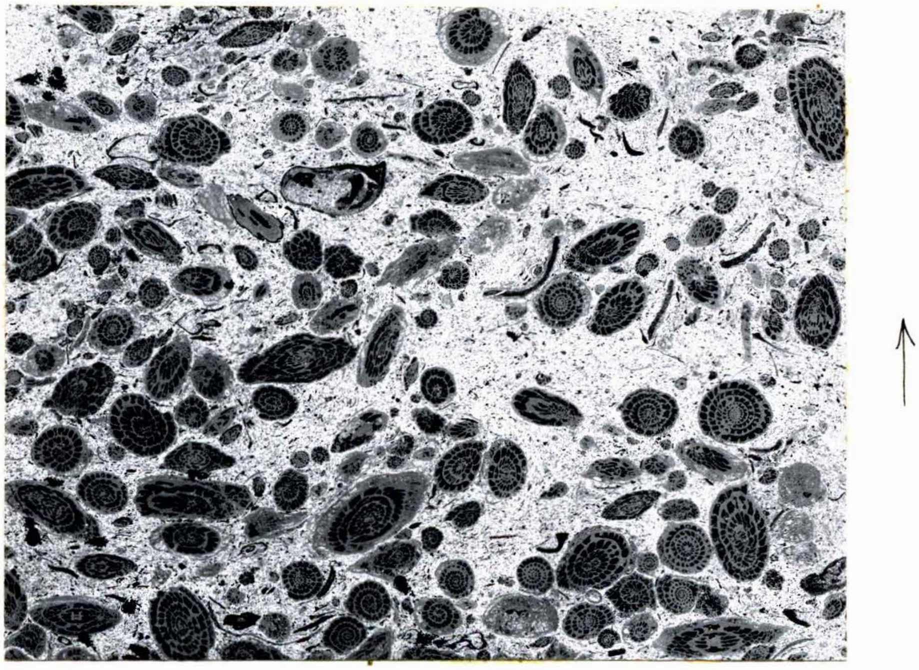


Fig. 78. Upper Utopia limestone in locality 22.

Fig. 79. Upper fusulinid-bearing Utopia limestone. Locality 28. North and up directions indicated.

THE HOWARD MEGACYCLOTHEM

Cyclic Significance of the Howard Limestone

The time of deposition of the Howard Limestone and adjacent units was presumably marked by repetitive transgressions and regressions of the shallow seas.

A cyclical repetition of strata has been given the name "cyclothem" by Weller (1932, p. 1003). The term "megacyclothem" refers to a cycle of cyclothems (Moore, 1935, p. 29).

The Wabaunsee Group, unlike the Shawnee Group, does not show evidence of identifiable megacyclothems. The cyclic sedimentation typical of this group has been termed the Wabaunsee type (Moore, 1948, p. 8). It has been stated that cyclic sedimentation of the Howard Limestone represents a transition between the megacyclothems of the Shawnee Group, and the more simple cyclothems of the Wabaunsee Group (Moore, 1935, p. 205). The Howard Limestone sedimentary cycle resembles more closely the megacyclothems of the Shawnee than a single cyclothem of the Wabaunsee Group. This is shown especially by the presence of a persistent coal bed, a black platy shale, and abundance of varied arenaceous foraminifera. Moore (1935, p. 30) has assigned letters (A to V) to megacyclothems of the Shawnee Group. However, this classification has not been applied to the Wabaunsee Group, and the letters (A to M) of the Wabaunsee refer to cyclothems.

From the study of the cyclical sediments in the Howard, the writer believes that this formation and adjacent units represent a megacyclothem, and will be referred to as megacyclothem "W". This unit extends from the disconformity separating the Severy Shale from the Topeka Limestone up to the base of the channel sandstone in the White Cloud shale.

Megacyclothem W seems to comprise five incomplete cyclothems, which have been named after limestones, and given roman numerals designations to distinguish them from those of the Shawnee and Wabaunsee Groups. These are given in table below.

Table 3. Division of the Howard Megacyclothem

Cyclothems	Symbol
Upper Utopia cyclothem	V
Lower Utopia cyclothem	IV
Church cyclothem	III
"Wauneta" cyclothem	II
Bachelor Creek cyclothem	I

In the northern area, only the upper three cyclothems can be differentiated, inasmuch as the "Wauneta" and Bachelor Creek limestones are absent.

Environments of Deposition and Cyclothems of the Howard Limestone

A study of depositional environments is based upon: lithology, principles of sedimentation, paleontology, stratigraphy, inferred paleoecology, paleogeography, and tectonics.

In this section, an attempt will be made to interpret the conditions prevailing at the time of rock genesis in the area under consideration. Inasmuch as environments of deposition are closely related to the cyclical repetition of beds, these relations will be discussed concurrently.

The depositional environments of the Howard Limestone are related to those of the underlying and overlying strata, therefore the origin of these beds also will be discussed briefly.

Figure 80 is a representation of the Howard formation generalized from several exposures. Inferred variations in sea level during time of deposition are shown by a curve.

Bachelor Creek Cyclothem I

Severy Shale.- The Severy Shale which underlies the Howard Limestone may be regarded to have been developed under both nonmarine and marine conditions. These nonmarine beds are composed of channel-filling deposits, which disconformibly overlie the Topeka Limestone, and occur in a channel deeply cut into it (Moore and others, 1951, p. 63). The absence

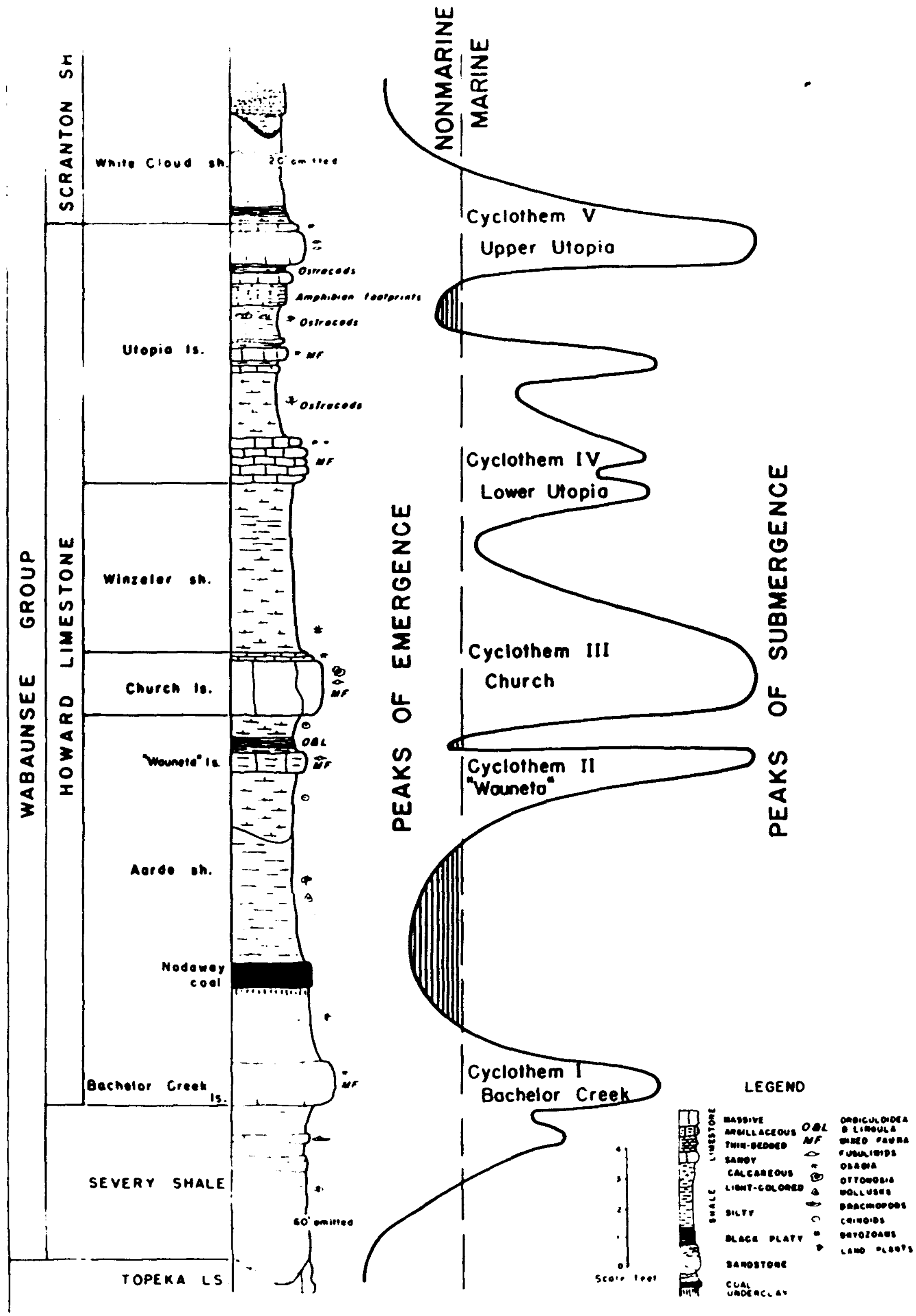


FIG. 80 CURVE INDICATING SHIFTING OF SEA LEVEL IN REFERENCE TO THE BEDS OF THE HOWARD LIMESTONE

of fossils and the irregular disposition of these sediments indicate most likely that they were subaerial in origin rather than marine.

The marine part of the Severy includes uniform, thinly-laminated, fine siltstones and shales, which are chiefly in the upper part. Locally, this phase includes thin sandy limestone beds with marine fossils such as Juresania and Dictyoclostus, and some clams. The seas at the time of deposition of the Severy must have been shallow with probably no restrictions; this is indicated by the lateral persistence of beds.

Bachelor Creek limestone member.- The shallow marine conditions existing during the deposition of the upper part of the Severy Shale are believed to have persisted into the time of Bachelor Creek deposition. Abundant Chonetes give evidence of gradual encroachment of the sea; deeper waters appear to have favored the occurrence of diverse fauna. In general a habitat favorable to several formas of marine life is indicated. The clastic inflow of clay material and quartz sand must have been copious, inasmuch as the Bachelor Creek limestone is highly impure. In some localities the percentage of insoluble residue constituents exceeds that of the calcium carbonate content.

The presence of unfossiliferous, silty, green shale, which are locally interbedded with limestone in the Bachelor Creek member indicates that the bottom must have been highly irregular with small depressions or some fouled conditions existed locally. This accounts for the sparseness of fauna. However, the latter conditions must not have been widespread, because the local occurrence of osagite-limestone beds with some mollusks and brachiopods show that the environment was favorable to the growth of Osagia, which is found encrusting shell fragments. The deposition of the Bachelor Creek seemingly was ended by a regression of sea waters and a greater inflow of clay.

Aarde shale member.- Discussion of the environmental conditions under which the Aarde shale was deposited is arranged in accordance to units from the base upwards, following the pattern already established under "Stratigraphy".

Aarde shale Unit a, shale.- Continental or nonmarine conditions must have prevailed during the deposition of the lower shale in the Aarde member. This shale contains profuse plant fossils, and locally is interbedded with sandstone lenses, which are crossed-bedded, thin, and irregular. As a whole, these shales appear to be devoid of fossils. In places this unit grades upward into a thin, clayey, gray shale. Unit a is identified only in the southern area.

Aarde shale Units b and c, underclay and coal (Nodaway).- The presence of the Nodaway coal in the Aarde represents widespread paludal environment that must have prevailed in the region at the time of deposition. The fact that this thin coal, ranging in thickness from only a few inches to 2 feet, is traceable from Iowa, through Nebraska and Kansas, and 50 miles into Oklahoma is believed to indicate swampy conditions over a large area.

The underclay is light gray in color, smooth, clayey, plastic, and locally contains numerous limonite stringers. Locally, a clayey-gray shale occurs below the coal in place of the underclay.

The meaning of the underclays associated with coal is a controversial subject, and there is no intention of advancing any new possibilities. Weller (1931, p. 175) stated that underclays are possibly developed by "...atmospheric weathering during long periods of quiescence." McMillan (1955) concluded that the "...Nodaway underclay is a "fossil" (soil) or buried gley.... Characteristics of gley and underclay are due to organic acids which have moved downward from peat by diffusion." Gley is a soil horizon, bluish gray, sticky, and often structureless.

Aarde shale Unit d, shale.- The last vestiges of continental conditions are indicated by deposition of a silty, micaceous, gray shale above the Nodaway coal. Locally this shale is represented by about 5 feet of thinly-laminated shale, with alternating light and dark-gray bands, resembling varves.

The subaerial weathering which must have affected this shale is indicated in several sections by the local occurrence of the mineral gibbsite, incorporated in the overlying shale. Gibbsite is a hydrous aluminum oxide, and is a principal constituent of many bauxites. It is believed to have been formed in fairly warm climates under terrestrial weathering, and above ground-water level.

This paraconformity, at the gibbsite zone, possibly represents the extreme continental conditions in the area, which ended the Bachelor Creek cyclothem. This nonmarine shale grades upward into a marine-near-shore, gray shale of the succeding cyclothem.

"Wauneta" Cyclothem II

Aarde shale Unit e, shale.- The transgression of the sea is shown by the appearance of marine fossils in the upper part of the shale described above, and marks the beginning of the "Wauneta" cyclothem. This shale, which is below the "Wauneta" limestone bed, is calcareous and contains numerous limestone nodules. Among the fossils present are abundant *Dunbarella*, *Crurithyris*, and crinoid stems. The presence of fauna such as one containing crinoids does not necessarily implies that the water was deep, since they have been found in shallow water deposits. According to Moore (1931, p. 470) crinoids ".... are clearly indicative of slight depth, and even with deposits that represent emergent conditions, is sufficient proof that deep water was not required by these organisms."

Aarde shale Unit f, "Wauneta" limestone.- The emergent seas continued during the time of the deposition of the "Wauneta", but the water probably was somewhat deeper permitting lime-secreting organisms to live.

The limestone bed is highly argillaceous and somewhat impure in the area studied, however, it becomes less argillaceous towards the south, where fusulinids are common.

The insoluble residues showed a constant decrease of clay material toward the south and increasing numbers of arenaceous foraminifers. This is shown in Figure 46.

The fauna is diverse, but fenestrate bryozoans and brachiopods are dominant. The association of bryozoans and brachiopods is common, inasmuch as they are indicative of the same environmental conditions. These organisms are benthonic types which depend more on muddy bottom conditions than on other aspects of the environment.

The deeper water, probably open sea, in which the "Wauneta" limestone was deposited, changed to restricted shallow water conditions and the overlying black shale of the Church cyclothem was deposited.

Church Cyclothem III

Aarde shale Unit a, black platy shale.- This black shale is a very persistent unit. Its stratigraphic position is constantly a few inches below the Church limestone, and overlying the "Wauneta" bed. However, where the "Wauneta" is absent the black shale overlies a highly impure, unconsolidated brown shale, which could indicate the transitional change from continental conditions to a restricted marine environment. The inarticulate brachiopods and brackish-water mollusks contained in this black shale attest that the environment must have been shallow or brackish marine. Black shales, it is believed, usually are deposited in marine or brackish basins in which bottom waters are stagnant, and in which a reducing environment predominates. According to Schuchert (1911, p. 262) "... many of the species of linguiids occur in bays and estuaries, indicating that they prefer a habitat more or less freshened by land waters."

The acidic and perhaps toxic conditions indicated by the presence of finely-divided pyrite and small phosphatic nodules, suggests some stagnation of extremely shallow water. The apparent transgression of this shallow and restricted sea, must have occurred over a fairly wide area as indicated by the uniform persistence of the black shale.

Aarde shale Unit h, pale-brown shale.- This shale indicates a more normal marine condition than the black shale. The stagnant environment was destroyed by invasion of cleaner marine waters eliminating the restrictions which persisted during the deposition of the underlying shale.

The new environmental conditions promoted the growth of numerous carbonate-secreting organisms as shown by abundant crinoid stems and some brachiopods such as *Punctospirifer* and *Chonetes*.

This shale is a persistent unit underlying the Church limestone with a sharp contact and is the highest unit of the Aarde shale sequence.

Church limestone member.- This limestone represents the maximum encroachment of the sea. The widespread environmental conditions must have been very uniform, inasmuch as it is a very persistent bed, recognized with the same lithologic characteristics from Oklahoma to Iowa. The texture of the limestone is typically fine-grained.

The biota of the limestone is dominated by crinoid stems, brachiopods, and sparse corals. Among the brachiopods Enteletes, Composita, Marginifera, and Dictyoclostus are abundant. According to Menard and Boucot (1951, p. 144-145) the brachiopods best adapted to live in faster currents are ones with spherical shapes. The presence of fast currents may be indicated also by broken crinoid columnals.

As previously noted, the algae Ottonosia is typical of the upper portion of the Church limestone. This is found encrusting other fossils. Currents were required to overturn fossils permitting all-around coating by Ottonosia in concentric layers (Figs. 56, 57, and 75). The abundance of Ottonosia may indicate that the water were fairly clear and probably warm to allow the profuse growth of the algae (Johnson, 1947, p. 1108). He states that "... the majority of lime-secreting algae are associated with molluscan and mixed fauna." This statement agrees with the faunal characteristics of this limestone.

Coarse residue was found to increase steadily towards the north. It is difficult to say, however, whether this change indicates nearness to a northern source, because the study was carried out in such a small area (Fig. 46).

The abundance of pyrite in the Church indicates that possibly the limestone was laid down in a reducing environment. Krumbein and Garrels (1952, p. 20) state that "In a marine environment..... precipitation of pyrite is favored by solution of low Eh and high pH also, for they promote the formation of both Fe^{+++} ion and $S^{=}$ ion." Locally, pyrite-replaced fossils and fragments are abundantly present in the Church, clearly indicating that these are of epigenetic origin. Pirsson and Knopf (1947, p. 74) state that "Pyritic replacements of fossils have been atributed to reactions between the sulfur of decaying matter.... and the ion in the enclosing sediments." The Church limestone when weathered shows a typical chocolate brown color, which may be due to the high content of pyrite.

The seas started receding when the upper part of the Church was deposited. This is characteristically shelly and argillaceous. The fauna includes abundant algae and small mixed fauna (Punctospirifer, crinoid stems, and bryozoans).

The abundance of glauconite in this thin crust suggests slow accumulation, inasmuch as this favors the formation of the mineral (Twenhofel, 1932, p. 110).

The upper portion of the Church limestone probably represents the algal-phase of the Church cyclothem, deposited from receding sea waters in a shallow environment.

Winzeler shale member.- The time of deposition of the Winzeler shale was marked by a regression of the sea, resulting in a nearer-shore shale facies. This shale is typically marine, inasmuch as numerous bryozoans are abundantly present. Crinoid stems, pectinids, and some brachiopods are also found locally, and fenestrate bryozoans are diagnostic of the member. These supposely are more prolific in sublittoral regions, and they are adapted for life in environments where wave action and currents are strong (Elias, 1937, p. 419). The excellent preservation and lack of apparent reworking of these fenestrates indicates that they lived and died in essentially the same place.

During the deposition of the Winzeler shale, variations in environment must have occurred vertically and laterally to account for the various limestones comprised in the member. The limestones are lithologically and faunally different from one outcrop to another (Figs. 22-24, and 51, 58-60).

It is believed that the sea was deeper in the areas where such limestones were deposited. These areas of deeper lime-mud were presumably not connected, or perhaps restricted, and consequently the organisms were not free to mingle.

The complete absence of Winzeler shale in some localities may indicate a facies change to a mottled limestone, that overlies the Church member (Fig. 64).

It is interesting to note that, except for local variations, the Winzeler shale is a persistent member with the same lithological and faunal characteristics from Oklahoma to Iowa. This suggests the widespread envirónment in which the shale was deposited.

The Winzeler probably includes the end-phase of the Church cyclothem, and the starting-phase for the Utopia cyclothem.

Lower Utopia Cyclothem IV

Lower Utopia limestone unit.- A return to a more normal marine environment came about during the time of deposition of the Utopia limestone member. This invasion of the sea possibly was gradual as shown by the alternating thin shales and limestones of the lower part of the Utopia.

Exceedingly shallow seas presumably were present to account for the thin-bedding characteristics of this unit. The interval represented by the deposition of the shales and interbedded limestone units, was marked by abundant clastics laid in shallow waters. However, the clastics were probably deposited slowly, inasmuch as most of the same organizms continued to live in the environment.

Fossils are extremely abundant in this unit. Mollusks, brachiopods, crinoid stems, bryozoans, Osagia, and arenaceous foraminifers are characteristic of the lower Utopia.

However, these fossils are chiefly concentrated in the thin limestones, with the exception of ostracods which are also present in the shales. Ostracods are supposely adapted to all types of environment. This is corroborated by the presence of these organisms in silty-gray shales, black shales, and even in thin limestones of the lower Utopia unit.

The delicate ostracod shells are not fractured or broken which suggests that they have not been reworked or carried by currents for very long distances. Locally, the shales contain land plants.

Throughout most of the area studied, osagite beds are common in the Utopia. Osagite limestones are believed to have formed in clear, shallow water about 60 feet deep; the water must have been agitated gently in order that the algae be encrusted on all sides of the shells. The fossil fragments were possibly developed in shallow water where breaking by waves was common.

Arenaceous foraminifers tests were found abundantly and well preserved. The state of preservation may be indicative that quiet waters prevailed during the time of deposition. The abundance of these arenaceous forms may account for the almost complete absence of silt-size particles, which are generally used by these organisms to make their tests (Fig. 45).

The presence of amphibian footprints in this limestone, presupposes a shallow water environment. Whether these amphibians were fresh-water or marine is not known.

In summary the lower Utopia unit was probably deposited in a shallow and fluctuating marine environment. At times the seas apparently were very shallow leaving the area along the coast under very low water, but never reaching terrestrial conditions. The seas were restricted at times to account for the formation of black shales. These shallow seas abounded with living fauna, and enough micro-organisms present to provide nutrients. The same fauna was not widespread, but rather confined to local areas, in order to account for the lateral discontinuity of thin beds containing this same fauna.

Abundant euhedral quartz is evidence of a nearby source area; the amount of quartz decreases towards the south (Fig.45).

These alternating beds of limestone and shale grade into a massive limestone in the upper part of the member, and form the fusulinid-bearing upper Utopia unit.

Upper Utopia Cyclothem V

The presence of fusulinids has been interpreted as representing the maximum transgressions of the sea, thus indicating that the upper Utopia was deposited during the deeper water phase of this cyclothem.

The environment of deposition must have been widespread, inasmuch as this limestone appears with the same lithology and faunal characteristics throughout the area studied.

According to Moore (1929, p. 467) fusulinids "... are important rock builders, in many places crowding out almost all other forms of life." The fusulinids make up the bulk of this rock, with other fossils almost absent. Moore also states that the presence of wellpreserved fusulinids may be indicative that the water was unagitated by currents. Fusulinids are supposedly more abundant in warm, shallow waters, the largest forms being formed where the temperature is the warmest.

The presence of Osagia, in rare amounts in places, may suggest that some algae can occur along with fusulinids in the same waters (Johnson, 1946, p. 1108). Arenaceous foraminifers are abundantly present in some localities, and where these are more abundant the content of silt aggregates diminishes, an indication that these forms used the particles to form their agglutinated tests (Fig. 45).

Locally, a thin limestone occurs above the fusulinid-bearing unit; this upper limestone contains Osagia and a mixed fauna. This may indicate a change in environment toward shallow waters. The limestone is overlaid by shales, which represent the recession of sea waters.

White Cloud shale member.- The lithology and sparse fauna of the shales comprised in the White Cloud represent the gradual regression of the seas and the close of sedimentation of the Howard cycle. The presence of channels cut deeply into the underlying beds most likely indicates the terrestrial nature of the succeding sediments, and the unconformity marks the end of the upper Utopia cyclothem and the final-phase of the Howard megacyclothem.

REFERENCES

ADAMS, G. I., 1903, Stratigraphy and Paleontology of the Upper Carboniferous rocks of the Kansas section: U. S. Geol. Survey, Bull. 211, p. 50.

BEEDE, J. W., 1898, The Stratigraphy of Shawnee County: Kansas Academy of Science Transactions, v. 15, p. 29-30.

__________, 1902, Bulletin of the University of Kansas: Kan. Sci. Bull., v. 1, p. 171.

CONDRA, G. E., 1927, The Stratigraphy of the Pennsylvanian System in Nebraska: Neb. Geol. Survey, Bull. 1, 2nd ser.,

ELIAS, M. K., 1937, Depth of deposition of the Big Blue (late Paleozoic) sediments in Kansas: Geol. Soc. America Bull., v. 58, p. 403-432.

FATH, A. E., 1921, Geology of Eldorado oil and gas field: Kan. Geol. Survey, Bull. 7, p. 43-44.

GALLAHER, J. A., 1898, Bien. Rept. Bur. Geol., and Mines, State of Missouri, p. 54.

HALL, JAMES, 1896, The University Geol. Survey of Kansas, v. 1, p. 104.

HAWORTH, ERASMUS, 1898, Special report on coal: Kan. Univ. Geol. Survey, v. 3. p. 67.

HINDS, H., and GREENE, F. C., 1915, Stratigraphy of the Pennsylvanian Series in Missouri: Mo. Bur. Geol., and Mines, v. 13, 2nd ser., p. 35.

IRELAND, H. A., 1956, Upper Pennsylvanian arenaceous Foraminifera from Kansas: Jour. Paleontology, v. 30, no. 4, p. 831-864.

__________ and others, 1947, Terminology for insoluble residues: Am. Assoc. Petroleum GeologistsBull., v. 31, p. 1479-1490.

JOHNSON, J. H., 1946, Lime-secreting algae from the Pennsylvanian and Permian of Kansas: Geol. Soc. America Bull., v. 57, no. 12, p. 1087-1119.

KRUMBEIN, W. C., and GARRELS, R. M., 1932, Origin and classification of chemical sediments in terms of pH and oxidation-reduction potentials: Jour. Geol., v. 60, p. 1-33.

McMILLAN, N. J., 1956, *Petrology of the Nodaway underclay (Pennsylvanian) Kansas*: Kan. Geol. Survey Bull., v. 119, no. 6, p. 187 and 249.

MENARD, H. W., and BOUCOT, A. J., 1951, *Experiments on the movements of shells by water*: Am. Jour. Sci., v. 249, p. 131-154.

MOORE, R. C., 1920, *Oil and gas resources of Kansas*: Kan. Geol. Survey, Bull. 6, pt. 2, p. 45.

____________, 1929, *Environment of Pennsylvanian life in North America*: Am. Assoc. Petroleum Geologists Bull., v. 13, p. 459-487.

____________, 1932, Kan. Geol. Soc., Guidebook, Sixth Ann. Field Conf., p. 94.

____________, 1936, *Stratigraphic classification of the Pennsylvanian in Kansas*: Kan. Geol. Survey, Bull. 22, p. 29-30.

____________, 1948, *Late Paleozoic cyclic sedimentation in Central United States*: Int. Geol. Cong., 18th Rept., pt. 4, p. 5-16. (1950)

____________, 1949, *Division of the Pennsylvanian System in Kansas*: Kan. Geol. Survey, Bull. 83, p. 165.

____________, and HAYNES, W. P., 1917, *Oil and gas resources of Kansas*: Kan. Geol. Survey, Bull. 3, p. 105.

____________, and others, 1951, *The Kansas Rock Column*: Kansas Geol. Survey, Bull. 89, p. 55-63.

O'CONNOR, H. G., and others, 1953, *Geology, mineral resources, and ground-water resources of Lyon County, Kansas*: State Geol. Survey of Kansas, v. 12, pt. 1

____________, and others, 1955, *Geology, mineral resources, and ground-water resources of Osage County, Kansas*: State Geol. Survey of Kansas, v. 13, pt. 1.

PERKINS, H. C., 1952, *The use of insoluble residues in the study of limestone beds in the Shawnee Group of the Kansas River Valley*: Unpublished Master's thesis, Univ. of Kansas, p. 12-33.

PIRSSON, L. V., and KNOPF, A., 1947, *Rocks and rock minerals*, 3rd ed.: New York, John Wiley and Sons., p. 74.

PROSSER, C. S., 1895, *The Classification of the Upper Paleozoic rocks of central Kansas*: Jour. Geol., v. 3, no. 6, p. 682-705.

SCHOEWE, W. H., 1956, Geographic locations and stratigraphic horizon of Pennsylvanian fossil footprints discovered in Osage County, Kansas by B. F. Mudge in 1873: Jour. of Paleontology, v. 30, no. 2, p. 389-393.

SCHUCHERT, CHARLES, 1911, Paleogeographic and geologic significance of recent Brachiopoda: Geol. Soc. America Bull., v. 22, p. 260-275.

SWALLOW, G. C., 1866, Preliminary report of the Geology of Kansas: Lawrence, p. 21.

TWENHOFEL, W. H., 1932, Treatise on sedimentation: Williams and Wilkins Co., Baltimore, p. 255 and 848.

WAHRHAFTIG, LEON., 1952, Insoluble residue limestones of the Upper Pennsylvanian in northern Kansas: Unpublished Master's thesis, Univ. of Kan., 98 p.

WANLESS, H. R., and WELLER, J. M., 1932, Correlation and extent of Pennsylvanian cyclothems: Geol. Soc. America Bull., v. 43, p. 1003.

WELLER, J. M., 1931, Cyclical sedimentation in the Pennsylvanian and its significance: Jour. Geology, v. 38, p. 175.

APPENDIX A

MEASURED SECTIONS OF THE HOWARD LIMESTONE BETWEEN THE KANSAS AND NEOSHO RIVER VALLEYS, KANSAS

The units and members described below are in stratigraphic order, from the top down.

Locality 1. NE¼, SE¼, Sec. 10, T. 10 S., R. 16 E., Shawnee County, Kansas; measured on south bank of Muddy Creek, 0.2 miles from bridge on State Highway 4, 2 miles W. of Meriden.

	Thickness Feet
Howard Limestone (thikness 12.2')	
Utopia limestone member	
11. Limestone, grayish-brown, weathers yellowish-brown, medium hard, thin-bedded, numerous highly weathered fossils, common fenestrate bryozoans, rare *Dictyoclostus*, common crinoid stems.	2.0
10. Covered interval.	3.5
Winzeler shale member	
9. Shale, medium dark-gray, blocky, calcareous, partially covered. . . .	2.0
Church limestone member	
8. Limestone, bluish-gray, weathers dark brown, hard, massive, dense, numerous crinoid stems and brachiopods.	1.9
Aarde shale member	
7. Shale, pale-brown, blocky to flaky, calcareous, abundant crinoid stems, shell fragments.	1.0
6. Shale, black, fissile.	0.3

Locality 1. (Cont'd)	Thickness Feet
5. Shale, pale-brown, poorly consolidated, carbonaceous material, grades above into 0.1 foot of clayey shale.	0.6
4. Nodaway coal, bituminous, vitreous. . .	0.9
Severy Shale (12.6' exposed)	
3. Underclay, olive to light-gray, plastic, limonite stringers.	1.6
2. Shale, medium-gray, blocky, silty. . . .	4.0
1. Shale, gray, silty, plant impressions, interbedded with sandstones 1 foot thick, buff, fine-grained, lower part covered. .	7.0+

Locality 2. Center, Sec. 23, T. 10 S., R. 16 E., Shawnee, County; measured on N-S road embankment, in center of section.

Howard Limestone (thickness 11.9')	
Utopia limestone member	
8. Limestone, blue-gray, weathers pale-brown, hard, thin-bedded, weathered.	1.0+
Winzeler shale member	
7. Shale, partially covered.	2.5+
Church Limestone member	
6. Limestone, blue to bluish-gray, weathers dark brown, hard, medium-bedded, *Dictyoclostus*, other brachiopods; upper 2 inches shelly.	1.6
Aarde shale member	
5. Shale, pale-brown, blocky to thin-bedded, abundant crinoid stems, brachiopods. . .	1.1
4. Shale, black, fissile, slightly calcareous, few *Orbiculoidea* and *Lingula*.	0.4

Locality 2. (Cont'd)	Thickness Feet
3. Shale, pale-brown, crumbly, soft, detrital.	1.2
2. Covered interval.	3.0
1. Nodaway coal, weathered.	1.1

Locality 3. SE corner, Sec. 2, T. 11 S., R. 15 E., Shawnee, County; measured in west roadcut by N-S bridge, and by stream bank.

Scranton Shale

White Cloud shale member (30.1' exposed)

16. Sandstone, buff to tan, fine-grained, thinly laminated, micaceous, abundant limonite concretions, clay pebbles. . .	26.0
15. Shale, light-gray, blocky, silty, noncalcareous; grades into dark-gray shale near the base.	4.1

Howard Limestone (thickness 15.7')

Utopia limestone member

14. Limestone, blue-gray, weathers pale-brown, hard, massive, full of fusulinids. . . .	1.7
13. Limestone, blue-gray, weathers,yellowish-brown, hard, thin-bedded, weathers into thin slabs, abundant algae, brachiopods. .	0.3
12. Shale, black, platy to fissile, slightly calcareous, abundant ostracods.	0.7
11. Limestone, bluish-gray, weathers yellowish-brown, thin-bedded, medium hard, argillaceous and sandy, micaceous, full of ostracods, few brachiopods and clams. . .	0.2
10. Shale, dark-gray, calcareous, silty. . .	0.3
9. Limestone, gray, weathers pale-brown, medium hard, argillaceous, thin-bedded to nodular, coarse-grained, brachiopods. . .	0.35
8. Shale, medium-gray, flaky to blocky, calcareous.	0.4

Locality 3. (Cont'd)	Thickness Feet
7. Limestones and shales thin, partially covered.	2.6
Winzeler shale member	
6. Shale, medium-gray, blocky, clayey, calcareous, numerous fenestrate bryozoans near the base.	2.1
Church limestone member	
5. Limestone, dark-blue to bluish-gray, weathers dark-brown, hard, dense, one massive bed, fossils weathered out in relief, brachiopods, crinoid stems, and <u>Ottonosia</u> near the top.	2.5
Aarde shale member	
4. Shale, light-brown, flaky, calcareous, numerous crinoid columnals.	2.0
3. Shale, fissile, black, <u>Orbiculoidea</u> and <u>Lingula</u>.	1.5
2. Nodaway coal, bituminous, , , , ...	1.0
Severy Shale (8.0' exposed)	
1. Underclay, light-gray, clayey, plastic. .	2.0
0. Shale, dark-gray, interbedded with thin sandstones.	6.0+

Locality 4. NW¼, NE¼, Sec. 27, T. 11 S., R. 15 E., Shawnee County; measured in south bluff of Kansas River, near new bridge on State Highway 4, by Rock Island R.R., tracks.

Scranton Shale	
White Cloud shale member (37' exposed)	
20. Sandstone, buff to pale-brown, fine-grained, thinly laminated, micaceous, abundant, plant impressions, thin limestone conglomerates at different horizons, irreular contact at base.	15.0+

Locality 4. (Cont'd)	Thickness Feet
19. Shale, light olive-gray, blocky, clayey, silty in places, non-calcareous, _Dunbarella_; lower 3 feet dark-gray to black shale, fissile, sharp contact with limestone below.	.22.0
Howard Limestone (thickness 12.9')	
Utopia limestone member	
18. Limestone, light olive-gray, weathers pale-brown, hard, massive, vuggy, medium-grained, full of fusulinids.	1.75
17. Shale, light-gray, weathers yellowish-brown, flaky, medium hard, calcareous, silty, abundant brachiopods.	0.25
16. Limestone, light-gray, weathers pale-brown, hard, thin-bedded, medium-grained, _Pernopecten_, _Composita_, _Chonetes_, _Derbyia_, and fossil fragments.	0.3
15. Shale, medium-gray, fissile, abundant ostracods, limestone lentils in lower part. .	0.8
14. Limestone, light olive-gray, weathers pale-brown, thin-bedded, coarse-grained, abundant ostracods.	0.6
13. Shale, medium-gray, weathers yellowish-gray, calcarous, slightly silty.	0.2
12. Limestone, medium-gray, weathers yellowish-brown, hard, thin-bedded, medium-grained, few _Dictyoclostus_, other brachiopods.	0.5
11. Shale, medium-gray, flaky, slightly silty, calcareous, micaceous, some shell fragments.	0.5
10. Limestone, bluish-gray, weathers pale-brown, thin-bedded, hard, medium-grained, shell fragments.	0.4
Winzeler shale member	
9. Shale, medium-gray, weathers pale-brown, blocky, slightly silty, fenestrate brwyozoans, present near the top in places 1 inch thick limestone with cone-in-cone.	2.7

Locality 4. (Cont'd) | Thickness Feet

Church limestone member

8. Limestone, dark-blue to bluish-gray, weathers dark-brown, hard, massive, dense, fine-grained, breaks with subconchoidal fracture, abundant crinoid columnals, *Dictyoclostus*, *Composita*, *Enteletes*, *Ottonosia* near the top; sharp contact above and below.	1.8

Aarde shale member

7. Shale, greenish-gray, weathers light-brown, flaky, calcareous, slightly silty, abundant crinoid columnals and brachiopods; locally is 4 feet thick with abundant *Hustedia*, *Crurithyris*, *Astatella*, *Juresania*, *Chonetes*, *Dictyoclostus*, lacy and ramose bryozoans, crinoid stems. . . .	0.6
6. Shale, medium dark-gray, fissile, slightly calcareous, common *Orbiculoidea*, *Lingula*. . .	0.95
5. Shale, greenish-gray, crumbly, soft, abundant fossil plant and carbonaceous material.	0.5
4. Nodaway coal, bituminous.	1.1

Severy Shale (18.0+ exposed)

3. Underclay, light greenish-gray, clayey, limonite stringers.	0.4
2. Shale, light-gray, medium hard.	1.2
1. Shale, greenish-gray, silty, interbedded with sandy stringers, and thin limonitic sandstones, greenish-gray, fine-grained, micaceous, micro-crossed-bedded, limonite nodules.	16.4

Locality 5. NW¼, Sec. 19, T. 12 S., R. 16 E., Shawnee County; measured in south bank of Kansas Turnpike, northeast of south Topeka Interchange.

Howard Limestone (thickness 5.9')

Church limestone member

Locality 5. (Cont'd)

	Thickness Feet
8. Limestone, dark bluish-gray, weathers brown, hard, massive, numerous fossils; upper part thin-bedded and argillaceous.	1.0-3.0
Aarde shale member	
7. Shale, pale-brown, flaky, calcareous, common *Chonetes*, *Hustedia*, *Marginifera*, large crinoid stems, brachiopods, ramose bryozoans, showing irregular thickening, limestone nodules near base.	0.4-3.0
6. Shale, gray, flaky to blocky, scattered grains of kaolinite or gibbsite?, abundant *Hustedia*, *Composita*, *Dunbarella*, crinoid stems.	0.5
5. Shale, light-gray to pale-brown, crumbly, detrital, soft, carbonaceous material, gypsum layer near base.	0.9
4. Nodaway coal, bituminous.	1.0
Severy Shale	
3. Underclay, light gray, plastic.	0.2
2. Shale, medium-gray, clayey.	0.1
1. Shale, olive-gray, silty.	7.0+

Locality 6. SE¼, Sec. 26, T. 12 S., R. 15 E., Shawnee County; measured in north bank of Kansas Turnpike, about 2 miles southwest of south Topeka Interchange and Highway 75.

Howard Limestone (thickness 16.1')

Utopia limestone member

18. Limestone, olive to bluish-gray, weathers gray, with smooth surfaces, hard, medium-bedded, full of fusulinids, some crinoid stems, rare echinoid spines, fenestrate bryozoans, and *Lophophyllidium*.	1.4

Locality 6. (Cont'd)

		Thickness Feet
17.	Limestone, brownish-gray, weathers gray, hard, thin-bedded, nodular in places, abundant *Osagia*.	0.6
16.	Shale, gray, weathers pale-brown, flaky to blocky, clayey, calcareous, carbonaceous and land plant fossil impressions. . . .	0.2
15.	Limestone, gray to brownish-gray, weathers pale-brown, medium hard, thin-bedded, wavy, full of ostracods, abundant pelecypods in bedding planes.	0.15
14.	Limestones and shales, same as 15 and 16. .	0.9
13.	Limestone, dark-gray, weathers pale-brown, hard, medium-bedded, medium-grained, argillaceous to nodular towards top, full of *Osagia* algae.	2.4
Winzeler shale member		
12.	Shale, gray, weathers pale-brown, flaky to blocky, brachiopods fragments, abundant fenestrate bryozoans near the base; clayey towards top containing few bryozoans. . .	3.1
11.	Limestone, light bluish-gray, weathers pale-brown, hard, thin-bedded, fine-grained, argillaceous towards top, abundant bryozoans, common pectinids, crinoid stems, both contacts irregular.	1.0
10.	Shale, gray, flaky, calcareous, *Crurithyris*, *Chonetes*, *Juresania*, ramose bryozoans, spiriferids, gradational contact with limestone above.	0.2
Church Limestone member		
9.	Limestone, dark-gray, weathers dark-brown, one massive bed, dense, fine-grained, breaks with subconchoidal fracture, *Marginifera*, *Dictyoclostus*, crinoid stems, *Ottonosia* incrusting other fossils; upper 2 inches become shelly and argillaceous, numerous fossils and fragments.	2.4

Locality 6. (Cont'd)

	Thickness Feet
Aarde shale member	
8. Shale, dark-gray, weathers pale-brown, clayey, calcareous, abundant crinoid stems. .	0.75
7. Shale, black, fissile, blocky in places, hard, *Dunbarella*, *Lingula*, *Orbiculoides*, few small articulate brachiopods.	1.4
6. Shale, pale-brown, impure, sandy, micaceous, some shell fragments; lower part is black, platy resting on coal.	0.4
5. Nodaway coal, bituminous.	1.2
Severy Shale	
4. Underclay, light gray, plastic.	0.3
3. Shale, gray, blocky, silty, sparsely fossiliferos, few brachiopods, plant impressions. .	1.5
2. Shale, olive-gray, flaky to blocky in places, sandy,micaceous, thin-laminated in places, abundant pyrite nodules 1.5 inches in diameter, numerous well-preserved plant fossils. .	32.5
1. Sandstone, tan to buff, weathers pale-brown, fine-grained, micaceous, limonitic, irregular bedding, non-calcareous, unfossiliferous. .	2.0+

Locality 7. SE corner, Sec. 16, T. 13 S., R. 15 E., Shawnee County; measured in notth roadcut of corner section.

Howard Limestone (thickness 8.7')	
Utopia limestone member	
11. Limestone, blue-gray, weathers yellowish-brown, hard, medium-grained, partially covered.	0.5
10. Covered interval.	2.7
9. Mottled limestone, pinkish-gray, hard, slumped and weathered.	0.3
8. Covered interval.	2.0

Locality 7. (Cont'd)

	Thickness Feet
7. Limestone, medium-gray, weathers pale-brown, medium hard, coase-grained, three thin beds, arenaceous to silty, argillaceous, plant impressions.	0.7
Winzeler shale member	
6. Shale, pale-brown, limy.	0.1
Church limestone member	
5. Limestone, light-gray, weathers yellowish-brown, hard, sub-oolitic, one thin bed, _Lophophyllidium_, spiriferids, crinoid stems, _Ottonosia_, ...	0.7
Aarde shale member	
4. Shale, brownish-gray, limy, grades into limestone above, few crinoid stems, plant fragments.	0.8
3. Nodaway coal, lignitic, limonitic in places. .	0.6
Severy Shale	
2. Underclay, light-gray, plastic.	0.3
1. Shale, light olive-gray, weathers whitish-gray, blocky to flaky in places, limonitic in part, silty, more clayey towards top, no fossils present.	36.0+

Locality 8. NW¼, SW¼, Sec. 33. T. 13 S., R. 15 E., Shawnee County; measured in stream bank, south of house on east side of road.

Howard Limestone (thickness 21.4')

Utopia limestone member

8. Limestone, blue-gray, weathers pale-brown, hard, thin wavy-bedded, medium-grained, upper 3 feet full of fusulinids, lower part nodular and argillaceous, containing numerous, fossils, ...	4.4

Locality 8. (Cont'd) | Thickness Feet

7. Shale, black, fissile, full of ostracods, rare inarticulate brachipods.	0.8
6. Limestone, dark bluish-gray, weathers pale-brown, hard, thin-bedded, medium-grained, highly fossiliferous: _Dielasma_, _Juresania_, _Myalina_, _Composita_, _Punctospirifer_, _Cancrinella_, _Crurithyris_, _Neospirifer_, _Osagia_, ramose and fenestrate bryozoans, crinoid stems, pectenids, mollusks, echinoid parts, interbedded with shale partings.	6.7

Winzeler shale member

5. Shale, olive-gray, weathers brownish-gray, flaky to blocky, calcareous, slightly silty, _Neospirifer_, abundant fenestrate bryozoans, crinoid stems.	1.2
4. "Limestone", light olive-gray, weathers same, hard, dense, fine-grained, highly siliceous, slightly calcareous, contains large and small argillaceous limestone nodules of oblong shape with striated or grooved surfaces, rare _Composita_, and _Dictyoclostus_; upper 0.8 foot are nodular and limonitic, argillaceous, grading into shale above.	4.2

Church limestone member

3. Limestone, dark bluish-gray, weathers pale-brown, hard, dense, medium-bedded, breaks into rectangular blocks, sharp contact at base, _Chonetes_, _Lophophyllidium_, _Composita_, _Hustedia_, _Punctospirifer_, _Marginifera_, crinoid stems, spired gastropods.	2.1

Aarde shale member

2. Shale, gray to light-gray, flaky, calcareous, slightly silty, crinoid stems. . .	1.4
1. Shale, dark-gray to black, fissile, partially covered.	0.6+

Locality 9. SE corner, Sec. 15, T., 14 S., R. 15 E., Shawnee County; measured along north side of section roadcut.

	Thickness Feet
Howard Limestone (thickness 4.9')	
Utopia limestone member	
6. Limestone, brownish-gray, weathers pale-brown, medium hard, thin-bedded, coarse-grained, full of *Osagia*, rare *Myalina*, other fossils.	0.7
5. Limestone, pale-brown, highly argillaceous and weathered.	0.3
Church limestone member	
4. Limestone, blue-gray, weathers pale-brown, hard, medium-grained, thin-bedded, abundant *Ottonosia* towards top.	2.3
Aarde shale member	
3. Shale, gray, calcareous, flaky to blocky. . .	1.0
2. Nodaway coal, limonitic and weathered. . .	0.6
Severy Shale	
1. Shale, light-gray, flaky to blocky.	0.5+

Locality 10. SW¼, NE¼, Sec. 25, T. 14 S., R. 15 E., Osage County; measured in quarry owned by R. A. Linville, about 1 mile southwest of Carbondale.

Howard Limestone (thickness 31.0')	
Utopia limestone member	
12. Limestone, blue-gray, weathers yellowish-brown, hard, thin-bedded, smooth edges, full of fusulinids, rare brachiopods, and fenestrate bryozoans.	0.5
11. Limestone, gray, weathers yellowish-brown, hard, weathered and nodular.	0.9

Locality 10. (Cont'd)

		Thickness Feet
10.	Limestone, brownish-gray, weathers pale-brown, medium hard, thin-bedded, medium-grained, ostracods, rare spired gastropods, abundant Myalina.	1.8
9.	Limestone, blue-gray, weathers pale-brown, thin-bedded, medium hard, sub-oolitic, cone-in-cone, full of Osagia, Myalina, and other pelecypods.	1.1
8.	Mottled limestone, pinkish-gray, weathers pale-brown, medium-bedded, hard, dense, fine-grained.	0.5
Church limestone member		
7.	Limestone, blue-gray, weathers dark-brown, one massive bed, dense, fine-grained, sharp and even contact on top, irregular on bottom, abundant Composita, Naticopsis, few corals, numerous crinoid stems, spired gastropods, spiriferids, abundant Ottonosia incrusting other fossils.	2.1
Aarde shale member		
6.	Shale, yellowish-gray, calcareous, slightly silty, abundant shell fragments, and carbonaceous,material, some crinoid stems, Crurithyris; lower part black, fissile, slightly calcareous, few Orbiculoidea.	0.5
5.	"Wauneta" limestone bed, dark-gray, weathers light-gray, medium hard, one thin bed, highly fossiliferous, argillaceous, coarse-grained, large crinoid stems, Numerous Crurithyris, Juresania, ostracods. . . .	0.3
4.	Shale, light-gray, weathers pale-brown, calcareous, soft, crumbly and detrital, numerous crinoid stems, fenestrate bryozoans Chonetes; irregular bottom contact, abundant shell fragments.	0.5
3.	Shale, medium-gray, weathers light-gray, flaky to blocky, micaceous, impure, silty, numerous pyrite nodules, abundant fossil plant impressions, common Dunbarella	20.7

Locality 10. (Cont'd) — Thickness Feet

2. 2. Shale, black, fissile, abundant pectinids, pyrite nodules; at bottom 0.5 inch thick black, fissile shale above coal, containing numerous pyritized fossils. . . . 0.95

1. Nodaway coal, vitreous, bituminous. . . . 1.2

Locality 11. SW¼, NW¼, Sec. 1, T. 15 S., R. 15 E., Osage County; measured in road bank between sections 1 and 2, along N-S road, about 0.3 miles south of State Highway 56.

Howard Limestone (thickness 18.5+)

Utopia limestone member

12. Limestone, blue-gray, weathers light-brown, hard, thin-bedded, full of fusulinids, ... 0.5

11. Limestone, brownish-gray, weathers pale-brown, medium hard, thin-bedded, medium-grained, full of crinoid stems, brachiopods, fenestrate bryozoans, Osagia. . . . 1.4

10. Covered interval. 4.1

9. Limestone, brownish-gray, weathers same, hard, thin-beded, coarse-grained, some crinoid stems, brachiopods. 1.0

Church limestone member

8. Limestone, blue-gray, weathers brown, hard, dense, Enteletes, crinoid columnals; lower part is partially covered. . . . . 1.0+

Aarde shale member

7. Shale, light to greenish-gray, flaky to blocky, non-calcareous, slightly silty, micaceous, partly covered. 9.5

6. Nodaway coal, partially covered. 1.0

Severy Shale

5. Underclay and shale, partly covered. . . 0.3

Locality 11. (Cont'd) — Thickness Feet

4. Covered interval. 6.0

3. Sandstone, olive-gray, weathers pale-brown, hard, fine-grained, calcareous, micaceous, smooth rounded-edges. . . . 0.6

2. Limestone, blue-gray, weathers light-gray, hard, thin-bedded, micaceous, highly arenaceous, abundant productid brachiopods _Juresania_, _Dictyoclostus_, few clams. 0.7

1. Shale, olive-gray, silty, micaceous, flaky to blocky, slightly calcareous, unfossiliferous,. . . . . 15.0+

Locality 12. Center line, Sec. 20 and 21., T. 15 S., R. 15 E., Osage County; measured on N-S road, about 1.6 miles south of Kansas Highway 56, between Burlingame and Scranton.

Howard Limestone (thickness 18.2')

Utopia limestone member

10. Limestone, blue-gray, weathers pale-brown, hard, thin-bedded, coarse-grained, rare fusulinids, few brachiopods and crinoid stems. 0.5

9. Limestone, dark blue-gray, weathers yellowish-gray, hard, thin-bedded, medium-grained, full of fusulinids. 1.0

8. Covered interval. 5.2

7. Mottled limestone, dark blue-gray, weathers pale-brown, hard, thin-bedded, medium-grained. 0.5

Church limestone member

6. Limestone, blue-gray, weathers a deep-brown, hard, massive, dense, fine-grained, numerous crinoid stems, rare corals, few _Dictyoclostus_, _Ottonosia_, bryozoans. 1.5

Locality 12. (Cont'd)	Thickness Feet
Aarde shale member	
5. Shale, light-gray, flaky to blocky, clayey, slightly calcareous, mostly covered.	8.5
4. Nodaway coal, earthy, weathered.	1.0
Severy Shale	
3. Underclay, light-gray, plastic.	0.2
2. Shale, olive-gray, blocky, clayey. . . .	0.5
1. Shale, brownish-gray, flaky to blocky, highly limonitic, pattly covered. . . .	25.0+

Locality 13. SE¼, Sec. 27, T. 15 S., R. 14 E., Osage County; measured by old bridge on Dragoon Creek, near Highway 75.

Howard Limestone (3.7' exposed)	
Utopia limestone member	
3. Limestone, dark-blue, hard, thin-bedded, flaggy in places, breaks into rhombohedral blocks, abundant fusulinids.	1.7
2. Limestone, light-gray, weathers pale-brown, thin-bedded, full of Osagia, crinoid stems, few brachiopods.	0.6
1. Shale, dark-gray to black, fissile, few ostracods.	1.4

Locality 14. Center south, Sec. 17, T. 16 S., R. 15 E., Osage County; measured in abandoned coal pit, about 220 yards north of E-W road.

Howard Limestone (thickness 13.7')	
Utopia limestone member	
16. Limestone, blue-gray, weathers pale-brown, hard, smooth, full of fusulinids.	0.8

Locality 14. (Cont'd)	Thickness Feet
12. Limestone, brownish-gray, weathers pale-brown, thin-bedded, hard, argillaceous, abundant spired gastropods, *Osagia*. . .	0.4
11. Limestone, brownish-gray, weathers brown, hard, medium-bedded, coarse-grained, pseudoolitic, abundant ostracods, rare corals, common spired gastropods.	0.8
10. Shale, yellowish-brown, soft, earthy, calcareous, interbedded with thin limestone stringers.	1.3
9. Shale, light-brown, flaky to blocky in places, calcareous, slightly silty, abundant fossil plants, interbedded with two thin (0.5 inch) limestones full of ostracods, few pelecypods. . .	1.9
8. Limestone, brownish-gray, weathers light-brown, medium hard, coarse-grained, thin-laminated, full of ostracods, fossil plants, small clams, carbonaceous material, fucoids at the base.	0.3
7. Limestone, blue-gray, weathers light-brown, medium- grained, hard, abundant *Osagia*.	0.6
6. Limestone, dark to blue-gray, weathers pale-brown, thin-bedded, medium hard, coarse-grained, micaceous, argillaceous, abundant ostracods, clams, fenestrate bryozoans, brachiopods, Osagia; lower part grades into nodular limestone. . . .	2.3
Winzeler shale member	
5. Shale, olive-gray, flaky to blocky, calcareous, slightly silty, clayey, abundant fenestrate bryozoans, *Dunbarella*, rare small brachiopods near the top and base. .	1.1
Church limestone member	
4. Limestone, blue-gray, weathers chocolate brown, hard, dense, massive, irregularly jointed, abundant crinoid stems,	

Locality 14. (Cont'd) — Thickness Feet

4. (Cont'd) pelecypods, brachiopods, Ottonosia towards top; upper 2 inches shelly, argillaceous, with numerous Chonetes, other brachiopods. 2.6

Aarde shale member

3. Shale, brownish-gray, blocky, silty, calcareous, crinoid stems and other shell fragments. 0.6

2. Shale, black to brownish-black, fissile, blocky in places, slightly calcareous, few inarticulate brachiopods. 0.4

1. Shale, light-brown, earthy, crumbly, impure, calcareous in places, carbonaceous material, silty, interbedded with shaly limestone nodules. 0.6

Locality 15. SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 30, T. 16 S., R. 15 E., Osage County; measured along N-S roadcut, about 0.9 miles south of State Highway 31.

Howard Limestone (thickness 16.3)

Utopia limestone member

7. Limestone, light-gray, weathers pale-brown, smooth, hard, thin-bedded, medium-grained, numerous crinoid stems, brachiopods, spired gastropods, few Osagia. . . . 2.0

6. Covered interval. 2.5

Church limestone member

5. Limestone, blue-gray, weathers dark-brown, massive, dense, numerous Dictyoclostus, Composita, Lophophyllidium, crinoid stems, Ottonosia. 2.0

Aarde Shale member

5. Shale, light-gray, flaky, clayey, partly covered. 1.8

Locality 15. (Cont'd)

	Thickness Feet
3. Limestone, yellowish-brown, weathers pale-brown, punky, medium hard, unfossiliferous.	1.0
2. Shale, light-gray, clayey, calcareous, unfossiliferous.	2.0
1. Shale, light greenish-gray, limonitic, flaky, partly covered.	5.0+

Locality 16. NW¼, Sec. 7, T.17 S., R. 15 E., Osage County; measured along ditch about 0.2 miles from NW corner of se section.

Howard Limestone (9.8' exposed)

Church limestone member

3. Limestone, dark blue-gray, weathers brown, hard, dense, fine-grained, slumped. . . .	1.8

Aarde shale member

2. Covered interval.	6.0±

Bachelor Creek limestone member

1. Limestone, olive-gray, weathers pale-brown, hard, medium-bedded, arenaceous, few brachiopods and clams.	2.0

Locality 17. NW¼, NW¼, Sec. 18, T. 17 S., R. 15 E., Osage County; along south bank of roadcut, near the corner of section.

Howard Limestone (3.0' exposed)

Bachelor Creek limestone member

Limestone, greenish-gray, hard, arenaceous, impure, micaceous, abundant _Aviculopecten_, _Juresania_, _Rhombopora_, ramose bryozoans, crinoid stems, ...	3.0

Locality 18. Center line, Sec. 14, T. 17 S., R. 14 E., Osage County; measured along small stream east and west of State Highway 170.

	Thickness Feet
Howard Limestone (thickness 29.7')	
Utopia limestone member	
13. Limestone, blue-gray, weathers pale-brown, hard, medium-bedded, medium-grained, smooth, full of fusulinids. . .	2.3
12. Limestone, light-gray, weathers pale-brown, hard, thin wavy-bedded, medium-grained, abundant _Osagia_, _Bellerophon_, common _Myalina_, _Goniasma_, spired gastropods, other brachiopods.	3.3
11. Limestone, light bluish-gray, weathers pale-brown, platy, medium-grained, arenaceous, smooth, containing abundant impressions of amphibian footprints. . .	1.4
10. Shale, gray, silty, abundant land plant impressions, interbedded with thin-calcareous siltstones.	0.7
9. Limestone, light-gray, weathers pale-brown, medium hard, arenaceous, unfossiliferous.	0.1
8. Shale, dark-gray, fissile, slightly calcareous, silty, blocky in places, limy concretions 1 feet from the base, full of ostracods; sharp contact above and below.	2.9
7. Limestone, blue-gray, weathers brownish-gray, medium hard, coarse-grained, platy- to thin-bedded, smooth, ostracods in upper part, abundant _Nuculana_, _Myalina_, fucoids on bottom.	0.6
6. Limestone, light to dark bluish-gray, weathers drab-brown, thin wavy-bedded, medium hard, coarse-grained, argillaceous, numerous _Myalina_, _Aviculopecten_, _Nuculana_, _Fistulipora_, few _Avilopinna_. . .	2.8

Locality 18. (Cont'd) | Thickness Feet

Winzeler shale member	
5. Shale, dark-gray, clayey, blocky, calcareous, slightly silty, numerous fenestrate bryozoans; sharp contact above and below.	2.5
Church limestone member	
4. Limestone, blue-gray, weathers dark-brown, hard, dense, fine-grained, abundant crinoid stems, *Dictyoclostus*, *Echinoconchus*, *Ottonosia*.	2.3
Aarde shale member	
3. Shale, pale-brown, calcareous, partially covered; grades into black, fissile shle, few *Orbiculoidea*.	1.7
2. "Wauneta" limestone, partly covered. . .	0.3
1. Covered interval.	2.5
0. Nodaway coal, weathered.	0.8

Locality 19. SW¼, SW¼, Sec. 17, T. 17 S., R. 15 E., Osage County; measured along south bank of E-W road, starting in a gully about 0.2 miles from southwest corner of section.

Howard Limestone (thickness 24.9')

Utopia limestone member	
12. Limestone, bluish-gray, hard, thin-bedded, partially covered.	9.4
Winzeler shale member	
11. Shale, medium-gray, calcareous, slightly calcareous, silty, partly covered. . . .	3.0
Church limestone member	
10. Limestone, blue-gray, weathers pale-brown, hard, massive, *Ottonosia*, crinoid stems. .	2.1

Locality 19. (Cont'd)	Thickness Feet
Aarde shale member	
9. Shale, light-gray, mostly covered.	5.3
8. Nodaway coal, partially covered.	1.0±
7. Shale, light-gray, partially covered. . .	1.0±
Bachelor Creek limestone member	
6. Limestone, light olive-gray, weathers buff, hard, thin-bedded, highly sandy, ...	1.0
5. Shale, greenish-gray, flaky, silty. . . .	1.0
4. Limestone, olive-gray, weathers pale-brown, hard, massive, sandy, numerous _Dictyoclostus_, _Orthomyalina_, _Neospirifer_, _Acanthopecten_, _Derbyia_, _Linoproductus_, _Chonetes_, _Composita_, fenestrate bryozoans, crinoid stems, echinoid spines, spired gastropods.	1.1
3. Shale, olive greenish-gray, silty, flaky, slightly calcareous,.	2.0
2. Limestone, olive-gray, weathers drab-brown, hard, thin-bedded, highly sandy and argillaceous.	1.0
Severy Shale	
1. Shale, greenish-gray, silty, flaky, unfossiliferous.	7.0±

Locality 20. SW¼, SW¼, Sec. 19, T. 17 S., R. 15 E., Osage County; measured along south ditch in E-W road, about 2 miles east of State Highway 170.

Howard Limestone (thickness 28.2')	
Utopia limestone member	
10. Limestone, blue-gray, weathers pale-brown, hard, thin-bedded, medium-grained, smooth, _Osagia_, brachiopods.	0.8

Locality 20. (Cont'd) | Thickness Feet

9. Covered interval.	10.0
Church limestone member	
8. Limestone, blue-gray, weathers chocolate-brown, hard, massive, dense, fine-grained, numerous crinoid stems, brachiopods, *Ottonosia* towards top.	1.9
Aarde shale member	
7. Shale, Nodaway coal, and underclay present, but mostly covered.	8.0
Bachelor Creek limestone member	
6. Limestone, light olive-gray, weathers pale-brown, hard, massive, thin-bedded in lower part, impure, arenaceous, micaceous, numerous, *Dictyoclostus*, *Chonetes*, *Juresania*, *Enteletes*, *Myalina*, spiriferids, crinoid stems, echinoid spines, gastropods.	2.4
5. Shale, greenish-gray, blocky, silty. . . .	1.0
4. Limestone, olive-gray, weathers pale-brown, arenaceous, medium-grained, abundant *Juresania*, *Chonetes*, ramose bryozoans, interbedded, greenish-gray, calcareous shale, silty, micaceous, blocky, numerous crinoid stems, fenestrate bryozoans, rare Myalina.	2.0
3. Shale, greenish-gray, blocky, micaceous, silty, rare pectinids, few brachiopods. . .	1.3
2. Limestone, olive-gray, weathers pale-brown, medium hard, argillaceous, arenaceous, impure, thin-beded.	0.8
Severy Shale	
1. Shale, olive greenish-gray, flaky to blocky, silty, micaceous, rare *Orbiculoidea*. . . .	8.2

Locality 21. Center north to SW¼, Sec. 34, T. 17 S., R. 14 E., Osage County; measured along small stream and in southwest corner of section.

Howard Limestone (thickness 31.7')	Thickness Feet
Utopia limestone member	
14. Limestone, bluish-gray, weathers pale-brown, hard, thin-bedded, medium-grained, numerous _Myalina_, _Orthomyalina_, _Aviculopecten_, _Composita_, osagite layers.	8.0+
13. Limestone, blue-gray, weathers pale-brown, hard, one thin bed, full of _Osagia_. .	0.2
Winzeler shale member	
12. Shale, gray, clayey, calcareous, numerous fenestrate bryozoans in lower part. . . .	2.3
Church limestone member	
11. Limestone, bluish-gray, weathers brown, hard, dense, massive, fine-grained, numerous, crinoid stems, fenestrate bryozoans, spired gastropods, rare _Lophophyllidium_, common _Enteletes_, _Marginifera_, _Myalina_, _Ottonosia_.	2.2
Aarde shale member	
10. Shale, light-gray, silty, flaky, soft, calcareous, numerous fossils, crinoid stems, rare _Chonetes_, common _Punctospirifer_	0.1
9. Shale, dark-gray to black, slightly calcareous, blocky, hard, rare _Dunbarella_, numerous _Lingula_, _Orbiculoidea_, _Crurithyris_, other brachiopods.	0.6
8. "Wauneta" limestone, medium-gray, weathers pale-brown, medium hard, argillaceous, silty, numerous crinoid stems, _Crurithyris_, rare _Juresania_, _Hustedia_, productid spines, ostracods, other brachiopods.	1.0
7. Shale, light-gray, thin-laminated, silty, limonitic, micaceous.	8.3

Locality 21. (Cont'd)	Thickness Feet
6. Nodaway coal, bituminous.	0.9
5. Underclay, light-gray, plastic.	0.2
4. Shale, greenish-gray, silty, impure, clayey in places, laminated.	1.4
3. Shale, gray, blocky, sandy, limonitic, land plants, thin-laminated.	2.0
Bachelor Creek limestone member	
2. Limestone, light greenish-gray, weathers pale-brown, hard, medium-bedded, coarse-grained, arenaceous, impure, numerous *Myalina*, *Orthomyalina*, *Dictyoclostus*, *Neospirifer*, *Chonetes*, *Composita*, crinoid stems, spired gastropods..	4.5
1. Shale, gray to medium-gray, blocky, silty, slightly calcareous, rare *Dictyoclostus*, abundant Chonetes; interbedded with limestone stringers, argillaceous, sandy, full of Chonetes, rare clams.	2.2
Severy Shale	
0. Shale, olive-gray, blocky, silty, slightly calcareous, gradational upper contact, partly covered.	3.8

Locality 22. Center line. Sec. 4 and 5, T. 18 S., R. 14 E., Osage County; measured in road ditch and in small stream, about 0.7 mile south of State Highway 170.

Howard Limestone (thickness 37.4')	
Utopia limestone member	
11. Limestone, bluish-gray, weathers yellowish-brown, hard, medium-grained, thin-bedded, full of fusulinids.	2.4
10. Covered interval.	5.6

Locality 22. (Cont'd)

	Thickness Feet
9. Limestone, blue-gray, weathers pale-brown, hard, thin-bedded, coarse-grained, abundant <u>Osagia</u>.	1.0
8. Covered interval.	5.0
Church Limestone member	
7. Limestone, dark-blue, weathers pale-brown, hard, massive, dense, fine-grained, abundant; crinoid stems, <u>Dictyoclostus</u>, <u>Punctospirifer</u>, <u>Chonetes</u>, <u>Ottonosia</u>. . . .	1.9
Aarde shale member	
6. Shale, light olive-gray, flaky, limonitic, silty, micaceous, clayey, carbonaceous impressions, few pectinids.	11.0
5. Nodaway coal.	0.85
4. Underclay, light-gray, limonitic, plastic.	0.4
3. Shale, light olive-gray, flaky, clayey, micaceous, silty to arenaceous in lower part, interbedded with thin siltstone beds, laminated, microscopic crossed-bedded, abundant plant impressions.	4.2
Bachelor Creek limestone member	
2. Limestone, olive-gray, weathers light brown, hard, medium-bedded, arenaceous, micaceous, sparsely fossiliferous, towards top contains <u>Dictyoclostus</u>, <u>Composita</u>, spiriferids, few <u>Chonetes</u> near base.	5.0
Severy Shale	
1. Shale, gray, flaky to blocky, clayey in places, silty, micaceous.	15.0+

Locality 23. SW¼, Sec. 16, T. 18 S., R. 14 E., Osage County; measured in the west bank of N-S roadcut leading to Arvonia.

Howard Limestone (thickness 30.6')

Locality 23. (Cont'd) | Thickness Feet

Church limestone member

5. Limestone, blue-gray, weathers brown, hard, massive, dense, irregularly-jointed, fine-grained, numerous crinoid stems, *Dictyoclostus*, *Enteletes*. 1.8

Aarde shale membr

4. Covered interval. 14.3

Bachelor Creek limestone member

3. Limestone, light olive-gray, weathers pale-brown, hard, sandy, micaceous, medium-bedded, coarse-grained, smooth, sparsely fossiliferous throughout, towards top a-abundant *Juresania*, *Othomyalina*, fenestrate bryozoans, spired gastropods, near the base numerous *Dictyoclostus*, *Myalina*, *Chonetes*, *Composita*, *Aviculopinna*. 15.5

Severy Shale

2. Shale, dark olive-gray, silty, slightly calcareous, micaceous, near the top contains numerous *Chonetes*, rare *Bellerophon*, few ramose bryozoans, gradational contact above. . 3.0

1. Shale, greenish-gray, blocky, silty, silt slightly calcareous in places, micaceous, sparsely fossiliferous, rare *Chonetes*, rare ramose bryozoans, spired gastropods. . . . 14.0

Locality 24. SW¼, Sec. 20, T. 18 S., R. 14 E., Osage County; measured in abandoned coal strip mine, about 0.2 mile SW of corner of section.

Howard Limestone (thickness 13.4')

Winzeler shale member

9. Shale, olive-gray, blocky to flaky in places calcareous, slightly silty, *Cancranella*, rare *Bellerophon*, ohter brachiopods. . . 5.0

Locality 24. (Cont'd)	Thickness Feet
8. Limestone, yellowish-brown, encrinal, full of crinoid columnals, plates, cups of *Delocrinus*, spired gastropods, ramose and lacy bryozoans, rare *Pleurophorus*, *Cancranella*, *Dunbarella*.	0.05
7. Shale, greenish-gray, flaky to blocky, arenaceous, micaceous, numerous fenestrate bryozoans, ramose, clams. . .	1.0
Church limestone member	
6. Limestone, pinkish-gray, shelly, numerous crinoid stems, ramose bryozoans, spiriferids, Osagia?.	0.07
5. Limestone, blue-gray, weathers dark-brown, hard, dense, massive, fine-grained, abundant fossils crinoid stems, *Dictyoclostus*, *Enteletes*, *Marginifera*, *Myalina*, *Ottonosia*. .	2.5
Aarde shale member	
4. Shale, light-gray, flaky to blocky, calcareous, fossiliferous, crinoid stems, brachiopods, sharp contact with limestone above. . .	0.7
3. Shale, dark-gray to black, fissile, hard, gypsum crystals in places, abundant *Lingula*, *Orbiculoidea*.	1.1
2. "Wauneta" limestone, medium-gray, weathers light-gray, medium hard, coarse-grained, thin-bedded, argillaceous, abundant crinoid stems, brachiopods, ramose and lacy bryozoans	0.6
1. Shale, dark-gray, abundant carbonaceous material, gypsum grains, lower part covered	0.5

Locality 25. NW¼, NW¼, Sec. 5, T. 19 S., R. 14 E., Coffey County; measured in an open coal mine, property of Mr. H. A. Jones, near the Osage-Coffey county line.

Howard Limestone (thickness 33.0±)

Utopia limestone member

Locality 25. (Cont'd)	Thickness Feet
13. Limestone, bluish-gray, weathers pale-brown, hard, coarse-grained, thin-bedded, abundant *Osagia*, few brachiopods. .	1.0
Winzeler shale member	
12. Shale, light olive-gray, blocky, silty, calcareous in lower part, abundant fenestrate bryozoans and crinoid stems; "punky" limestone 0.5 foot about 1.5 feet from base, in places grades into limy concretions of weird shapes.	10.0
Church limestone member	
11. Limestone, blue-gray, weathers dark-brown, hard, dense, massive, fine-grained, irregularly jointed, numerous fossils *Enteletes*, *Dictyoclostus*, *Marginifera*, rare corals, crinoid stems, *Ottonosia*; the upper 2 inches become shelly.	1.9
Aarde shale member	
10. Shale, light-brown, flaky, calcareous, numerous;shell fragments and small pectinids. . .	0.7
9. Shale, black, fissile, slightly calcareous, phosphatic nodules, common *Orbiculoides*, *Lingula*.	0.3
8. Shale, gray, flaky.	0.1
7. "Wauneta" limestone, light-gray, weathers pinkish-gray, medium hard, thin-bedded, coarse-grained, argillaceous, nodular in places, abundant ramose bryozoans, Cancranella, Crurithyris, crinoid stems, ostracods, spired gastropods, productid spines. .	0.4
6. Shale, light-brown, medium hard, calcareous, numerous crinoid stems, rare brachiopods, abundant gypsum and gibbsite grains scattered throughout, small limestone nodules containing *Dunbarella*, *Crurithyris*, crinoid stems.	2.1
5. Shale, medium-gray, arenaceous, laminated, resembling varved-like deposits, few *Dunbarella*, upper contact highly irregular, lower 1 foot clayey, blocky.	5.5

Locality 25. (Cont'd) | Thickness Feet

4. Nodaway coal, bituminous, vitreous. . .	1.1
3. Shale, medium-gray, blocky, silty. . .	5.0
Bachelor Creek limestone member	
2. Limestone, olive-gray, weathers pale-brown, hard, arenaceous, coarse-grained, medium-bedded, numerous _Myalina_, _Dictyoclostus_, _Juresania_, _Chonetes_, crinoid stems..	1.5
1. Shale, greenish-gray, blocky, silty, calcareous, abundant Astartella, Chonetes, in places grades into nodular limestone. .	4.0

Locality 26. Center north, Sec. 34, T. 19 S., R. 13 E., Lyon County; measured in small stream bank 1.5 miles east of State Highway 130 and Neosho Rapids, about 0.5 mile from Lyon-Coffey county line.

Howard Limestone (thickness 17.5')

Utopia limestone member	
12. Limestone, blue-gray, weathers pale-brown, hard, irregularly-bedded, medium-grained, full of fusulinids, crinoid stems.	0.2
11. Shale, brownish-gray, flaky.	0.2
10. Limestone, light-gray, weathers pale-brown, medium hard, thin-bedded, arenaceous, impure, interbedded with thin shales, ostracods.	0.9
9. Shale, dark-gray, flaky, thin-laminated, silty, slightly calcareous, few limonite concretions, thin limestone stringers in places, common Myalina.	1.0
8. Shale, gray, flaky, calcareous, full of ostracods.	0.1
7. Limestone, blue-gray, weathers pale-brown, hard, medium-grained, full of _Myalina_. . .	0.3

Locality 26. (Cont'd)	Thickness Feet
6. Shale, brown, flaky, limy, abundant ostracods.	0.1
5. Limestone, dark blue-gray, weathers brownish-gray, arenaceous, Osagia.	0.1
4. Shale, greenish-gray, blocky.	1.7
3. Limestone, blue-gray, weathers pale-brown, hard, thin-bedded, coarse-grained, full of Myalina, brachiopods.	1.3
Winzeler shale member	
2. Shale, olive-gray, blocky, slightly calcareous, clayey in places, lower part covered.	10.0
Church limestone member	
1. Limestone, blue-gray, weathers dark-brown, hard, dense, massive, fine-grained, numerous crinoid stems, brachiopods, few bryozoans, Ottonosia towards top.	1.55

Locality 27. Center line between Sec. 33 and 34, T. 19 S., R. 13 E., Lyon County; measured along road ditch in N-S road, 1 mile east and 0.5 mile of Neosho Rapids.

Howard Limestone (thickness 12.1')

Church limestone member	
6. Limestone, blue-gray, weathers deep-brown, hard, massive, dense, fine-grained, rectangular-jointed, brachiopods, crinoid stems, bryozoans, Ottonosia.	1.6
Aarde shale member	
5. Shale, gray, flaky to blocky, carbonaceous material, partly covered.	5.0
4. Nodaway coal, weathered.	0.3
3. Underclay, light-gray, plastic.	0.3
2. Shale, medium-gray, flaky, slightly silty, numerous plant and carbonaceous impressions	3.2

Locality 27. (Cont'd) | Thickness Feet

Bachelor Creek limestone member

1.	Limestone, light-gray, weathers pale-brown, hard, medium-bedded, micaceous, arenaceous, common brachiopods.	1.7

Locality 28. Center south, Sec. 6, T. 21 S., R. 13 E., Lyon County; measured along small creek by steel bridge on E-W road, about 0.4 mile from southwest corner of section.

Howard Limestone (thickness 24.6')

Utopia limestone member

15.	Limestone, blue-gray, weathers pale-brown, hard, medium-bedded, medium-grained, full of fusulinids, partly covered.	0.6
14.	Covered interval.	2.4
13.	Limestone, brownish-gray, weathers same, hard, coarse-grained, thin-bedded, full of *Myalina*, *Osagia*, partly covered.	0.5
12.	Covered interval.	1.0
11.	Limestone, blue-gray, weathers pale-brown, medium hard, coarse-grained, Osagia. . . .	1.5

Winzeler shale member

10.	Shale, pale-brown, blocky, slightly silty, micaceous, calcareous, few fenestrate bryozoans.	6.0

Church limestone member

9.	Limestone, blue-gray, weathers dark-brown, hard, dense, massive, fine-grained, abundant crinoid stems, brachiopods, *Dictyoclostus*, *Marginifera*, upper part is shelly with few *Derbyia*, fenestrate bryozoans, crinoid stems.	1.5

Aarde shale member

Locality 28. (Cont'd) | Thickness Feet

	Thickness Feet
8. Shale, dark-gray, weathers yellowish-brown, flaky, slightly calcareous, common *Orbiculoidea*.	1.0
7. "Wauneta" limestone, medium-gray, weathers pale-brown, medium hard, argillaceous, silty, brachiopods, crinoid stems.	0.5
6. Shale, greenish-gray, blocky, silty, micaceous, lower part contains abundant carbonaceous material.	5.0
5. Nodaway coal, lignitic, brown.	0.6
4. Shale, medium-gray, blocky, silty, clayey in places.	1.9
Bachelor Creek limestone member	
3. Limestone, dark-blue, weathers light-gray, hard, massive, coarse-grained, pseudolitic, common crinoid stems, fenestrate bryozoans, *Composita*, *Crurithyris*, *Myalina*, abundant *Osagia*.	1.9
2. Shale, olive-gray, blocky, silty, micaceous	0.2
Severy Shale	
1. Shale, light-gray, flaky to blocky, micaceous, silty, carbonaceous material; interbedded with thin siltstones, tan to buff, thin-laminated, fine-grained, micaceous, lower part covered.	6.0+

APPENDIX B

Percent Chart of the Insoluble Residue Analysis of the Howard Limestone between the Kansas and Neosho River valleys, Kansas

*Sample number	Total weight grams	Total residue grams	Total residue percent	Coarse fraction grams	Coarse fraction percent	Fine fraction grams	Fine fraction percent
3/5	20.0	3.29	16.5	0.10	3.0	3.19	97.0
3/9	20.0	4.56	22.8	1.16	25.5	3.40	74.5
3/11	20.0	1.65	8.3	0.36	21.8	1.29	78.2
3/13	20.0	3.52	17.6	0.30	8.5	3.22	91.5
3/14	20.0	3.0	15.0	0.05	1.6	2.95	98.4
4/8a	20.0	3.24	16.2	0.07	2.3	3.17	97.7
4/8b	20.0	3.22	16.1	0.05	2.1	3.17	97.9
4/10	20.0	5.61	28.1	1.58	28.8	4.03	71.2
4/12	20.0	4.05	20.3	0.47	18.9	3.58	89.1
4/14	20.0	6.50	32.5	2.18	37.4	4.32	62.6
4/16	20.0	2.22	11.1	0.17	7.2	2.05	92.8
4/18	20.0	4.31	21.6	0.05	5.9	4.26	94.1
6/9a	20.0	5.23	26.2	0.10	2.2	5.13	97.8
6/9b	20.0	2.81	14.1	0.01	0.4	2.80	99.6
6/9c	20.0	4.36	21.8	0.06	1.4	4.30	98.6
6/11	20.0	5.23	22.5	0.05	1.0	4.45	99.0

*Note: The locality and unit numbers corresponds with those measured sections in Appendix A. Letters refer to the location within the single stratum (_a_ being lower than _b_) i.e: 4/8a is stratigraphically lower than 4/8b.

Sample number	Total weight grams	Total residue grams	Total residue percent	Coarse fraction grams	Coarse fraction percent	Fine fraction grams	Fine fraction percent
6/13a	20.0	4.33	21.7	0.28	6.4	4.05	93.6
6/13b	20.0	4.21	21.1	0.23	5.4	3.98	94.6
6/14	20.0	2.95	14.8	0.40	13.5	2.55	86.5
6/15	20.0	4.06	20.3	0.31	7.6	3.75	92.5
6/17	20.0	2.71	13.6	0.06	2.2	2.65	97.8
6/18	20.0	3.40	17.0	0.10	2.8	3.30	97.2
7/5	20.0	2.48	12.4	0.01	0.4	2.47	99.6
7/7a	20.0	4.44	22.2	0.26	5.9	4.18	94.1
7/7b	20.0	2.57	12.9	0.20	7.8	2.37	92.2
7/9	20.0	4.02	20.1	0.12	2.9	3.90	97.1
7/11	20.0	1.27	6.4	0.02	1.6	1.25	98.4
8/3a	20.0	3.51	17.6	0.04	1.0	3.47	99.0
8/3b	20.0	1.84	9.2	0.53	28.8	1.31	71.2
8/4	20.0	2.60	13.0	0.25	9.5	2.35	90.5
8/5	20.0	2.08	10.4	1.36	65.4	0.72	34.6
8/6a	20.0	2.20	11.0	0.23	12.3	1.97	34.6
8/6b	20.0	3.17	15.9	1.00	32.8	2.17	67.2
8/6c	20.0	1.27	6.4	0.20	15.7	1.07	84.3
8/6d	20.0	0.52	2.6	0.05	9.6	0.47	90.4
8/8	20.0	3.53	17.7	0.06	2.6	3.47	98.4
10/5	20.0	10.58	52.9	0.18	1.7	10.40	98.3
10/7a	20.0	2.75	13.9	0.11	3.9	2.67	96.1
10/7b	20.0	1.44	7.2	0.02	1.3	1.42	98.7
10/8	20.0	1.17	5.9	0.22	18.8	0.95	81.2

Sample number	Total weight grams	Total residue grams	percent	Coarse residue grams	percent	Fine fraction grams	percent
10/9	20.0	3.96	19.8	0.31	7.8	3.65	92.2
10/10a	20.0	1.97	9.9	0.20	10.2	1.87	89.8
10/10b	20.0	1.37	6.9	0.05	3.6	1.32	96.4
10/11	20.0	1.73	8.7	0.07	4.0	1.66	96.0
10/12	20.0	2.51	12.6	0.04	1.6	2.47	98.4
11/2	20.0	1.73	8.7	0.01	0.6	1.72	99.4
11/8	20.0	2.74	13.7	0.04	1.4	2.70	98.6
11/9	20.0	10.71	53.6	3.16	29.4	7.55	70.6
11/11a	20.0	0.91	4.6	0.03	3.3	0.88	96.7
11/11b	20.0	0.71	3.6	0.06	8.4	0.65	91.6
11/12	20.0	3.32	16.6	0.02	0.7	3.30	99.3
12/6	20.0	1.47	7.4	0.03	2.0	1.45	98.0
12/7	20.0	0.90	4.5	0.01	1.2	0.89	98.9
12/9	20.0	3.22	16.1	0.02	0.6	3.20	99.4
14/4a	20.0	2.45	12.3	0.02	0.8	2.43	99.2
14/4b	20.0	2.55	12.8	0.05	1.9	2.50	98.1
14/5	20.0	1.92	9.6	0.15	7.8	1.77	92/2
14/6	20.0	2.89	14.5	0.08	2.7	2.81	97.3
14/7	20.0	3.28	16.4	0.21	6.4	3.07	93.6
14/8	20.0	2.16	10.8	0.06	2.6	2.10	97.4
14/11	20.0	5.95	29.8	0.26	4.3	5.69	95.7
14/12a	20.0	6.27	32.9	0.70	10.7	5.87	89.3
14/12b	20.0	1.65	8.3	0.03	1.8	1.62	98.2
14/13	20.0	2.92	14.6	0.05	1.7	2.87	98.3

Sample number	Total weight grams	Total residue grams	Total residue percent	Coarse fraction grams	Coarse fraction percent	Fine fraction grams	Fine fraction percent
15/7	20.0	2.24	11.2	0.07	3.1	2.17	96.9
18/4	20.0	1.73	8.7	0.01	0.5	1.72	99.5
18/7	20.0	1.32	6.6	0.17	12.7	1.15	87.2
18/12	20.0	1.22	6.1	0.02	1.6	1.20	98.4
18/13	20.0	1.89	9.5	0.01	0.5	1.88	99.5
19/4	20.0	9.86	49.3	1.36	13.8	8.50	86.2
20/2	20.0	7.29	36.5	1.02	14.0	6.27	86.0
20/4	20.0	11.27	56.4	0.55	4.9	10.72	95.1
20/6	20.0	8.27	41.4	2.97	35.9	5.3	64/1
21/2	20.0	14.86	74.3	0.36	2.5	15.4	97.5
21/3	20.0	10.44	52.2	2.67	25.6	7.76	74.4
21/12	20.0	2.04	10.2	0.02	0.8	2.02	99.2
21/14a	20.0	2.27	11.4	0.10	4.4	2.17	95.6
21/14b	20.0	3.62	18.1	0.20	4.5	3.42	95.5
22/2a	19.5	12.52	62.6	0.26	2.0	12.26	98.0
22/2b	20.0	11.54	57.7	0.42	3.5	11.12	96.5
22/7	20.0	1.79	8.9	0.01	0.5	1.78	99.5
22/9	20.0	2.92	14.6	0.10	3.3	2.82	96.7
22/11	20.0	2.61	13.1	0.02	0.7	2.59	99.3
23/3a	20.0	15.54	77.7	0.27	1.8	15.27	98.2
23/3b	20.0	12.11	60.6	0.13	1.1	11.98	98.9
23/3c	20.0	12.43	62.2	0.33	2.7	12.10	97.3
23/3e	20.0	13.26	66.3	1.65	12.5	11.61	87.5
23/3f	20.0	11.23	56.2	3.84	34.1	7.39	65.9

Sample number	Total weight grams	Total residue grams	percent	Coarse fraction grams	percent	Fine Fraction grams	percent
23/5	20.0	1.47	7.4	0.02	1.4	1.45	98.6
24/2	20.0	6.75	3.4	0.09	1.4	6.66	98.6
24/5	20.0	1.66	8.3	0.01	0.6	1.65	99.4
24/6	20.0	2.65	13.3	0.03	1.1	2.62	98.9
25/2	20.0	10.17	55.9	1.12	19.0	9.05	81.0
25/7	20.0	5.87	29.4	0.16	19.8	5.71	80.2
25/11a	20.0	1.57	7.9	0.02	1.2	1.55	98.8
25/11b	20.0	3.74	19.7	0.07	1.8	3.67	98.2
25/12	20.0	5.96	29.8	0.01	0.3	5.95	99.7
25/13	20.0	2.00	10.0	0.10	5.0	1.90	95.0
26/1	20.0	1.53	7.7	0.05	3.4	1.48	96.6
26/3a	20.0	2.19	10.9	0.20	9.2	1.99	90.8
26/3b	20.0	1.66	8.3	0.14	8.4	1.52	91.6
26/5	20.0	1.79	8.9	0.06	3.4	1.73	93.2
26/7	20.0	1.16	5.8	0.08	6.8	1.08	93.2
26/10a	20.0	4.29	21.5	0.02	0.6	4.27	99.4
26/10b	20.0	7.39	36.9	1.12	15.2	6.27	84.8
26/12	20.0	2.74	13.7	0.03	1.0	2.72	99.0
27/1	20.0	11.65	58.3	0.66	5.7	10.99	94.3
28/3a	20.0	4.20	21.0	0.48	11.4	3.72	88.6
28/3b	20.0	4.20	21.0	0.48	11.4	3.72	88.6
28/7	20.0	2.25	11.3	0.05	2.1	2.20	97.9
28/9	20.0	1.97	9.9	0.01	0.5	1.96	99.5
28/11	20.0	2.33	11.7	0.05	2.0	2.28	98.0

APPENDIX C

CONSTITUENT PERCENTAGES OF THE COARSE FRACTION FROM THE INSOLUBLE RESIDUES OF THE HOWARD LIMESTONE

Sample number	Per-cent	Description of samples
3/5	40	arenaceous foraminifers
	40	pyrite, anhedral to euhedral
	15	flocculated clay material, spongy, micaceous
	5	quartz, subrounded to subangular, clear to frosted
	T	mica flakes
3/9	45	flocculated clay material, spongy
	40	quartz sand, subangular
	8	mica flakes
3/11	75	quartz sand, subangular to angular
	20	flocculated argillaceous material
	3	mica flakes
	T	carbonaceuos material
3/13	86	arenaceous foraminifers
	10	quartz sand, angular, clear to frosted
	2	mica flakes
	2	pyrite
3/14	57	pyrite, anhedral to euhedral
	30	arenaceous foraminifers
	10	quartz sand
	2	mica flakes
	1	silicified fossils
4/8a	50	arenaceous foraminifers
	25	silt aggregates, micaceous, soft
	20	glauconite, amorphous
	5	pyrite, anhedral to euhedral
4/8b	50	arenaceous foraminifers
	25	glauconite
	15	silt aggregates
	10	pyrite, striated cubes, some amorphous
	T	quartz sand
	T	zircon, pink
4/10	65	quartz sand, euangular
	25	arenaceous foraminifers
	10	pyrite

4/14	70	flocculated clay material, micaceous, spongy
	20	quartz sand, subangular, clear to frosted
	10	mica flakes
	T	arenaceous foraminifers
4/16	65	arenaceous foraminifers
	30	quartz sand
	3	pyrite, anhedral to euhedral
	2	mica flakes
4/18	76	quartz sand, subangular to angular, clear
	15	flocculated clay material, spongy, micaceous
	5	arenaceous foraminifers
	2	mica flakes
	2	pyrite, amorphous
6/9a	58	pyrite, amorphous
	40	arenaceous foraminifers
	2	quartz sand
6/9b	55	pyrite, amourphous
	40	arenaceous foraminifers
	3	quartz sand
	2	flocculated clay material, spongy
6/9c	79	arenaceous foraminifers
	20	quartz sand
	1	mica flakes
6/11	75	pyrite, amorphous, pyritized ramose bryozoans and other shell fragments
	19	arenaceous foraminifers
	1	quartz sand
	1	glauconite
6/13a	55	arenaceous foraminifers
	40	quartz sand
	4	silt aggregates, micaceous, limonite stained
	1	mica flakes
6/13b	60	arenaceous foraminifers
	38	quartz sand
	2	mica flakes
6/14	80	quartz sand, subangular to angular
	15	silt aggregates
	3	mica flakes
	2	flocculated clay material
6/15	58	flocculated clay material, buff to gray
	40	wuartz sand
	2	mica flakes

6/17	90	arenaceous foraminifers
	10	quartz sand
6/18	85	silt aggregates, micaceous, spongy
	10	quartz sand
	5	arenaceous foraminifers
	T	mica flakes
	T	pyrite, amorphous
7/5	65	pyrite, amorphous
	33	arenaceous foraminifers
	2	quartz, angular, clear
7/7a	72	quartz sand, subrounded to subangular, very fine
	20	clay flocculated material
	5	arenaceous foraminifers
	3	mica flakes
7/7b	90	quartz sand, angular to subangular
	7	flocculated clay material
	3	mica flakes
	T	tourmaline, black
7/9	50	quartz sand, angular to subangular
	40	flocculated clay material
	5	limonite, spongy
	5	mica flakes
7/11	60	quartz sand, subangular to angular, clear
	20	arenaceous foraminifers
	18	silt aggregates
	2	chert, ordinary, white
8/3a	40	silicified fossils and fragments, _Punctospirifer_, fenestrate bryozoans, productid spines
	40	arenaceous foraminifers
	18	interstitial silica, white to buff
	2	mica flakes
8/3b	40	silicified fossils and fragments, _Hustedia_, _Cruirithyris_, _Punctospirifer_, spired gastropods
	37	silt aggregates, micaceous, quartzose
	18	interstitial silica, clear to opaque
	5	arenaceous foraminifers
	T	pyrite
8/4	45	silt aggregates, micaceous, soft
	30	sponge spicules, monaxons, triaxons, desmas
	15	silicified fossils and fragments
	10	chert, ordinary, lacy

8/5	63	silt aggregates, micaceous, soft
	14	siliceous sponge spicules
	10	quartz sand
	5	silicified fossil fragments
	3	carbonaceous material
	3	pyrite
	2	glauconite
8/6a	34	silicified fossil fragments
	30	arenaceous foraminifers
	29	quartz sand
	3	mica flakes
	3	glauconite
	1	pyrite
8/6b	85	flocculated clay material
	10	quartz sand
	5	mica flakes
8/6c	89	arenaceous foraminifers, white to light gray
	5	quartz sand
	3	pyrite
	3	silicified ostracods
8/6d	90	quartz sand, angular to subangular
	10	mica flakes
8/8	30	arenaceous foraminifers
	30	silt aggreagtes, micaceous, pyritic
	20	quartz sand
	10	flocculated clay material
	10	pyrite, amorphous
	T	mica flakes
10/5	40	quartz sand
	30	pyrite, amorphous
	25	arenaceous foraminifers
	5	flocculated clay material, spongy, micaceous
10/7a	68	pyrite, anhedral to euhedral, pyritized fossils
	30	arenaceous foraminifers
	2	quartz sand
10/7b	40	limonite, amorphous, spongy
	30	arenaceous foraminifers
	15	silicified fossils and fragments, partially en-crusted with beekite
	14	pyrite, amorphous
	1	quartz sand

10/8	63	quartz sand, micro-drusy aggregates, opaque
	30	limonite, amorphous, spongy
	5	arenaceous foraminifers
	2	mica flakes
10/9	48	arenaceous foraminifers
	40	quartz sand
	10	silt aggregates, limonitic, micaceous
	2	mica flakes
10/10a	60	quartz sand
	30	flocculated clay material
	5	mica flakes
	3	carbonaceous material
	2	arenaceous foraminifers
10/10b	50	glauconite, amorphous
	40	quartz sand
	10	arenaceous foraminifers
10/11	80	quartz sand, angular to subangular, clear to frosted
	15	limonite, amorphous, spongy
	5	mica flakes
10/12	55	arenaceous foraminifers
	40	silt aggregates, micaceous, soft
	5	quartz sand
	T	mica flakes
11/2	90	quartz sand, subangular
	5	carbonaceous material
	5	mica flakes
11/8	80	pyrite, amorphus, pyritized fossil fragments
	15	arenaceous foraminifers
	5	flocculated clay material, micaceous
	T	quartz sand
11/9	60	arenaceous foraminifers
	35	limonite, amorphous, spongy
	5	quartz sand, angular and subangular, clear
11/11a	43	arenaceous foraminifers
	40	quartz sand, subangular to angular
	10	pyrite, amorphous
	7	glauconite, light green, amorphous
11/11b	90	arenaceous foraminifers
	5	quartz sand, angular
	3	pyrite, amorphous
	2	silt aggregates, micaceous

11/12	73	silt aggregates, micaceous, pyritic
	15	arenaceous foraminifers
	10	quartz sand, angular to subangular
	2	mica flakes
	T	pyrite
12/6	80	arenaceous foraminifers
	10	quartz sand, angular to subangular
	10	limonite, spongy
12/7	83	silt aggregates, limonitic, micaceous
	15	arenaceous foraminifers
	2	quartz sand, clear
12/9	70	silt aggregates, micaceous, pyritic
	15	arenaceous foraminifers
	14	quartz sand
	1	pyrite, amorphous
	T	mica flakes
14/4a	45	arenaceous foraminifers
	35	pyrite, amorphous, striated cubes
	20	flocculated clay material, spongy
	T	quartz sand
14/4b	35	arenaceous foraminifers
	35	pyrite, anhedral to euhedral
	25	glauconite
	5	flocculated clay material
14/5	75	quartz sand
	23	arenaceous foraminifers
	1	mica flakes
	1	pyrite
14/6	42	arenaceous foraminifers
	40	quartz sand, subangular to angular, clear
	15	pyrite, amorphous
	3	mica flakes
14/7	60	arenaceous foraminifers
	40	quartz sand, clear to frosted
14/8	70	arenaceous foraminifers
	30	quartz sand, anhedral to subhedral
	T	mica flakes
14/11	58	flocculated clay material
	40	quartz sand
	2	mica flakes

14/12a	67	quartz sand, fine grained, subangular to angular, clear to frosted
	25	flocculated clay material, micaceous, spongy
	5	mica flakes
	3	carbonaceous material
14/12b	55	arenaceous foraminifers
	40	quartz sand
	5	mica flakes
14/13	80	silt aggregates, micaceous, argillaceous
	10	quartz sand
	10	arenaceous foraminifers
15/7	77	arenaceous foraminifers
	20	quartz sand
	3	mica flakes
18/4	40	arenaceous foraminifers
	40	chert, ordinary, opaque
	20	pyrite, amorphous
	T	quartz sand, angular
18/7	65	quartz sand, angular to subangular
	22	silt aggregates, micaceous
	5	mica flakes
	5	arenaceous foraminifers
	3	chert, ordinary to chalky
18/12	82	arenaceous foraminifers
	15	quartz sand, clear
	3	mica flakes
18/13	62	arenaceous foraminifers
	25	quartz sand, angular to subangular
	10	limonite, amorphous
	3	carbonaceous material
	T	pyrite
	T	mica flakes
19/4	85	quartz sand, angular to subangular, clear to frosted
	10	mica flakes
	5	pyrite, amorphous
20/2	90	quartz sand, angular to subangular, clear to frosted
	5	silt aggregates, micaceous, soft
	3	mica flakes
	2	carbonaceous material

20/4	92	quartz sand, limonite stained
	5	mica flakes
	3	carbonaceous material
20/6	93	quartz sand, angular to subangular
	4	carbonaceous material
	3	mica flakes
21/2	55	silt aggregates, micaceous, spongy
	40	quartz sand
	3	mica flakes
	2	carbonaceous material
21/3	90	quartz sand, angular to subangular, clear to frosted
	5	mica flakes
	5	carbonaceous material
	T	arenaceous foraminifers
	T	tourmaline
21/12	60	arenaceous foraminifers
	30	pyrite, amorphous, some crystals
	10	glauconite, amorphous
	T	quartz sand
21/14a	70	arenaceous foraminifers, white to light gray
	15	pyrite
	10	silt aggregates
	3	mica flakes
	2	carbonaceous material
21/14b	78	arenaceous foraminifers
	10	quartz sand
	10	silt aggregates, micaceous, quartzose
	2	mica flakes
22/2a	90	quartz sand, subangular to angular, limonitic
	5	carbonaceous material
	5	mica flakes
22/2b	90	quartz sand, same as above
	5	carbonaceous material
	5	mica flakes
22/7	50	arenaceous foraminifers
	50	pyrite, anhedral to euhedral

22/9	52	arenaceous foraminifers
	45	quartz sand
	3	mica flakes
22/11	77	silt aggregates, limonitic, micaceous
	20	arenaceous foraminifers
	3	pyrite, amorphous
	T	quartz sand
	T	mica flakes
23/3a	85	silt aggregates, soft
	10	quartz sand
	5	mica flakes
23/3b	50	silt aggregates, micaceous
	45	quartz sand, angular to subangular
	3	carbonaceous material
	2	mica flakes
23/3c	90	quartz sand, angular to subangular, clear to frosted
	5	silt aggregates, micaceous, spongy
	3	mica flakes
	2	carbonaceous material
23/3e	90	quartz sand, same as above
	5	silt aggregates
	5	mica flakes
23/3f	92	quartz sand, subangular to angular
	3	mica flakes
	3	carbonaceous material
	2	pyrite
23/5	55	arenaceous foraminifers
	30	limonite, amorphous
	10	quartz sand
	5	pyrite
24/2	60	arenaceous foraminifers
	20	quartz sand
	20	pyrite, amorphous
24/5	53	pyrite, anhedral to euhedral
	45	arenaceous foraminifers
	2	quartz sand, clear to frosted
24/6	50	arenaceous foraminifers
	40	glauconite
	5	pyrite
	5	quartz sand

25/2	85	quartz sand, angular to subangular
	5	mica flakes
	5	carbonaceous material
	3	arenaceous foraminifers
	2	glauconite
25/7	55	silt aggregates, soft
	30	quartz sand, angular to subangular
	12	arenaceous foraminifers
	2	pyrite
	1	mica flakes
25/11a	50	pyrite, amorphous, some pyritized fossils
	45	arenaceous foraminifers
	5	quartz sand, anhedral, clear
25/11b	68	arenaceous foraminifers
	25	glauconite, amorphous
	5	quartz sand
	2	mica flakes
25/12	45	silt aggregates, micaceous, soft
	25	alabaster, amorphous
	20	limonite, amorphous
	10	quartz sand
25/13	94	arenaceous foraminifers
	3	quartz sand
	2	mica flakes
	1	pyrite
26/1	55	arenaceus foraminifers
	25	pyrite, amorphous
	20	selenite flakes
	T	quartz sand
26/3a	42	arenaceous foraminifers
	35	quartz sand, angular to subangular, clear
	20	pyrite, amorphous
	3	mica flakes
26/3b	70	arenaceous foraminifers
	25	quartz sand, clear to frosted
	5	pyrite, amorphous
26/5	40	silt aggregates, micaceous, quartzose
	20	carbonaceous, material
	20	quartz sand, angular
	15	flocculated clay material
	5	pyrite

26/7	80	flocculated clay material
	7	quartz sand
	5	pyrite
	5	arenacedus foraminifers
	3	carbonaceous material
26/10a	87	quartz sand, angular to subangular, clear to milky, up to 0.1 mm in diameter
	7	quartz sand
	3	carbonaceous material
	3	pyrite
26/10b	87	quartz sand, angular to subangular, fine grained
	5	mica flakes
	5	carbonaceous material
	3	arenaceous foraminifers
26/12	57	arenaceous foraminifers
	20	quartz sand
	15	glauconite
	5	limonite, spongy
	3	mica flakes
	T	pyrite
	T	silt aggregates
27/1	45	silt aggregates, soft
	40	quartz sand
	5	pyrite
	3	carbonaceous material
	2	mica flakes
28/3a	35	arenaceous forminifers
	35	quartz sand, angular to subangular, clear
	30	pyrite
28/3b	55	quartz sand, angularto subangular
	33	arenaceous foraminifers
	10	pyrite, amorphous
	2	mica flakes
28/7	82	arenaceous foraminifers
	15	pyrite
	3	quartz sand, angular, clear
28/9	50	pyrite, amorphous
	48	arenaceous foraminifers
	2	quartz sand, clear to frosted