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Petrology of the Hogshooter Formation (Missourian) Washington and Nowata Counties, Oklahoma

by

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ABSTRACT

Detailed analyses of stratigraphic relationships, insoluble residues, and carbonate thin sections reveal rapid lateral and vertical variations of carbonate rock types in the upper part of the Coffeyville and Hogshooter sequence.

Characteristics of the Canville and Lost City Limestones and Stark Shale suggest these units are closely associated with upper Coffeyville sedimentation and are included within the Coffeyville rather than in the Hogshooter Formation. The Canville and Lost City Limestones are similar in several respects to the present-day banks found in Florida Bay. Carbonate rock types, biologic association, and terrigenous contents suggest that the Canville and Lost City Limestones were deposited in areas baffled by organisms (possibly algae) while high-energy terrigenous sequences were deposited contemporaneously with and adjacent to the baffled environments.

The Hogshooter Formation was divided heretofore into two units, the lower and upper Winterset. The lower Winterset is characterized by high current-energy rocks; abundant skeletal elements, crinoids, *Osagia* sp., mollusks, brachiopods, bryozoans, and arthropods associated with varying percentages of oölites, intraclasts, and phosphate pellets comprise the rock framework. Sparry calcite cement binds the rock framework.

The upper Winterset is dominated by micritic material associated with varying percentages of unabraded fenestrate bryozoans, brachiopods, and foraminifers. The upper Winterset was deposited in non-agitated low-energy environments.

Stratigraphically equivalent to the lower and upper Winterset are well-developed reef buildups. The reefs are characterized by abundant micrite bound together by *Solenopora*- and *Spongiostromata*-type algae and *Aulopora*-type coral. Smaller percentages of green algae and fenestrate bryozoans are scattered through the reef buildups. Biosparrudite occurs as talus facies around the reef cores. Laterally away from the reef buildups, the biosparrudites of the reef-flank facies interfinger with the upper Winterset micrites.

The Canville-Lost City-Stark-Coffeyville terrigenous sequence was deposited in a near-shore high-energy environment characterized by local baffled environments. With deepening of the water, the shelf lithology of the lower Winterset transgressed over the above mentioned sequence. In some areas that were stabilized by baffled environments, reefs began to develop. As the water depth continued to increase, low-energy environments were produced in which the upper Winterset micrites were deposited. The reefs continued to build as the water depth increased. The Nellie Bly siltstone was deposited over the Hogshooter Formation as water depth decreased. In the southern part of the area, the lower part of the Nellie Bly was deposited contemporaneously with the upper Winterset and reef sequence.

INTRODUCTION

In January of 1959, R. L. Folk published a new classification for limestones based upon the concept that most limestones are composed of fragmental calcareous material precipitated and transported within the basin of deposition. The classification presents a new avenue for the description and interpretation of limestones. This report represents the application of the new classification to the limestones of the Hogshooter Formation.

The primary purpose of this investigation was to determine the environmental significance of lateral and vertical variations as illustrated by the units of the Coffeyville and Hogshooter Formations in Washington and Nowata Counties, Oklahoma. The variations examined included the changes in thickness, lithology, insoluble content, terrigenous grain size, and other petrographic properties of the members and facies of the Hogshooter and Coffeyville Formations. A second purpose of this investigation was to determine the applicability of Folk's (1959a) petrographic classification of limestones to the limestone units in the Hogshooter and Coffeyville Formations.

The northeastward-trending outcrop pattern of the Hogshooter Formation across the eastern and southern parts of Washington County and the northwestern part of Nowata County is shown in figure 1. The length of this outcrop belt from the Kansas-Oklahoma state line to the Tulsa-Washington county line is approximately 42 miles. No subsurface information was employed in this study, and therefore only the exposed dimensions of the units were investigated.

The area of study is included within the Claremore Cuesta Plains physiographic province of Oklahoma (Curtis and Ham, 1957). The topography of the region is characterized by low rolling hills formed by numerous stream dissections. Good exposures of the Hogshooter Formation are found only along stream and road cuts. Thirty-nine stratigraphic sections were measured, but only two of these sections are complete because the upper part of the formation is exposed at few places in the area.

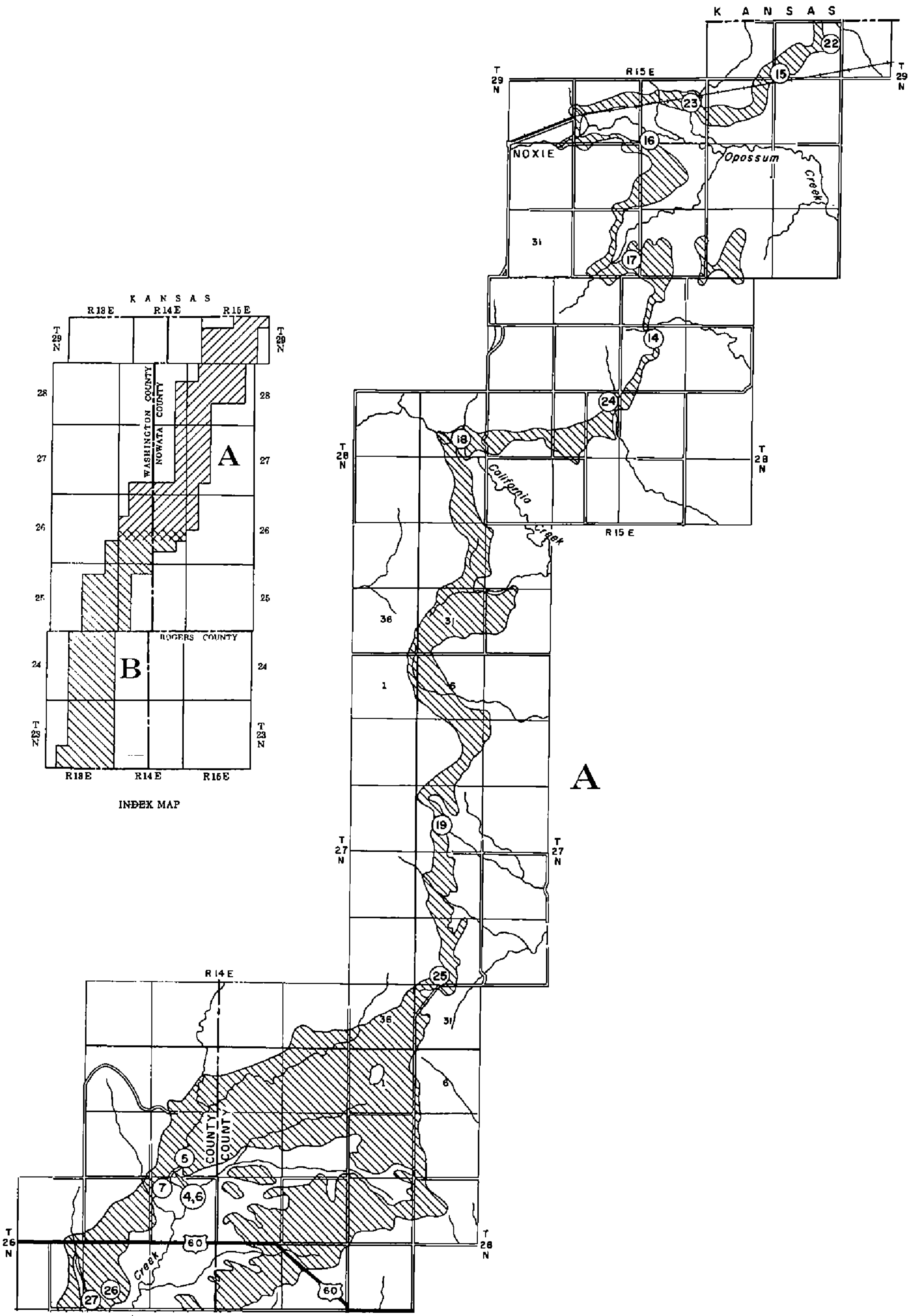
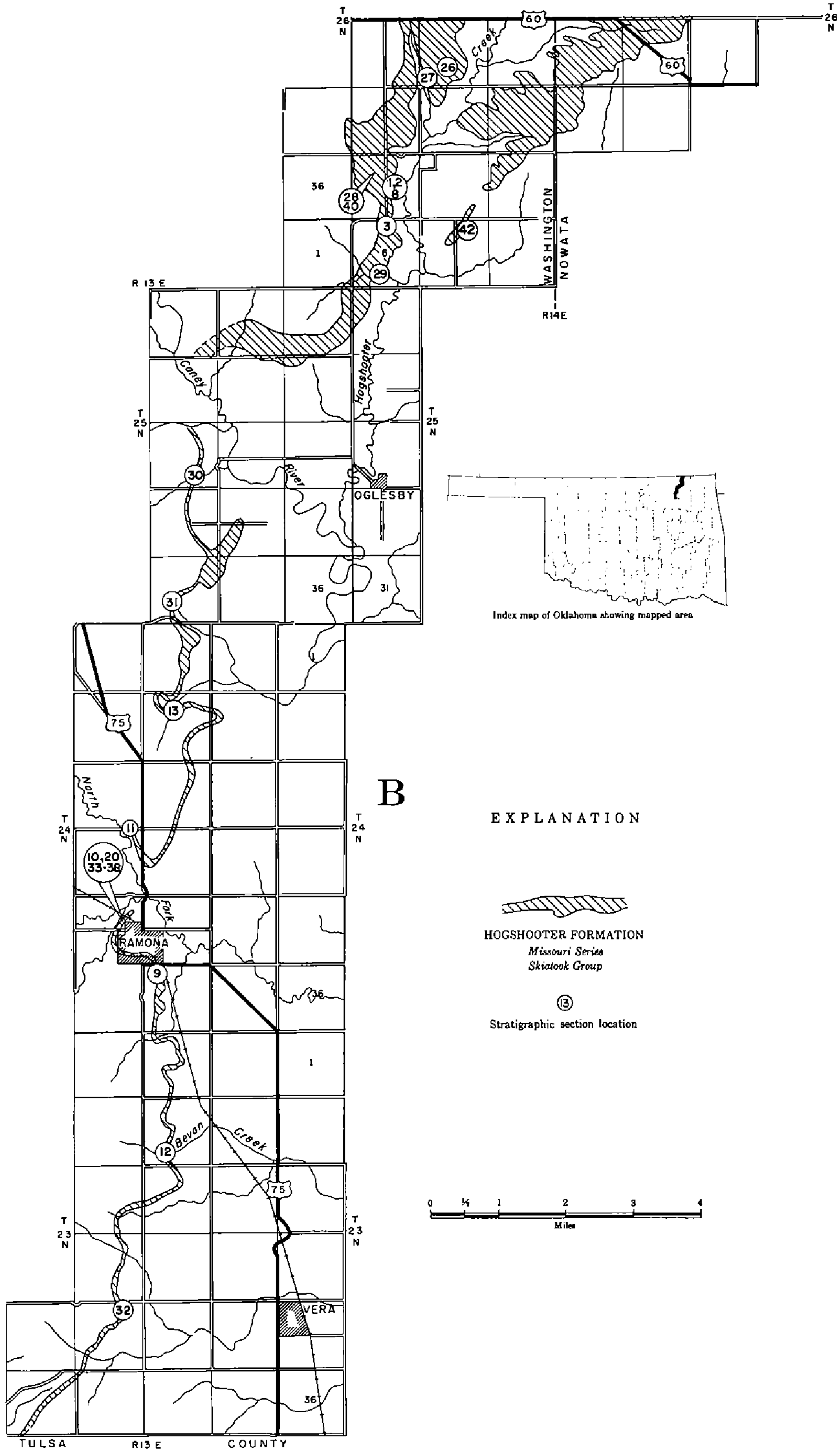


Figure 1. Outcrop map of the Hogshooter Formation in Washington and Nowata Counties, Oklahoma (modified from Oakes, 1940).



T 26 N
60
Creek
26
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36
1,2 8
28 40
3
42
1
6
29
WASHINGTON
NOWATA
R 13 E
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Caney
Hogshooter
T 25 N
T 25 N
30
River
OGLESBY
36
31
31
Index map of Oklahoma showing mapped area
1
13
75
North
B
EXPLANATION
T 24 N
T 24 N
11
10,20 33-38
Fork
HOGSHOOTER FORMATION
Missouri Series
Skiatook Group
RAMONA
9
36
13
Stratigraphic section location
1
12
Bevan
Creek
75
0 ½ 1 2 3 4
Miles
T 23 N
T 23 N
32
VERA
36
TULSA
R13 E
COUNTY

Previous Investigations

A brief chronological sequence for the history and development of the terminology associated with the Hogshooter Formation is presented below:

1903: G. I. Adams (Adams and others, 1903, p. 62-63) mapped the upper member of the Hogshooter Formation (the Winterset Member) as the Drum Limestone into Oklahoma from Kansas.

1910: D. W. Ohern (p. 28) named the unit mapped by Adams (1903) the Hogshooter Formation for the type section along Hogshooter Creek in SW¼ SE¼ SW¼ sec. 9, T. 26 N., R. 14 E., Washington County. Ohern considered the Hogshooter to consist of only the Winterset Member.

1928: Edward Bloesch (p. 358) indicated that the black shale beneath the Winterset Member should also be considered a member of the Hogshooter Formation.

1932: J. M. Jewett (p. 102) redefined the Dennis Formation of Kansas to include the Stark and Canville Members in addition to the Winterset Member. The Stark Shale Member is stratigraphically equivalent to the black shale discussed by Bloesch in 1928. The name Canville was proposed for the limestone underlying the Stark Shale Member.

1940: M. C. Oakes (p. 39-47) considered the name Hogshooter to have priority over Dennis; the Winterset, Stark, and Canville were mapped as members of the Hogshooter Formation. Oakes also mapped another limestone unit (the Lost City), which underlies the Winterset Member at scattered localities in Washington County, as a member of the Hogshooter Formation.

1958: B. V. Hansen compiled a regional study of the petrogenesis and stratigraphy of the Hogshooter Formation. Hansen's area of study extended from the Kansas-Oklahoma state line to Sand Springs, Oklahoma. Hansen found only slight variations existing between the lithology of the lower unit of the Winterset Member and that of the Lost City Member. Therefore the Lost City Member, as mapped by Oakes, was considered to be a part of the lower Winterset unit. In 1940, Oakes considered the Winterset Member to be composed of two distinct lithologic types, the lower and upper Winterset units.

Hansen found several widely scattered outcrops in which Oakes' upper Winterset was represented by a different lithologic type. Because of this difference in lithology, Hansen established another unit in the Winterset Member. The lower Winterset unit of Oakes remained the lower Winterset in Hansen's sequence, but the upper unit of Oakes was changed to the middle Winterset unit by Hansen and the new lithologic unit was then termed the upper Winterset.

Methods of Investigation

Several procedures were employed to determine variations occurring within the Hogshooter and Coffeyville Formations. These are summarized below. Detailed descriptions of the procedure regarding insoluble residues are given in the appendix.

1. Thirty-nine stratigraphic sections were measured throughout the area. On the average, one or more stratigraphic sections were measured every two miles from the Kansas-Oklahoma state line to the Washington-Tulsa county line (fig. 1).

2. One hundred seventy-three spot samples were collected from the 39 stratigraphic sections. Samples were collected from the upper part of the Coffeyville Formation, at the base of the Hogshooter Formation, and at all sites of significant lithologic change.

3. Approximately 30 grams each of 156 samples were treated with hydrochloric acid to determine the weight percentages of insoluble material.

4. Forty samples were digested in acetic acid to concentrate any minerals soluble in hydrochloric acid and insoluble in acetic acid.

5. Insoluble material obtained from the hydrochloric acid digestion of each sample so treated was wet-sieved on a 4.5 phi screen. The material remaining on the screen was weighed and the percentages coarser and finer than 4.5 phi were calculated.

6. One hundred twelve thin sections and 31 acetate peels were examined with a binocular microscope; thin sections were also analyzed with a petrographic microscope. A detailed description of each slide and peel was compiled in accordance with Folk's classification of limestones (1959a).

Folk's classification is primarily descriptive; it is based upon the concept that limestones are primarily fragmental and are analogous to terrigenous rocks. Table 1, modified from Folk (1959a), illustrates the limestone terminology used in this report.

TABLE 1. —PRINCIPAL DIVISIONS OF FOLK'S PETROGRAPHIC CLASSIFICATION OF LIMESTONES

		ALLOCHEMICAL CONSTITUENTS					
		Intraclasts	Oöliths	Pellets	Fossils		
ORTHOCHEMICAL CONSTITUENTS	Sparry Calcite	Intrasparite	Oösparite	Pelsparite	Biosparite	< 1 mm	AVERAGE SIZE OF ALLOCHEMS
		Intrasparrudite	Oösparrudite		Biosparrudite	> 1 mm	
	Micrite	Intramicrite	Oömicrite	Pelmicrite	Biomicrite	< 1 mm	
		Intramicrudite	Oömicrudite		Biomicrudite	> 1 mm	
		> 25% Intraclasts	> 25% Oöliths < 25% Intraclasts	< 25% Intraclasts & Oöliths			
		PERCENT ALLOCHEMS PRESENT					

Some of the terms from table 1 are discussed below to dispel any confusion arising from the terminology.

I. *Allochemical constituents*:

This group includes all chemical and biochemical precipitates formed and then transported within the basin of deposition.

Intraclasts are fragments of carbonate material which were initially deposited and then disturbed, transported, and redeposited all within the basin of deposition.

Oöliths are round particles which have radial and concentric internal structure; the oöliths which have concentric structure are formed by precipitation of carbonate material around a nucleus as it is agitated by currents (Illing, 1954, p. 43). Several thin sections from the Hogshooter Formation contain quartz grains with a single layer of carbonate material surrounding them. This type of allochem is defined as a superficial oölite (oölith) by Illing (1954, p. 36).

Pellets are particles composed of micritic material which contains a relatively high percentage of organic material. Many associated pellets have a uniform size and are considered by Folk (1959a) to be primarily fecal in origin. However, a pseudopellet occurrence may result from the partial recrystallization of calcareous mud (Folk, 1959a).

Fossils constitute a general group including all skeletal fragments which have originated within the basin of deposition. If a particular fossil type represents 10 percent or more of the rock, an adjective such as crinoidal or algal is added to the rock type (e.g., crinoidal biosparrudite).

II. *Orthochemical constituents*:

This group includes the normal precipitates formed within the basin of deposition which have been subjected to little or no transportation.

Sparry calcite cement commonly occurs as clear grains or crystals 10 microns or larger in diameter. Illing (1954, p. 48) indicated that sparry calcite cement forms subaerially by solution of exposed carbonate material with subsequent precipitation of calcite in the pore space of the exposed material.

Microspar is also clear in thin sections; the crystal size ranges from 4 to 10 microns in diameter. Folk (1959a, p. 32) stated that microspar probably represents recrystallization of micritic material to coarser microspar crystals. Bathurst (1959, p. 367) suggested that carbonate material ranging from approximately 3 to 15 microns in diameter may be mechanically deposited.

Micrite ranges from 1 to 4 microns in diameter and is subtranslucent, with a brownish color in thin sections. Although micrite is considered a chemical precipitate, it is analogous to a fine-grained clastic material (Folk, 1959a, p. 8; Bathurst, 1959, p. 366). Micrite may be transported and winnowed in the same manner as a fine-grained clastic material.

Recrystallized calcite is calcite which has been converted from its original size by postdepositional processes to another size with no obvious change in composition. The criteria discussed by Bathurst (1958, p. 25-27) for the recognition of recrystallization, such as the irregularity of grain boundaries, variability of grain size from one place to another in the same rock, and isolated remnants of the original finer grained material surrounded by coarsely crystalline sparry calcite, are the criteria used in this study to distinguish recrystallization spar from replacement spar. Recrystallization of fine-grained to coarse-grained calcite is a process of grain enlargement that occurs in the solid state (Bathurst, 1958, p. 24; 1959, p. 375).

Replacement calcite is calcite that has been precipitated subsequent to the precipitation of the calcareous material composing the original rock. Replacement or pore-filling calcite is distinguished from recrystallization calcite by the occurrence of rim cementation and plane intergranular boundaries (Bathurst, 1959, p. 18-20). Replacement calcite is normally found as fillings in fractures and voids in the original rock.

Terrigenous material in the thin sections was examined to determine the average grain size, from which it was possible to distinguish whether the clastic material was predominantly sand size or silt size. If more than 10 percent clastic material occurred in the thin section, a modifier of sandy or silty (depending on the average grain size) was added to the rock name.

For a more complete discussion of the terminology associated with Folk's classification, see Folk (1959a).

Although this classification is basically descriptive, Folk interpreted definite genetic relationships from it. For instance, a primary sparry calcite cement in a limestone indicates that the framework comprising the limestone had been subjected to relatively high-energy factors such as currents or waves, as the micrite had been removed. Conversely, if micrite is present, the energy in the depositional environment was low, and the waves or currents were not vigorous enough to remove the micritic material.

Additional genetic relationships will be presented later with the discussions of the individual members of the Hogshooter and Coffeyville Formations.

STRATIGRAPHY

General Statement

The Hogshooter Formation is included within the Skiatook Group of the Missourian Series. This unit is underlain conformably by the Coffeyville Formation and is overlain conformably by the Nellie Bly Formation. The Hogshooter Formation of Oklahoma (as mapped by Oakes) is lithically equivalent to the Dennis Formation of Kansas (Oakes, 1940, p. 41).

The Hogshooter Formation (as mapped by Oakes) consists of four members, the Stark, Canville, Lost City, and Winterset (Oakes, 1940, p. 39). However, characteristics were found suggesting that the Stark, Canville, and Lost City Members are closely associated with the deposition of the Coffeyville terrigenous facies and that they actually represent facies of the Coffeyville Formation. It is suggested that these three members be considered part of the depositional sequence of the upper part of the Coffeyville Formation. The Hogshooter Formation consists of the three facies of the Winterset Member (the lower and upper units and the reef facies).

The Canville and Stark Members are nowhere present at the same localities as the Lost City Member. Wherever the Canville Member is present (sec. 6, T. 25 N., R. 14 E.; secs. 31, 32, T. 26 N., R. 14 E., Washington County; and sec. 18, T. 27 N., R. 15 E., Nowata County), it is underlain by the Coffeyville terrigenous facies and overlain by the Stark Shale Member. The Stark in turn is overlain by the Winterset Member. In other restricted areas (sec. 28, T. 24 N., R. 13 E.; sec. 34, T. 24 N., R. 13 E.; sec. 9, T. 26 N., R. 14 E., Washington County), the Lost City Limestone Member underlies the Winterset Member and overlies the Coffeyville terrigenous facies. The Canville and Stark occupy the same stratigraphic interval as that of the Lost City Member, above the Coffeyville terrigenous facies and below the Winterset Limestone Member (fig. 2). However, the rock types and thicknesses of the Canville and Stark Members differ from those of the Lost City Member. These relationships will be discussed in a subsequent section.

The Winterset Member is the most extensive limestone unit in the upper Coffeyville-Hogshooter-Nellie Bly sequence and occurs throughout the area. This member is divided into the lower and upper Winterset units upon the basis of lithologic differences and faunal associations. These two units can be easily distinguished; the lower Winterset unit is relatively thin (4 to 13 inches thick) and is characterized by a high percentage (more than 65 percent) of crinoidal and other skeletal debris cemented with sparry calcite. The upper Winterset unit is much thicker, with a maximum thickness of 25 feet at stratigraphic section 4 (SW¼ SE¼ SW¼ sec. 9, T. 26 N., R. 14 E., Washington County). Erosion has removed a large portion of the upper Winterset unit throughout much of the area. Therefore, variations in the total thickness of this unit could not be determined. In contrast to the lower Winterset unit, the upper Winterset unit contains relatively small percentages of skeletal material (20-30 percent), primarily brachiopods and bryozoans. These skeletal fragments are more than 1 mm in diameter and commonly float in a micritic matrix.

Two reef structures were observed in the Hogshooter Formation. The most extensively exposed reef complex is

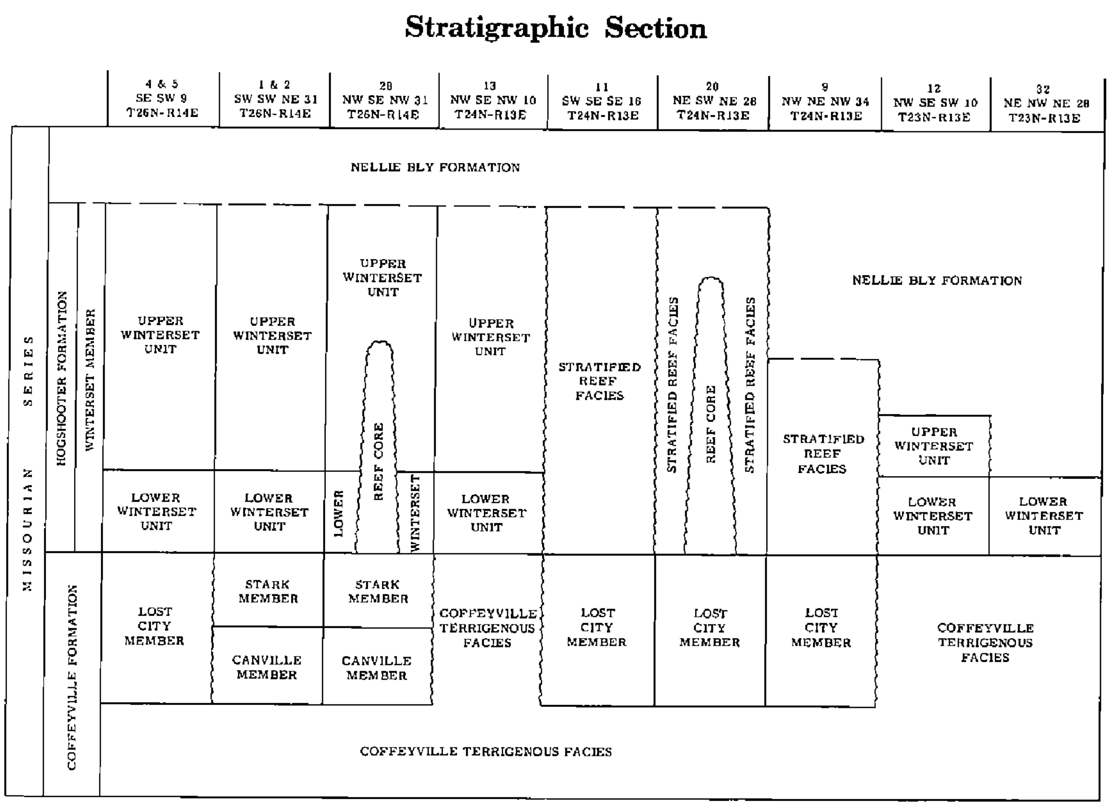

Figure 2. Correlation of the Hogshooter Formation in Washington and Nowata Counties, Oklahoma.

in NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, below the Santa Fe Railway's trestle across the South Fork of Double Creek. The other and less extensive reef is exposed in the west bank of a small creek in NW¼ SE¼ NW¼ sec. 31, T. 26 N., R. 14 E., Washington County.

The reef complex in sec. 28, T. 24 N., R. 13 E., consists of several cores and stratified lateral units which overlie the Lost City Member and the Coffeyville terrigenous facies. Within the cores, neither the lower nor upper Winterset units can be distinguished. Laterally from the cores, definite stratification exists. The vertical thickness of the cores (overlying the Lost City Member) is 12 feet. The lithology of the stratified beds surrounding the reef cores is considerably different from the widespread lithologic units of the "normal" Winterset sequence. Within the 18 feet of vertical section, only two thin dominantly micritic beds occur; the remainder of the section is composed of sparry calcite-cemented beds and skeletal-rich debris zones. In a "normal" sequence of the Winterset Member sparry calcite-cemented beds constitute only 4 to 13 inches, and the remainder of the section (25 feet) is dominantly micritic material.

The reef in sec. 31, T. 26 N., R. 14 E., consists of a single core which lies upon the Stark Shale Member. Laterally from the core is a normal Winterset sequence. Unlike the previously discussed reef complex, no change in the Winterset lithology adjacent to the core is evident.

Both reef structures lie upon units which underlie the Winterset Member at other localities (the Stark and Lost City Members). It is therefore assumed that the reefs occupy in part the same rock-stratigraphic interval as does the Winterset Member and represent a lithofacies of the Winterset Member. This assumption is supported by the occurrence of "normal" Winterset sequences peripheral to the reefs.

Environmental Significance of Faunal Elements

A brief discussion of the environmental significance of major faunal elements occurring in the Coffeyville-Hogshooter-Nellie Bly sequence as employed in this report is presented below.

Encrusting algae.—Encrusting algae (*Osagia* sp.) dominate the fossil assemblage characterizing several units in the

Hogshooter-Coffeyville sequence. *Osagia* commonly encrusts pelecypod and bryozoan fragments. These algal encrustations either completely surround a nucleus of skeletal material or encrust only one side of a fragment. The algal encrustations completely surrounding skeletal fragments are associated with sparry calcite cement (this cement suggests a relatively high-energy environment). The algal structures that completely surround a nucleus probably formed in a high-energy environment similar to that in which oöliths develop. In a high-energy environment, agitation of nuclei would permit algae to develop oölithlike encrustations completely around the nuclei. A micritic matrix is associated with the algal structures that encrust only one side of a fragment (the presence of micrite suggests a relatively low-energy environment). Micritic material suggests that the energy in the depositional environment was not sufficient to disturb skeletal fragments and that algae encrusted only the exposed available portion of the fragments.

Johnson (1945, p. 842; 1942, p. 216) suggested that oölithlike algal encrustations form in shallow marine waters as indicated by lithological associations, Illing (1954, p. 79) observed that boring and encrusting algae inhabit the interior parts of the Bahama Banks where the water is less than six feet deep. Newell and others (1959, p. 219) observed layers of calcareous material associated with filamentous algae forming around nuclei in high-energy environments on the Bahama Banks. Thus, oölithlike encrustations probably form in relatively high-energy environments. Although no definite depth is indicated by the presence of encrusting algae, wherever encrusting algae that completely surround nuclei associated with sparry calcite cement occur, it is probable that the environment of deposition was characterized by relatively shallow-water and high-energy conditions.

Mollusks.—Most pelecypod and gastropod specimens observed in the Hogshooter-Coffeyville sequence are associated with large percentages of terrigenous material and sparry calcite cement, a condition which suggests a high-energy environment. Pelecypod material is commonly fragmented, abraded, and oriented parallel to bedding in the unit and is associated with carbonaceous material and rounded muscovite flakes, suggesting nearshore, shallow-water, high-energy conditions.

On the Bahama Banks, Newell and others (1959, p.

216-224) observed that higher energy environments, such as the outer platform and the oölith sand shoals of the barrier rim (characterized by skeletal, oölith, and intraclast grains as well as encrusting algae and sparse vegetation) are dominated by a molluscan fauna. However, in stabilized areas on the Bahama Banks where energy factors are reduced, as indicated by the absence of ripple marks and the presence of mud-size calcareous material, the molluscan portion of the faunal assemblage is greatly reduced, and the assemblage is dominated by algal growths, sponges, and tunicates.

Molluscan fragments associated with encrusting algae in the lower Winterset unit and the Coffeyville terrigenous facies probably represent fragments of organisms that inhabited a relatively high-energy environment.

Bryozoans.—Fenestrate bryozoans occur in most of the Hogshooter-Coffeyville units. In some of the dominantly terrigenous units of the Coffeyville Formation, bryozoan material is absent. The lesser amount of bryozoan material in these terrigenous units is probably due to an absence of suitable substrata for attachment of the bryozoan larvae. Osburn (1957, p. 1109), Duncan (1957, p. 784), and Moore (1929, p. 468) observed that a suitable substratum must be present for bryozoan growth and that bottom conditions characterized by shifting sand and mud (without coarser admixtures) are not suitable for bryozoans. In high-energy sandy environments no suitable attachments for the bryozoans were available, and therefore these organisms are not associated with the terrigenous units.

Fenestrate bryozoans occur in beds dominated by either sparry calcite cement or micritic material. Duncan (1957, p. 787) indicated that brisk currents and strongly agitated waters are essential for bryozoan growth, as these factors are necessary to supply the required planktonic organisms to the bryozoans. In the sparry calcite-cemented units, the bryozoans are fragmented and abraded, whereas they are only slightly fragmented and are unabraded in the micritic units. Possibly the bryozoans associated with the micritic material acted as baffels which trapped the material brought in by mild currents along with plankton.

Newell and others (1959, p. 221, 224) and Ginsburg and Lowenstam (1958, p. 313) mentioned that bryozoans occur in stabilized, relatively low-energy environments in the Bahamas and Florida Bay. Ginsburg and Lowenstam also observed that in lower energy stabilized areas, skeletal material was not abraded or fragmented. The unabraded bryozoan fragments in the upper Winterset micritic units probably represent remains of organisms that inhabited relatively low-energy environments.

Brachiopods.—Most brachiopod specimens in the Hogshooter-Coffeyville sequence are concentrated in micritic units (these organisms probably inhabited low-energy environments). Absence of abrasion and the presence of long spines (greater than 1 mm in length) still attached to brachiopod shells indicate that these organisms lived in low-energy environments and were not subjected to transportation. A few abraded and fragmented brachiopod shells occur in sparry calcite-cemented units.

Crinoids.—Although minor percentages of unabraded (2 to 5 percent) crinoidal material occur in the upper Winterset, most of the crinoids probably inhabited high-energy environments because columnals, plates, and spines comprising from 15 to 40 percent of the rock are associated with encrusting algae and molluscan fragments. In the sparry calcite-cemented lower Winterset, the crinoidal material has suffered a relatively high degree of abrasion, again suggesting that these fragments were deposited in high-energy environments. Because micrite is indicative of low-energy conditions, it is inconceivable that large crinoid plates and columnals could be transported from such a low-energy environment without removal of the micritic material. Therefore some crinoids inhabited the micrite-accumulating environments. Based upon lithologic and faunal associations, the suggestion is made that the crinoids primarily lived in relatively shallow, high-energy environments.

Minor percentages of other fossil elements, such as calcareous algae (other than *Osagia*), sponge spicules, foraminifers, ostracodes, arthropod fragments, conodonts, and fish teeth, also occur in the Hogshooter-Coffeyville sequence. These minor constituents are discussed later with the particular unit in which they occur.

General Environmental Interpretations Based upon Faunal Associations

Molluscan fragments associated with carbonaceous material and high percentages of terrigenous material with little to no additional skeletal material are indicative of high-energy, nearshore environments. Encrusting algae, fenestrate bryozoan fragments, mollusks, crinoidal material, and arthropod fragments associated with a sparry calcite cement are suggestive of high-energy environments (less intense than during the deposition of the highly terrigenous pelecypod-bearing units). Unabraded brachiopod and fenestrate bryozoans associated with micritic material are indicative of low-energy conditions.

Differences in energy in the depositional environment are not necessarily due to differences in water depth. Elias (1937) proposed that specific faunal assemblages indicate definite water depths that occurred during the deposition of the Big Blue series in Kansas. Different faunal assemblages associated with different rock types were interpreted by Elias as having been deposited in waters with different depths. However, Ginsburg and Lowenstam (1958) and Newell and others (1959) have given conclusive evidence that different faunal assemblages and sediment accumulations may occur simultaneously in an environment with a reasonably constant depth. It is possible (as suggested by Newell and others, p. 188-189) that the occurrence of a particular rock type and faunal assemblage is controlled by energy factors in the depositional environment rather than by the depth of water. Stabilization produced by baffels could possibly produce the same type of low-energy environment as that formed by deeper water.

Detailed Description of Individual Units

The variations in thickness and gross lithology, insoluble content, terrigenous grain size, petrographic properties, and faunal associations are discussed for the facies of the upper part of the Coffeyville Formation, the Hogshooter Formation, and the Nellie Bly Formation. Following the detailed discussion of the variations, an environmental interpretation for each unit is presented.

COFFEYVILLE FORMATION

Several insoluble-residue analyses and thin-section examinations were made on samples collected from the terrigenous facies in the upper part of the Coffeyville Formation. The percentages of insoluble material in four samples from this terrigenous facies immediately below the contact with the Hogshooter Formation and the Lost City facies range from 39 to 76 percent (table 2). The data are inadequate to

TABLE 2.—AREAL VARIATION OF INSOLUBLE-RESIDUE AND FAUNAL CONTENTS IN THE COFFEYVILLE TERRIGENOUS FACIES

STRATIGRAPHIC SECTION	PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI	COARSEST PARTICLE SIZE (PHI)	PERCENTAGE AND TYPES OF FOSSILS PRESENT	
Southwest					
9	55	68	2.0	15	Pelecypod fragments
11	49	65	2.0	35	Pelecypod fragments, encrusting algae, brachiopod and crinoid fragments
5	39	53	3.0	40	Pelecypod fragments, encrusting algae, brachiopod and crinoid fragments
18	76	24	3.0	0	None
Northeast					

establish a valid pattern for the geographic distribution of the terrigenous material. An obvious relationship between the amount of insoluble residue and the percentage of skeletal material is illustrated in table 2. As the percentage of insoluble material increases, the percentage of skeletal material decreases, and the faunal assemblages change. The percentage of terrigenous material coarser than 4.5 phi is not directly proportional to the percentage of insoluble material. At stratigraphic section 18, the lowest percentage of terrigenous material coarser than 4.5 phi is associated with the highest percentage of insoluble material.

At stratigraphic section 5, four samples were collected from the Coffeyville sequence underlying the Lost City facies.

The characteristics of these four samples are listed in table 3. The lowermost sample was collected from a thick-bedded unit 6 feet below the base of the Lost City facies. Sample 5-2 is from a shale unit that overlies the lowermost sample. Samples 5-3 and 5-A-1 were collected from the base and top, respectively, of a 5.5-foot-thick sequence, composed of thin-bedded sandy and silty biosparrudite, which overlies the shale bed. No decrease upward in the percentages of insoluble material or terrigenous material coarser than 4.5 phi in diameter occurs. However, it was observed in the thin sections that the diameter of the coarsest terrigenous particle decreases upward. As this decrease occurs, the fauna changes upward from pelecypod-dominant at the base (base of exposed strata) to encrusting algae-dominant at the top.

It is possible to reconstruct the relative water depths or energies present during the deposition of the Coffeyville terrigenous facies by examining the faunal assemblages associated with the different units. At stratigraphic section 5, the faunal contents of the lowermost sample (5-1) and of the sample from the base of the biosparrudite unit (5-3) are dominantly pelecypod fragments. The terrigenous material in these two samples is coarser than that in the sample from the upper portion of the biosparrudite sequence. The upper part of this unit was probably deposited in a deeper water or a lower energy environment, as the faunal assemblage con-

TABLE 3.—STRATIGRAPHIC VARIATION OF INSOLUBLE-RESIDUE AND FAUNAL CONTENTS IN THE COFFEYVILLE TERRIGENOUS FACIES AT STRATIGRAPHIC SECTION 5

SAMPLE NUMBER	PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI	COARSEST PARTICLE SIZE (PHI)	PERCENTAGE AND TYPES OF FOSSILS PRESENT	
Top					
5-A-1	39	53	3.0	40	Encrusting algae, fenestrate bryozoans, crinoids
5-3	29	50	2.5	25	Pelecypod fragments
5-2	73	69			
5-1	35	59	2.0	20	Pelecypod fragments
Base					

sisting of pelecypods, encrusting algae, fenestrate bryozoans, and brachiopods is indicative of lower energy or deeper water than are the pelecypod fragments in the lower two units. The same relationships occur at stratigraphic sections 9 and 11. The fauna at stratigraphic section 9, primarily pelecypods, suggests relatively shallow-water and high-energy conditions. At stratigraphic section 11, the percentage and size of the terrigenous material are smaller than those at stratigraphic section 9. The faunal assemblage, consisting of pelecypods, encrusting algae, fenestrate bryozoans, brachiopods, and crinoids, also indicates a deeper water or lower energy environment than does that at stratigraphic section 9.

It is impossible to provide a specific water depth for the depositional environment of the Coffeyville terrigenous facies. By using Illing's (1954) information, it is possible to suggest reasonable limits for the water depth. Illing observed mollusks and calcareous algae at depths ranging from approximately 6 to 60 feet (encrusting algae were found primarily in water less than 6 feet deep). A shallow, nearshore environment is suggested by the occurrence of carbonaceous material (3%) in several units. According to Trask (1939, p. 450), shallow marl banks in the Bahamas and Florida coast region (depth of water ranges from 1 to 3 feet) are characterized by carbonaceous material constituting from 3 to 6 percent of the sample.

Canville Limestone Member

The Canville Member represents a local limestone accumulation above the highly terrigenous Coffeyville sequences and below the Stark Shale Member in sec. 6, T. 25 N., R. 14 E., and secs. 31, 32, T. 26 N., R. 14 E., Washington County, and sec. 18, T. 27 N., R. 15 E., Nowata County.

Thickness and lithology—The Canville Limestone Member consists of a single limestone bed, which ranges in thickness from 11 to 30 inches in sec. 6, T. 25 N., R. 14 E., and secs. 31, 32, T. 26 N., R. 14 E., Washington County. At stratigraphic section 1, the Canville is 30 inches thick; 100 yards west and ½ mile south of stratigraphic section 1, this unit thins to 15 and 11 inches, respectively. Approximately three-quarters of a mile south of stratigraphic section 3 (Canville is 11 inches thick) at stratigraphic section 29, the Canville is 13 inches thick (fig. 3). Approximately one mile east of stratigraphic section 3, the Canville is 3 inches thick. In sec. 18, T. 27 N., R. 15 E., Nowata County, the Canville is extremely irregular, ranging in thickness from 6 to 10 inches and eventually becoming nodular. The unit disappears into a laminated calcareous siltstone lithologically similar to the Coffeyville terrigenous facies.

Insoluble content—Nine samples of the Canville, collected from stratigraphic sections 1, 2, 3, 19, 29, and 42 (pl. I; fig. 3), were treated with hydrochloric acid to determine the weight percentages of insoluble material. Where possible, samples were collected at the top and at the bottom of the unit. The data are given in table 4. Lateral increase in the percentage of insoluble material, associated with a decrease in the thickness of the unit, occurs. From stratigraphic section 1, the 16 percent insoluble material at the base of the unit increases to 18 and 39 percent at sections 2 and 3, respectively. Southward from stratigraphic section 3 at stratigraphic section 29, the insoluble content decreases to 29 percent. The Canville Member is thickest at stratigraphic section 1, and thins toward stratigraphic sections 2, 3, and 42. From stratigraphic section 3 to stratigraphic section 29, the unit again thickens. Table 4 shows a decrease in insoluble content from the base to the top of the unit.

One sample, collected from the top of the unit at stratigraphic section 19 (sec. 18, T. 27 N., R. 15 E., Nowata County), contains 26 percent insoluble material. The section is approximately 50 yards from the locality where the unit becomes nodular.

The mineralogical composition of the insoluble material includes 99 percent angular quartz fragments with traces of rounded muscovite (the larger particles have the higher degree of rounding), pyrite, glauconite pellets, and overgrowth-bearing tourmaline. One acetic acid residue was examined and no additional minerals were found. However, traces of phosphate were observed in several thin sections of the Canville samples.

Terrigenous grain size—Each insoluble residue was analyzed to determine the percentages of material coarser and finer than 4.5 phi (table 4).

The insoluble residues of the Canville Member consist predominantly of material finer than 4.5 phi. At stratigraphic sections 2 and 29, the proportion of coarser material decreases

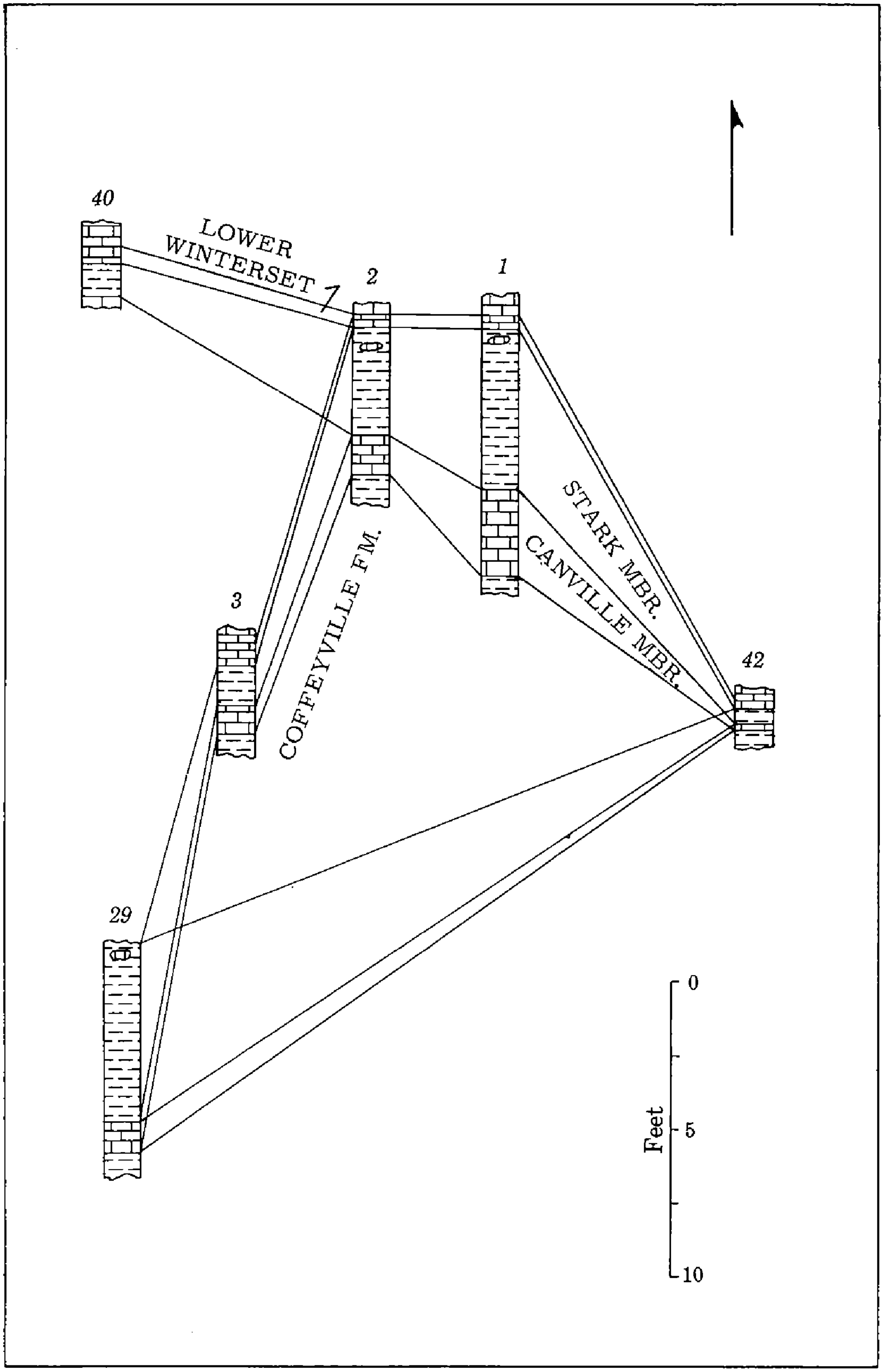

Figure 3. Canville-Stark relationships in secs. 31, 32, T. 26 N., R. 14 E., and sec. 6, T. 25 N., R. 14 E.

from base to top, whereas in stratigraphic section 3 it does not change significantly. A decrease in grain size does not necessarily correspond to a decrease in the percentage of insoluble material. At stratigraphic section 3, the amount of insoluble material decreases by 19 percentage points from base to top, although the relative proportions of coarser and finer material remain unchanged.

Petrographic properties—Five thin sections and one acetate peel of the Canville Member were examined and three distinct limestone types were observed. At stratigraphic section 1, the basal part of the member is a silty, spiculiferous biomicrosparite; the thin section contains a few skeletal fragments, principally of monaxon sponge spicules, which float in a matrix of micrite and microspar. The sample from the base of the unit at stratigraphic section 29 is similar but contains large brachiopod and fenestrate bryozoan fragments rather than sponge spicules. Both thin sections illustrate the recrystallization of micrite and skeletal material to microspar. West of stratigraphic section 1, at stratigraphic section 2, the limestone type is a silty, spiculiferous, intraclast-bearing biomicrosparite.

TABLE 4.—INSOLUBLE RESIDUES AND FAUNAL CONTENT IN THE CANVILLE MEMBER

STRATIGRAPHIC SECTION		PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI	THICKNESS (INCHES)	FOSSIL TYPES
1	Base	16	30	30	Sponge spicules
2	Base	18	42	15	Sponge spicules
	Top	12	22		
3	Base	39	22	11	Encrusting algae, crinoids, gastropods, pelecypods
	Top	20	23		
19	Top	26	13	10	do.
29	Base	29	13	13	Brachiopods, bryozoans
	Top	7	4		
42	Top	16	----	3	Encrusting algae, crinoids, gastropods, pelecypods

The intraclasts are well developed and well rounded. Many sponge spicules are partly or entirely replaced by pyrite. South and east at stratigraphic sections 3 and 42, the unit changes to a silty, algal-bryozoan biosparrudite. Pyrite is associated with both the bryozoan and algal material. The cement at these localities is fine-grained sparry calcite (traces of microspar occur in the sample from stratigraphic section 42).

Approximately nine miles north of stratigraphic section 1, at stratigraphic section 19, the fauna is similar to that at stratigraphic section 3. The limestone type differs as the matrix is micrite instead of sparry calcite cement.

Faunal associations—Thin sections from stratigraphic sections 1 and 2 show a predominance of monaxon sponge spicules as the main fossil constituent (approximately 20 percent of each thin section is composed of skeletal material). Traces of foraminifers, crinoids, brachiopods, and ostracodes also occur. A change in fauna occurs from stratigraphic sections 1 and 2 to stratigraphic sections 3 and 42, where bryozoans, encrusting algae (*Osagia* sp.), and crinoids are the dominant fossil types. A few brachiopods, gastropods, and pelecypod fragments also occur (these samples contain approximately 35 percent fossil material). At stratigraphic section 29, the dominant fossil types are brachiopods and bryozoans. Generally the same fauna found at stratigraphic section 3 is also present at stratigraphic section 19. Encrusting algae, pelecypods, and gastropods are more abundant at stratigraphic section 19, and bryozoans and crinoidal material less abundant.

Synthesis of above data—In the vicinity of stratigraphic sections 1, 2, 3, 29, and 42, several trends can be established in the Canville Member. An inverse relationship between the percentage of insoluble material and the thickness of the unit exists. From stratigraphic section 1, the thickness of the unit decreases to the west, east, and south. However, the percentage of insoluble material increases to the west, east, and south of stratigraphic section 1. South of stratigraphic section 3, the Canville Member again thickens and also shows a corresponding decrease in the amount and size of the terrigenous material (fig. 3; table 4).

West and south of stratigraphic section 1, an increase in the energy of the environment of deposition is suggested. The only allochemical constituent occurring at stratigraphic section 1 is fossil material. At stratigraphic section 2, 100 yards west, micrite intraclasts, associated with fossil material, are composed of material similar to that found in the thin section from stratigraphic section 1. Because of an increase in energy, some fine-grained micritic material may have been eroded, rounded, and then redeposited. South and east at stratigraphic sections 3 and 42, absence of micritic material is indicative of a relatively high-energy environment in which the fine material was removed by wave and current action. The pore space remaining around the allochemical and terrigenous framework was subsequently filled with sparry calcite. South of stratigraphic section 3, the Canville again thickens; the matrix is micrite, with brachiopod and bryozoan fragments being the only allochemical constituent present. The micrite again probably indicates relatively low-energy conditions.

A change in faunal assemblages occurs between stratigraphic sections 1, 2, and 29 and stratigraphic sections 3 and 42. At stratigraphic sections 3 and 42, the sparry calcite cement and fossil assemblage, consisting of encrusting algae, gastropods, bryozoans, and pelecypods, indicate a relatively shallow-water, high-energy environment. At stratigraphic sections 1 and 2, monaxon sponge spicules are the dominant fossil constituent, with minor percentages of unabraded brachiopods, bryozoans, and foraminifers. DeLaubenfels (1957, p. 1083) stated that Calcispongea inhabit only normal marine shallow-water (in most cases less than 10 meters deep) environments, characterized by mild currents, solid substratum, freedom from covering silt, and the absence of stagnant conditions. At stratigraphic sections 1 and 2, the recrystallized micrite indicates a low-energy environment similar to that favoring sponge development (the spicules are probably indigenous to this general vicinity and were not transported into the low-energy environment). At stratigraphic section 29, brachiopods, and bryozoans are associated with a micrite matrix. Unabraded bryozoans and brachiopods normally indicate a somewhat deeper water or lower energy environment than do mollusks and encrusting algae. It is possible that brachiopods and bryozoans are dominant at this locality because of sponge exclusion caused by the higher terrigenous content in the environment (29 percent as compared with 18 percent at stratigraphic section 1).

The differences in thickness, insoluble content, limestone types, and faunal association may be interrelated. In 1940, Oakes discussed two possible origins for the Canville Member: (1) the Canville Member represented erosional remnants of a once wide-spread unit which had been folded and eroded, leaving the Canville only in the synclines, and (2) the Canville Member was deposited in small structural depressions in the Coffeyville Formation.

Another and possibly better explanation for the Canville limestone accumulations is that the fine-grained calcareous material (micrite) may have been concentrated by baffles similar to those described by Ginsburg and Lowenstam (1958, p. 312-314). These workers found that in Florida Bay marine grasses act as stabilizing and sediment-trapping agents. In stabilized areas, the grass produces a semimotionless layer of water over the bottom from which sediment that would otherwise be winnowed away can settle out of suspension (Ginsburg and Lowenstam, 1958, p. 313). Ginsburg and Lowenstam observed that once fine-grained calcareous material filtered into the root mat, it was not resuspended by wave action or tidal currents. These stabilized areas may occur in extremely shallow waters (less than 1 foot in depth to more than 15 feet). The protective grass baffles can also preserve delicate skeletal material from fragmentation by mechanical abrasion (Ginsburg and Lowenstam, p. 313). Because the grass baffles are local, the accumulation of micrite is also local. Ginsburg and Lowenstam also observed that along the flanks of these stabilized areas, where currents are stronger, sand-sized shell debris was concentrated. These grass-stabilized areas are often subaerially exposed during low-water periods.

Newell and others (1959, p. 222-223) observed that low-energy environments in which lime muds accumulate exist contemporaneously adjacent to high-energy environments. The mud-accumulating environments are stabilized by algae and marine grasses.

The Canville limestones were possibly deposited under conditions similar to those studied by Ginsburg and Lowenstam (1958) in Florida Bay. The Canville is thickest in a central area, and thins in all directions, in a manner similar to that of the elongate mud banks described by Ginsburg and Lowenstam. In the central or thicker part of the accumulation, the dominant fossil materials are either sponge spicules or unabraded bryozoans and brachiopods. Toward the areas of thinner accumulation, more fossil material occurs (encrusting algae, crinoids, pelecypods, gastropods, and fenestrate bryozoans). The fossil types associated with the thinner areas are similar to those found in some parts of the Coffeyville terrigenous facies, which was probably deposited in a relatively high-energy environment as indicated by the presence of biosparrudites. Sparry calcite cement in the marginal areas also suggests that the energy was higher in these areas than in those where micrite was preserved. The Canville may have been deposited in stabilized areas contemporaneously with the deposition of the Coffeyville biosparrudites in adjacent areas. The characteristics of the margins of these local limestone accumulations were influenced by the mixing of the two environments. Where the Canville is thinner (indicating a possible marginal position), the terrigenous content and the faunal assemblage suggest higher energy similar to that present during the deposition of the Coffeyville terrigenous facies. If these plant-stabilized areas (possibly stabilized by algal growths) were subjected to subaerial conditions, sparry calcite could have been precipitated in the void spaces that resulted from the removal of micritic material in the higher energy environments (Illing, 1954, p. 48).

Microspar in the samples from stratigraphic sections 1, 2, and 29 was formed by the recrystallization of micritic material. In two thin sections, grading of micrite into coarser microspar indicates that the micrite is recrystallizing to microspar (Folk, 1959a, p. 32). In many cases the microspar also transgresses across fossil material.

Stark Shale Member

The Stark Member represents localized shale accumulations, normally underlain by the Canville and overlain by the Winterset limestone units. At one location, sec. 14, T. 29 N., R. 15 E., Nowata County, the base of the Stark is covered, and the Canville Member, if present, is not exposed.

Thickness and lithology—The Stark Member consists primarily of fissile, carbonaceous black shale which is separated from the underlying Canville and the overlying Winterset limestone units by brown and gray clay units. Approximately 2 to 10 inches of gray and brown clay separates the Canville Limestone from the black shale of the Stark Member; the upper 3 inches of the Stark Member is also composed of brown and gray clay. A zone of limestone concretions commonly occurs 8 to 10 inches below the overlying Winterset Member. These concretions are flattened parallel to the bedding in the black shale and range in length from 1 inch to slightly more than 1 foot. Many of the larger concretions are 3 to 5 inches wide. The concretions are absent at stratigraphic section 3 and are extremely reduced in size at stratigraphic section 40. At stratigraphic section 19, a continuous bed of limestone (similar in lithology to the concretions) approximately 20 feet long occurs; laterally the limestone bed grades into large limestone concretions similar to those found at other localities.

The Stark Member ranges in thickness from 5 inches to more than 6 feet. At stratigraphic section 1, the Stark is 5.5 feet thick. The unit thins to 5 inches approximately 1.5 miles to the southeast and to 3.5 feet 100 yards to the west. Farther west at stratigraphic section 40, the unit is 1 foot thick. Half a mile south of stratigraphic section 1, the Stark thins to 11 inches. Three-quarters of a mile south of stratigraphic section 3, the unit thickens to 6 feet (fig. 3). Several miles north at stratigraphic section 19, the unit is 2.5 feet thick. At stratigraphic section 15 (sec. 14, T. 29 N., R. 15 E., Nowata County), the Stark is 6 feet thick, with the base unexposed.

Insoluble content—One sample of black shale and four of limestone concretions were treated with hydrochloric acid. The black shale contains 88 percent insoluble material. Insoluble content in the limestone concretions ranges from 8 to 11 percent. Silt-size quartz, chert, and pyrite are the principal mineralogical components of the insoluble material in the limestone concretions. The terrigenous material (silt-size quartz) constitutes approximately 6 to 10 percent of the total sample. At stratigraphic section 15, pyrite composes approximately 7 percent of the total sample; the three remaining samples contain only minor amounts of pyrite. The presence of organic material in the residue was shown by an oily film which formed above the hydrochloric acid shortly after initial digestion of the sample. The limestone concretions effervesced only at a few random points. Each residue was composed of a large lump of brownish-black organic material, punctured by numerous small holes and essentially the same size as the initial sample. Calcite, impregnated in the organic framework, was removed by reaction with hydrochloric acid, leaving only a skeleton of material constituting 8 to 11 percent of the original sample.

Terrigenous grain size—Material finer than 4.5 phi constitutes 92 to 98 percent of the insoluble residues. Approximately half of the remainder is pyrite. The terrigenous material coarser than 4.5 phi constitutes a minor fraction of the initial sample. More than 99 percent of the insoluble material from the shale sample is finer than 4.5 phi. Traces of muscovite also occur in the black shale residue, but no pyrite was observed.

Petrographic properties—Four thin sections of the limestone concretions were examined. They are characterized by a fine-crystalline sparry calcite matrix. Allochemical constituents are rare. At stratigraphic section 19, the concretion contains approximately 3 to 5 percent fossil fragments. This is the only thin section that contains allochemical constituents. The absence of an allochemical framework excludes the possibility that the fine-crystalline sparry calcite represents a primary cement (Folk, 1959a).

In three thin sections of the concretions bedding is indicated by closely spaced, parallel, dark-brown areas, which probably represent laminae of organic material. Fine-crystalline sparry calcite is randomly disseminated throughout the slides.

Traces of pyrite, chert, and small circular areas of coarser sparry calcite are scattered throughout the thin sections. These minerals accumulated as void fillings in the fine-crystalline sparry calcite matrix. The areas of chert and coarse sparry calcite show excellent examples of rim cementation. The pyrite also occurs as void fillings; pyrite incompletely fills voids, leaving remnants of the initial voids surrounded by pyrite.

One X-ray analysis of the material of the concretions indicates that calcite is the only carbonate present, and that pyrite and quartz also occur.

Faunal associations—A minor amount of unidentifiable fossil material occurs in one limestone-concretion thin section. A few conodonts are associated with the black shale interval and one sample was found to contain hystrichosphaerids, spores, and algal fragments (J. B. Urban, personal communication, 1961).

Synthesis of above data—The Stark Member thins to the west, south, and east of stratigraphic section 1. The thickening and thinning illustrated by the Stark Member corresponds to the same trend in the underlying Canville Limestone Member. Oakes (1940, p. 43) suggested that the Stark and Canville Members either represent erosional remnants of a once widespread unit or were deposited within structural depressions in the Coffeyville Formation.

It is also possible that the deposition of the Stark Shale was contemporaneous with that of the terrigenous material in adjacent areas. The origin previously suggested for the Canville Limestone Member is a limestone accumulation formed by the stabilizing abilities of primitive plants (possibly algae). Under certain conditions, the stabilizing plant material may have supplied the organic material necessary to form the carbonaceous black shales. The most prolific growth of the plants occurs toward the centers of stabilized areas (Ginsburg and Lowenstam, 1958, p. 314) and, therefore, the supply of organic material is greater at these places. If favorable conditions for deposition existed, the thickest accumulations would occur in the central areas. In the Canville Limestone Member (below the Stark), a decrease upward in the percentage of and coarseness of the terrigenous material may indicate an energy decrease in the depositional environment toward the top of the unit. If the energy decreased sufficiently, reducing conditions may have formed (above or below the depositional interface), and the organic material may have accumulated. Hystrichosphaerids and spores indicate that a normal marine relatively nearshore environment existed in the vicinity of the Stark accumulation (J. B. Urban, personal communication, 1961). Algal material in the black shale of the Stark suggests that algae may have stabilized the low-energy environment.

According to Krumbein and Garrels (1952, p. 19), abundant organic material and pyrite in a black shale are indicative of reducing conditions. Twenhofel (1950a, p. 337) suggested that black shale accumulation is (1) primarily the result of rapid burial of organically rich material with an incomplete elimination of the organic material by bacteria and scavengers, or (2) due to the deposition of organic material in an oxygen-deficient environment characterized by a limited circulation of water. The limited circulation of water is commonly attributed to a barrier of some type (possibly the baffling effect of plants themselves). Krumbein and Garrels (1952, p. 22) suggested that reducing conditions may exist a few centimeters below the depositional interface owing to the exclusion of oxygen. The area above the depositional interface may exhibit unrestricted circulation of water with a positive oxidation-reduction potential.

The character of the black shale of the Stark was probably influenced by diagenetic changes which occurred below the depositional interface where the possible existence of reducing conditions would have favored the occurrence of anaerobic bacteria. These bacteria may have attacked the rapidly accumulating organic material and produced a relatively high concentration of hydrogen sulfide. The hydrogen sulfide and reduced (ferrous) iron below the depositional interface combined to form the iron disulfides that occur in the Stark. Where rapid accumulation occurred, numerous calcareous scavengers, planktonic and nektonic organisms, may have been buried as calcareous material. If this calcareous material was introduced into a reducing environment below the depositional interface where the pH is often lower, the calcareous material may have been dissolved and disseminated in solution through the accumulating clay and organic material. The calcium phosphate composition of the conodonts is stable at lower pH values than is calcite, and therefore the conodonts may have been preserved even though calcareous organisms were dissolved. If it is assumed that the reducing conditions occurring during deposition of the Stark Shale were below the depositional interface, fewer restrictions, such as water circulation or stagnation, are required to explain the calcareous black shale accumulation.

Limestone concretions found in the Stark Member are epigenetic in origin. Several concretions have laminations which are parallel to and continuous with the bedding in the black shale. Pettijohn (1957, p. 203) and Weeks (1957, p. 99) suggested that relict bedding in a concretion indicates an epigenetic or secondary origin. Compaction of thin laminae of the black shale around the concretions indicates that the concretions were formed before complete compaction of the shale occurred.

At stratigraphic sections 3 and 40, the Stark is 11 and 12 inches thick, respectively. The limestone concretions are absent at stratigraphic section 3 and are much smaller (approximately 1 inch in diameter) at stratigraphic section 40. These conditions may be related to the thickness of the black shale unit. Where the thickness of the black shale ranges from 3 to 6 feet, the concretions are relatively large. When compaction of the Stark was initiated, much of the calcareous material disseminated in solution through the sediment may have been driven out of the fine-grained material. After sufficient compaction occurred, a suitable concentration of calcareous material was possibly obtained to initiate nucleation of the calcareous material with subsequent formation of the concretions. Where the black shale is exceptionally thin, the concentration of calcareous material may not have been sufficient for concretion development.

Lost City Limestone Member

The Lost City Member, a localized limestone unit, occurs above the Coffeyville terrigenous facies and below the Winterset Member in secs. 28, 34, T. 24 N., R. 13 E., and sec. 9, T. 26 N., R. 14 E., Washington County. At stratigraphic section 20 (sec. 28, T. 24 N., R. 13 E.), the unit is underlain by approximately 20 feet of Coffeyville shale and siltstone and is overlain by the reef facies of the Winterset Member.

Thickness and lithology—In secs. 28, 34, T. 24 N., R. 13 E., Washington County, three vertical sections of the Lost City Member were measured. This member consists of a single limestone bed, ranging in thickness from 6 to 28 inches. In NW¼ NE¼ NW¼ sec. 34, T. 24 N., R. 13 E., at stratigraphic section 9, the unit is 6 inches thick. Approximately four-fifths of a mile northwest of this locality, at stratigraphic section 20, the Lost City Member is 28 inches thick. At stratigraphic section 39, 200 feet east of stratigraphic section 20, the unit thins to 8.5 inches. At stratigraphic section 11, approximately one mile north of stratigraphic section 20, the Lost City Limestone unit is unidentifiable, but the unit beneath the reef facies of the Winterset Member is similar (fossil material, quartz types, and heavy minerals) to the Lost City Member and may be a lateral facies of this member. Approximately 100 yards west of stratigraphic section 20, the unit is absent, and the stratified reef facies overlies the Coffeyville terrigenous facies. At stratigraphic section 5 (sec. 9 T. 26 N., R. 14 E., Washington County), the Lost City Member is 8 inches thick. One hundred feet southwest of this location, the unit thickens to 14 inches. Oakes (1940) measured a thickness of 20 inches for this unit approximately 150 yards southwest of stratigraphic section 5 (Oakes' locality is now covered by water).

Insoluble content—Four samples were digested in hydrochloric acid. Three samples were collected in secs. 28, 34, T. 24 N., R. 13 E., Washington County. An inverse relationship between the thickness of the unit and the insoluble content exists in the Lost City Member (this same relationship has been previously discussed for the Canville Limestone Member). From stratigraphic section 20 to stratigraphic sections 9 and 39 (south and east, respectively), the thickness of the Lost City Member decreases from 28 inches to 8.5 and 6 inches, respectively. The insoluble content increases from 11 percent at stratigraphic section 20 to 16 percent and 21 percent to the east and south, respectively. One sample was collected from stratigraphic section 5, where the insoluble content is 12 percent.

The mineralogical composition of the insoluble material from the hydrochloric acid digestions is 99 percent angular quartz particles with a trace of muscovite and slight traces of glauconite and pyrite. Four acetic acid digestions were made. Two residues contained a minor amount of phosphate pellets. Several residues yielded abundant phosphatic internal molds of gastropods.

Terrigenous grain size—Insoluble material from the Lost City Member is composed dominantly of particles with diameters less than 4.5 phi. At stratigraphic sections 9, 20, and 39, a direct relationship exists between the thickness of the unit, the insoluble content, and the percentage of residue coarser than 4.5 phi. At stratigraphic section 20, 16 percent of the insoluble material is coarser than 4.5 phi; southward and eastward, the percentage increases to 22 and 26 percent, respectively, whereas the thickness of the unit decreases.

Petrographic properties—Three thin sections and two acetate peels of the Lost City Member were examined.

The limestone type at stratigraphic section 9 is a silty, algal-pelecypod biomicrudite. The thin section contains numerous large skeletal fragments parallel to geopetal structures, indicating that the larger fragments are oriented parallel to the depositional surface. Several thin laminations containing fragmental skeletal material and parallel geopetal structures occur. Most of the terrigenous material occurs in these fragmental zones. The highly terrigenous and fragmental bands probably represent intervals during which material was carried into and deposited in a relatively low-energy environment. The larger skeletal fragments probably represent remains of organisms that lived in the low-energy environment. Encrusting algal structures cover only one side of skeletal fragments, indicating that the fragments were not agitated and that the algae grew only on the exposed upper surfaces.

The same rock type occurs at stratigraphic section 20, but the faunal types differ. Large unbroken brachiopod fragments and algae dominate the fauna. A large terrigenous rock fragment, similar in lithology to that of the previously discussed Coffeyville terrigenous facies, occurs in this sample. The skeletal and terrigenous material are not oriented.

At stratigraphic section 5, the thin section shows a high degree of recrystallization, as the original matrix, probably micrite, and much skeletal material have been recrystallized to microspar. The skeletal material is not oriented. Several large rock fragments composed of highly terrigenous material, similar to the rock fragments occurring at stratigraphic section 20, also occur in this sample.

Faunal associations—At stratigraphic section 9, the Lost City Member contains abundant algae, including both *Osagia* sp. and *Epimastopora* sp. (Johnson, 1946), gastropods, pelecypods, and bryozoans with traces of fusulinids and other foraminifers. Well-preserved burrows also occur. The faunal association changes slightly to the north at stratigraphic section 20. Algae, principally *Osagia*, brachiopods, bryozoans, and crinoid fragments dominate this thin section. At stratigraphic section 5, the fauna is again slightly different. Both *Osagia* and *Epimastopora* are abundant, with bryozoans, crinoid fragments, gastropods, and pelecypods also relatively abundant. Traces of fusulinids and other foraminifers also are present.

In thin sections from stratigraphic sections 5 and 9, many gastropod shells are filled with dark-brown phosphatic material. The phosphate may be forming within the gastropod shells owing to some favorable physicochemical condition. Ames (1959, p. 838) stated that it is highly improbable that the concentration of phosphate ion could become sufficient to produce phosphorite deposits in the presence of calcite. Probably the phosphate was formed by the replacement of micrite by carbonate apatite.

Synthesis of above data—As in the Canville Member, several trends can be established in the Lost City Limestone Member. In stratigraphic sections 9, 20, and 39, an inverse relationship exists between the thickness of the unit and the percentage and coarseness of the insoluble residue. As the unit decreases in thickness to the east and south of stratigraphic section 20, the percentage and coarseness of the insoluble material increase. The coarser and more abundant terrigenous material indicates a higher energy environment to the east and south.

The Lost City Member may represent accumulation of micrite in stabilized areas similar to those found by Illing (1954, p. 61), Newell and others (1959, p. 222), and Ginsburg and Lowenstam (1958, p. 312-314) in the Bahamas and Florida Bay. The Lost City Limestone accumulated contemporaneously with highly terrigenous facies in adjacent areas. A local area of primitive plants may have caused, in part, the precipitation and entrapment of micritic and fossil material. Completely surrounding the stabilized area, a highly terrigenous environment existed. The increase in terrigenous material toward the thinner areas of the Lost City indicates a mixing of the two environments where sparser plant growth was not sufficient to stabilize the bottom. Intraclasts composed of terrigenous material suggest erosion and subsequent incorporation of the adjacent terrigenous facies into the stabilized facies. Approximately one mile north of stratigraphic section 20, the Coffeyville terrigenous facies contains a fauna similar to that of the Lost City Member (*Osagia*, brachiopods, bryozoans, and pelecypods). This part of the Coffeyville terrigenous sequence may represent a lateral facies of the Lost City Member.

The fauna at stratigraphic section 20 (dominantly *Osagia*, brachiopods, and bryozoans) is suggestive of an environment of lower energy than that of the adjacent areas where pelecypods and gastropods dominate the fauna. The fauna of the terrigenous facies may have encroached onto the margins of the stabilized, micrite-accumulating area but did not penetrate to the central part. Therefore the fauna of the central area lacks faunal elements that characterize the terrigenous environment.

Dascycladaceae algae, principally *Epimastopora* sp., occur only in the Lost City Member of the Coffeyville Formation and the reef facies of the Winterset Member. This branching form of alga may have assisted in stabilizing the micrite.

Hansen (1958) considered the Lost City Member to be part of the lower Winterset unit. However, because of several pronounced differences between these two units, they are treated as separate lithologic divisions in this report. The lower Winterset unit is everywhere characterized by a single bed of allochemical constituents cemented with sparry calcite. A micritic matrix occurs in the Lost City Member. Crinoidal material is the main allochemical constituent in the lower Winterset unit, whereas it is uncommon in the Lost City Member. Conodonts, phosphate pellets, and glauconite pellets are abundant in the lower Winterset unit. Only slight traces of phosphate and glauconite, and no conodonts, were observed in the Lost City Member, which occurs as local accumulations overlain by the lower Winterset unit and by the reef facies of the Winterset Member. At stratigraphic section 20, the reef facies overlies the Lost City Member, and the lower Winterset unit is absent. The stratigraphic position of the Lost City Member, in addition to the differences in lithology, fauna, and mineralogical content, is sufficient to separate these units into distinct lithologic units.

The Lost City Member, similar in several respects to the Canville Member, also contains a micrite matrix at several localities. The two differ primarily in faunal content, the Lost City Member containing more algal material and the Canville Member being characterized by sponge spicules at several localities. The Canville and Lost City Members probably had similar origins (stabilized primitive-plant baffles) varying only in that the areas of Canville deposition were also areas favorable for the accumulation of black shale sequences (Stark Member).

HOGSHOOTER FORMATION

Winterset Member

The Winterset Member consists of three facies: the lower Winterset, the upper Winterset, and the reef facies. As shown in figure 2, the reef facies represents a lithofacies of both the lower and upper Winterset units.

Lower Winterset Unit

The lower Winterset unit occurs in most of the area. Near Ramona, Oklahoma (secs. 28, 34, T. 24 N., R. 13 E.) and at stratigraphic section 28 (sec. 31, T. 26 N., R. 14 E.), this unit is absent. At these localities, the reef facies overlies the Lost City and Stark Members, respectively (fig. 2). The lower Winterset unit is underlain by the Stark Member at stratigraphic sections 1, 2, 3, 15, 19, 40, and 42, and by the Lost City Member at stratigraphic section 5. Elsewhere in the area, this unit is underlain by calcareous siltstones of the Coffeyville terrigenous facies.

Eighteen stratigraphic sections of the lower Winterset were measured. Several of the lithologic units associated with the reef developments are lithologically similar to the lower Winterset. These lithologic types will be discussed in the section on the reef facies.

Thickness and lithology—The unit consists of a single limestone bed ranging in thickness from 3 to 13 inches. In the central part of the area (bounded on the north by stratigraphic sections 1, 2, 3, 5, 25, 26, 27, 30, 40, and 42), the thickness of this unit ranges from 3 to 6 inches. The thickness decreases from stratigraphic section 1 toward stratigraphic sections 19 and 31. The thickness at stratigraphic section 1 is 6 inches. To the northeast at stratigraphic section 19, the unit thins to 4 inches; to the southwest at stratigraphic section 31, the unit is 3 inches thick. In the southern part of the area, the thickness ranges from 10 to 13 inches, with the thickest accumulation at stratigraphic section 32, approximately 2 miles north of the Washington-Tulsa county line. The unit also illustrates a thickening trend in the northern part of the area, where the unit ranges in thickness from 7 to 12 inches. At stratigraphic sections 15 and 18, the unit is 12 inches thick.

Insoluble content—The percentage of insoluble material in the lower Winterset unit ranges from 9 to 62 percent. Superficially samples containing high percentages (20 to 62 percent) of insoluble material appear to have a random areal distribution. However, at each locality where a high percentage of insoluble material occurs, the lower Winterset unit either overlies the Stark Member or is near a Stark Member occurrence. At stratigraphic sections 1, 3, 15, 19, and 40, where the amount of insoluble material is 20, 62, 44, 32, and 35 percent, respectively, the lower Winterset overlies the Stark Member. At stratigraphic sections 16, 24, and 25 (insoluble content is 26, 36, and 21 percent, respectively), the lower Winterset overlies the Coffeyville terrigenous facies but is adjacent to an area of Stark Shale accumulation. Approximately half a mile north of stratigraphic section 16, the Stark Member is present in a small stream cut. Oakes (1940, p. 43) mentioned that the Stark Member was found in sec. 16, T. 28 N., R. 15 E., and in the NE¼ sec. 30, T. 27 N., R. 15 E., Nowata County (the writer was unable to find these exposures). Stratigraphic section 24 is in sec. 16, T. 28 N., R. 15 E., and stratigraphic section 25 is in sec. 30, T. 27 N., R. 15 E., approximately two-thirds of a mile from the point where Oakes found the Stark Member. Other outcrops of the lower Winterset unit are far removed from any known Stark accumulation and have an insoluble content ranging from 9 to 18 percent.

Mineralogically the residues are primarily angular quartz in amounts ranging from 96 to 98 percent. Glauconite is everywhere present and constitutes 0.5 to 1 percent of the residues. The glauconite occurs as rounded pellets. All the residues contain traces of rounded muscovite flakes (much larger than the quartz grains), overgrowth-bearing tourmaline, and limonite. Authigenic pyrite constitutes 3 percent of the residue from stratigraphic section 12; approximately 2 percent authigenic barite occurs in the residue from stratigraphic section 13.

Ten acetic acid determinations were made on samples collected from the lower Winterset unit. Phosphate (carbonate apatite) is the only additional mineral concentrated in the acetic acid residues. It is present in amounts ranging from 1 to 8 percent; most samples contain 4 to 8 percent. Phosphate occurs mostly as irregular botryoidal lumps, which range from approximately ⅛ mm to slightly more than 1 mm in diameter. However, in some hand specimens, the phosphate occurs as nodules more than 1 inch in diameter. It is also found as internal molds of gastropods and as conodont fragments. Glauconite occurs in the acetic acid residues as internal molds of gastropods and as pellets.

Terrigenous grain size—The amount of material coarser than 4.5 phi ranges from 11 to 78 percent of the hydrochloric acid residue (table 5). In table 5, percentages of residue and material coarser than 4.5 phi are listed in a geographical sequence, with the northernmost stratigraphic section first and the southernmost section last.

Generally the amount of material coarser than 4.5 phi decreases southward. Several deflections from this trend occur at stratigraphic sections 1, 3, and 40 in the central part of the area. At these localities, the insoluble material is coarser than in the areas immediately north and south. However, in the central area the greater amount of coarser material is accompanied by a corresponding increase in the percentage of insoluble material, whereas, in the northern part of the area, coarse material is dominant even where the percentages of insoluble material are small (e. g., stratigraphic section 18).

Several deflections occur in the coarseness trend in the northern part of the area also. Each of these deflections is associated with an increase in amount of insoluble material. Larger accumulations of terrigenous material occur where the lower Winterset unit overlies the Stark Member. At the localities where the insoluble content is greater, the terrigenous grain size is also greater, indicating a possible relationship between the amount and size of the terrigenous material and controlling energy factors. As the energy in the depositional environment increased, the amount and size of the terrigenous material increased correspondingly.

Petrographic properties—Seventeen thin sections and two acetate peels of the lower Winterset unit were examined. Two limestone types occur in this unit. The more common lime-

TABLE 5.—INSOLUBLE RESIDUES IN THE LOWER WINTERSET UNIT

STRATIGRAPHIC SECTION	PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI
CH-15-2 (North)	44	78
CH-16-2	26	55
CH-17-2	17	44
CH-24-1	36	74
CH-18-2	11	55
CH-19-3	32	68
CH-25-1	21	34
CH-5-A-3	15	28
CH-26-1	12	20
CH-27-1	12	22
CH-1-5	20	39
CH-3-5	62	52
CH-40-1	35	62
CH-30-1	9	24
CH-31-1	18	16
CH-13-1	15	19
CH-12-1	14	17
CH-32-2 (South)	15	11

stone type is biosparrudite; the other limestone type, occurring at one locality (stratigraphic section 1), is an oösparite.

Thin sections of this unit contain phosphate and glauconite. Glauconite occurs as rounded grains, some with and most without a weathered exterior rim. Phosphate occurs as round grains ranging in size from —2 to 3 phi. The larger phosphate nodules are composed of numerous, much smaller phosphate grains cemented by calcite, similar to those described by Bushinsky (1935, p. 88). Phosphate, associated with terrigenous and organic material, commonly occurs as internal fillings in gastropod shells. Many of the phosphate particles may represent fragmented gastropod molds.

Sparry calcite, the only primary cement in the lower Winterset unit, occurs as pore-filling calcite in a framework of skeletal material, phosphate, glauconite, and terrigenous material. The skeletal content ranges from 25 to 75 percent of the total sample. Approximately 5 to 8 percent of each thin section is composed of phosphate and glauconite. Terrigenous material ranges from 9 to 62 percent. At stratigraphic section 3, the unit contains 62 percent terrigenous material and is not a limestone. At this locality, the rock type is a fine sand and siltstone: sparry calcite-cemented, submature, phosphatic glauconitic algae-bearing orthoquartzite (Folk, 1959b). Only at

TABLE 6.—TERRIGENOUS MATERIAL AND FAUNAL CONTENT IN THE LOWER WINTERSET UNIT

STRATIGRAPHIC SECTION	TERRIGENOUS CONTENT (PERCENT)	COARSEST PARTICLE SIZE (PHI)	ALLOCHEMS PRESENT[1] (PERCENT)			FOSSILS PRESENT[2] (PERCENT)					
			I	O	F	C	A	Bz	Bp	G	P
CH-15	44	1.5	1		30	20			3	2	
CH-16	26	1.0	5	3	40	27	10			1	
CH-17	17	1.5	1	2	65	35	15			3	3
CH-24	36	2.0	1	1	40	30	7	4			
CH-18	11	2.0	2		70	40	15	7			
CH-19	32	2.0			40	30			5		3
CH-25	21	3.5	1		60	25	20	8			3
CH-5	15	2.0			65	35	25				
CH-27	12	2.5			70	33	20	8			4
CH-1	20	4.0		30	30	10	10		5		
CH-3	62	3.0			25	13	10				
CH-30	9	2.5	1	15	50	30	20	5			
CH-31	18	2.5	2	5	60	35	20				4
CH-32	15	3.0	10		55	30	13			8	

[1]I-intraclasts, O-oöliths, F-fossils.
[2]C-crinoids, A-algae, Bz-bryozoans, Bp-brachiopods, G-gastropods, P-pelecypods.

stratigraphic section 30 is the amount of terrigenous material less than 10 percent of the sample.

Thin sections from stratigraphic sections 15, 16, 17, and 18, in the northern part of the area, contain intraclasts or rock fragments composed of silt-size terrigenous material (intraclasts are more than 1 mm in diameter). In the southern part of the area at stratigraphic sections 30, 31, and 32, intraclasts composed of fossiliferous micritic material occur. Oöliths and superficial oöliths occur at stratigraphic sections 1, 13, 16, 17, 30, 31, and 32.

In table 6, the important petrographic properties are listed and the stratigraphic sections are arranged in a sequence from north to south. The presence or absence of allochemical constituents, other than skeletal fragments, bears no relationship to the amount of terrigenous material. At stratigraphic section 16, the unit contains 26 percent terrigenous material, which is associated with three allochemical constituents: intraclasts, oöliths, and skeletal material. These same allochems are found at stratigraphic section 30, where the content of terrigenous material is only 9 percent. The only allochemical constituent at stratigraphic sections 3, 15, 19, and 24 is skeletal material (encrusting algae, crinoidal material, pelecypods, bryozoans, gastropods, and arthropods). Terrigenous contents are considerably higher (range from 42 percent at stratigraphic section 19 to 62 percent at stratigraphic section 3) at these localities than elsewhere. As table 5 illustrates, the terrigenous material associated with the higher percentages is coarser than material from other stratigraphic sections. The amount of skeletal material is considerably less (15 to 20 percentage points less) than the amounts occurring elsewhere.

Faunal associations—All skeletal material examined in the thin sections shows abrasion. The degree of abrasion is greater in samples having higher percentages of terrigenous material. An inverse relationship exists between the abundance of skeletal material and the abundance of terrigenous material (including oöliths and intraclasts; fig. 4). For example, at stratigraphic sections 3 and 18, the terrigenous content is 62 and 11 percent, respectively; the skeletal content at these same localities is 25 and 70 percent, respectively.

The faunal assemblages in each thin section are listed in table 6. Crinoidal and algal fragments dominate the skeletal material. Four genera of algae occur in this unit. *Osagia* is found in all the thin sections, and *Epimastopora*, although not so abundant as *Osagia*, also occurs in most samples. *Ottonosia* and *Girvanella* occur sporadically in this unit. Brachiopod, pelecypod, gastropod, and bryozoan fragments are less abundant than crinoidal and algal material. The gastropods are commonly filled with phosphatic material.

Synthesis of above data—The above-given data suggests that the lower Winterset unit was deposited in a shallow, relatively turbulent environment. The occurrence of gastropods, pelecypods, and calcareous algae suggests a possible depth of 6 to 60 feet and the presence of oöliths, intraclasts, high terrigenous contents, and sparry calcite cement suggests a rela-

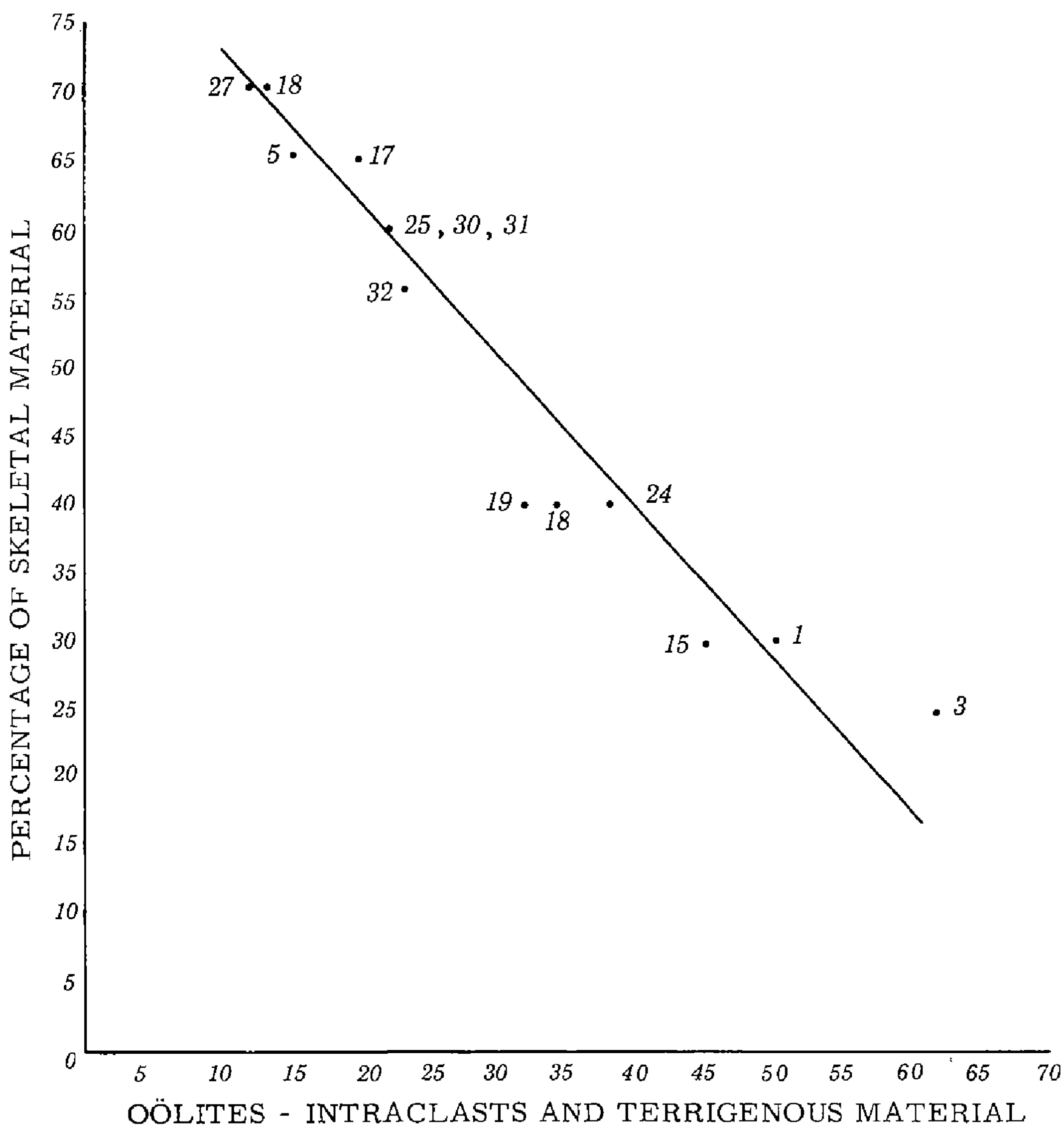

Figure 4. Relationship between skeletal material and other framework constituents in the lower part of the Winterset Member.

tively high-energy environment (Folk, 1959a). Sparry calcite cement in this unit implies that currents were strong enough to remove micritic material. Oöliths indicate an environment in which currents were able to move and roll quartz and skeletal nuclei of the oöliths (Folk, 1959a). The framework consists of skeletal fragments and other allochems (oöliths and intraclasts), with no micritic material. Slight fluctuation in sea level may have subjected this framework to subaerial conditions to permit solution of part of the calcareous framework and its reprecipitation as sparry calcite cement (Illing, 1954, p. 48).

The abundance of terrigenous material (including oöliths and intraclasts) bears relationships to the abundance of skeletal material (fig. 4) and to the degree of abrasion of skeletal material (fig. 5). In the first case the relationship is inverse; in the latter it is direct. A possible explanation for these relationships is that the higher terrigenous contents indicate areas of higher energies in which organisms either did not live or were less prolific. The greater degree of abrasion of skeletal material in areas of higher terrigenous contents suggests higher energy for these areas. Probably organisms flourished more readily in areas of less turbulence. Illing (1954, p. 17) observed a similar relationship in a present-day higher energy environment. He observed that on the Bahama Banks the skeletal content comprises approximately 23 percent of the allochemical constituents, whereas on the margins of the banks, the skeletal content ranges from 87 to 92 percent. The average water depth on the banks is approximately 10 to 20 feet, and on the margins of the banks the depth ranges from 20 to 40 feet. But, in general, skeletal content decreases as depth decreases.

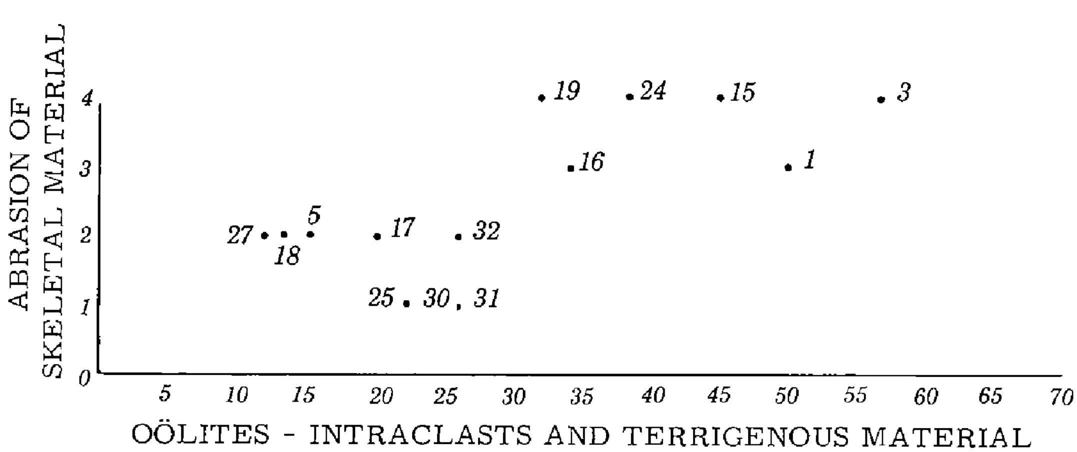

Figure 5. Relationship between abrasion of skeletal material and percentage of other framework elements in the lower part of the Winterset Member.

As tables 5 and 6 illustrate, an increase in coarseness of the terrigenous material occurs from the southern to the northern parts of the area, indicating a source for the terrigenous material to the north of the area. Intraclasts composed of terrigenous material occur only in the northern part of the area (stratigraphic sections 15, 16, 17, 18). These intraclasts may represent parts of a terrigenous facies of the lower Winterset unit that have been torn up and redeposited farther south. In the southern part of the area evidence of an increase in energy also exists. Approximately 10 percent of the thin section from stratigraphic section 32 is composed of micritic intraclasts cemented with sparry calcite. At stratigraphic section 32, the unit is 13 inches thick; the thin section from the base contains 73 percent skeletal material, whereas the thin section from the top contains 55 percent. The percentage of intraclasts increases from 1 percent at the base to 10 percent at the top of the unit. Shallowing of the water may have occurred between the deposition of the base and the top of the unit so that previously deposited material may have been subjected to more wave action, thus producing the increased percentage of intraclasts.

Phosphate particles occur in all samples of the lower Winterset unit and seem to be related in some respect to the fauna. Gastropods observed in thin sections are filled with phosphatic material. Many solitary phosphate particles in the acetic acid residues appear to be fragmented internal molds of gastropods. Botryoidal particles of phosphate and glauconite are also common in the acetic acid residue, and both are possibly fecal in origin. The botryoidal fecal-appearing phosphate particles may have been produced by gastropods or other organisms.

Ames (1959, p. 834) observed that fine-grained carbonate material is replaced more rapidly by phosphate than are coarser calcite particles. Illing (1954, p. 25) mentioned that fecal pellets on the Bahama Banks are composed of silt-sized carbonate particles and organic material. In the lower Winterset unit, no fine-grained calcareous material occurs. If the phosphate pellets were once fecal pellets composed of fine-grained calcareous material and if suitable conditions of pH level and phosphate concentration prevailed, the first material to be replaced by phosphate (according to Ames) would have been the fine-grained calcite particles. The phosphate particles in the lower Winterset possibly represent such a replacement of micrite by carbonate apatite.

Upper Winterset Unit

The lower Winterset unit is overlain by the upper Winterset unit throughout the area except in stratigraphic section 32 in the southern part, where it is overlain by the Nellie Bly Formation. The contact between the upper Winterset and the Nellie Bly Formation was observed only at stratigraphic section 12, approximately four miles from the southern boundary of the area. Elsewhere the top of this unit has been eroded, thus prohibiting total-thickness determinations. Eighteen stratigraphic sections of this unit were measured. In several areas, lithologies similar to those of the upper Winterset unit were observed in association with reef developments. These lithologies are discussed with the reef facies.

Thickness and lithology—Limestone beds of the upper Winterset unit are separated from the underlying lower Winterset by a thin, brown and gray clay bed which is 15 inches thick in the northern part of the area (stratigraphic section 16), 7 inches thick at stratigraphic sections 18 and 27, 3 inches thick at stratigraphic sections 30 and 31, and 1 inch thick in the southern part of the area at stratigraphic section 12. The thickness of this clay bed decreases southward, although exceptions to this trend occur at several stratigraphic sections. At stratigraphic section 18 the thickness of this bed is 7 inches, but at stratigraphic section 24, 2 miles east, the thickness is only 4 inches. Where the clay unit is 3 to 15 inches thick, it contains scattered limestone lenses lithologically similar to the upper Winterset limestones.

At most stratigraphic sections, only a few inches to a few feet of the upper Winterset unit are preserved. As previously mentioned, its contact with the overlying Nellie Bly Formation was observed at only one stratigraphic section; at the remaining 17 stratigraphic sections it is incomplete. Hence, no interpretations can be made concerning the total thickness of this unit. At stratigraphic section 12, calcareous siltstone of the Nellie Bly Formation overlies the upper Winterset. At this locality the unit is 14 inches thick and northward, at most stratigraphic sections, it is more than 14 inches thick. At stratigraphic section 32, the Nellie Bly lies upon the lower Winterset unit. Although absolute values for the total thicknesses of the upper Winterset cannot be determined north of stratigraphic section 12, enough outcrops occur to indicate a thinning of the unit in the southern part of the area.

Three stratigraphic sections, 4, 16, and 18, in the northern part of the area are relatively thick, with a considerable portion (24, 4, and 11 feet, respectively) of the unit exposed. The thickest section of the upper Winterset unit is at stratigraphic section 4, where approximately 24 feet is exposed. The lithology of the unit at this locality is variable. Limestone units above the basal shale and clay unit overlying the lower Winterset are irregularly bedded, with beds ranging in thickness from 2 to 5 inches. Three thin shales occur in this sequence. Above the irregularly bedded sequence at the base is 9 feet of thick-bedded limestone, with only one well-defined shale bed in the sequence. Above the thick-bedded sequence, approximately 11 feet of irregularly bedded limestone is exposed. At stratigraphic section 18, the lithology differs; the shale content increases and occupies approximately one-half of the total section. At stratigraphic section 16, approximately 4.5 miles northeast of stratigraphic section 18, the percentage of shale again increases and comprises more than one-half of the total thickness. The percentage of shale increases north of stratigraphic section 4.

Insoluble content—Insoluble content ranges from 3 to 15 percent. No apparent change in the insoluble content occurs from one locality to another. At most localities, where the upper unit overlies the lower, a definite decrease occurs in the insoluble content from the lower to the upper unit. For ex-

TABLE 7.—COMPARISON OF INSOLUBLE-RESIDUE CONTENT BETWEEN UPPER AND LOWER WINTERSET UNITS

STRATIGRAPHIC SECTION	UNIT	PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI
CH-3	Lower Winterset	62	52
	Upper Winterset	16	12
CH-13	Lower Winterset	15	19
	Upper Winterset	14	8
CH-16	Lower Winterset	26	55
	Upper Winterset	9	7
CH-18	Lower Winterset	11	55
	Upper Winterset	7	4
CH-19	Lower Winterset	32	68
	Upper Winterset	11	6
CH-24	Lower Winterset	36	74
	Upper Winterset	8	9
CH-25	Lower Winterset	21	34
	Upper Winterset	6	5
CH-30	Lower Winterset	9	24
	Upper Winterset	6	4
CH-31	Lower Winterset	18	16
	Upper Winterset	11	4

ample, at stratigraphic section 3, the lower unit contains an insoluble content of 62 percent, whereas the upper unit contains only 16 percent.

The mineralogical composition of the hydrochloric acid residue is approximately 99 percent fine sand and silt-size quartz particles with minor traces of muscovite and limonite. No glauconite, conodonts, or phosphate particles occurred in the acetic acid residues. In many hydrochloric acid residues, traces of white amorphous material occur. These accumulations are generally coiled or tube-shaped structures and possibly represent the remains of opal-secreting organisms. The material is opaque under crossed nicols, suggesting that it is opaline silica, similar to that found by Mitchell (1935).

Terrigenous grain size—Fifty-three samples of the upper Winterset unit were treated with hydrochloric acid. A decrease in coarseness of the insoluble material occurs from the lower to the upper Winterset unit. The percentage of insoluble material coarser than 4.5 phi ranges from 2 to 16 percent.

Table 7 shows the change in coarseness of the insoluble material from the lower Winterset to the basal limestone bed of the upper Winterset at several stratigraphic sections. At stratigraphic section 13, the difference in the total amount of residue is 1 percent, but the difference in the amount of material coarser than 4.5 phi is 11 percent. In every case, even where the total amount of residue is approximately the same in the two units, the lower Winterset has a markedly greater amount of coarse material. Material less than 4.5 phi in diameter constitutes the bulk of the residues from the upper Winterset.

Petrographic properties—Forty-seven thin sections and one acetate peel of the upper Winterset were examined. The terrigenous material comprises 3 to 15 percent of the total rock and the content of skeletal material ranges from 2 to 50 percent.

The limestone type of the basal upper Winterset bed is reasonably uniform throughout the area. The terrigenous content in this lower bed ranges from 6 to 15 percent. Brachiopod fragments are the dominant skeletal type, but in several samples, bryozoans, crinoids, and algal fragments (not *Osagia*) also occur. The matrix of this bed is micritic, with no primary sparry calcite cement. Areas of coarse-crystalline sparry calcite occur in most thin sections, but these are the result either of recrystallization of micritic material to sparry calcite or of precipitation of sparry calcite in fractures and voids. The limestone type of this lower bed varies only to the extent that in some thin sections the dominant skeletal types are brachiopods and in others are bryozoans or crinoids. Because most skeletal material is greater than 1 mm in diameter, the limestone type is a brachiopod, crinoidal, or bryozoan biomicrudite.

At stratigraphic sections 4, 6, and 7 (within 200 yards of each other) a thick sequence of this unit is exposed. Twenty thin sections from this vicinity were examined to determine the lateral and vertical variations occurring within a short distance (table 8). Only minor variations are in the unit laterally, but definite vertical changes occur. At the base of the unit, the only allochem present is skeletal material. Approximately 12

TABLE 8.—LITHOLOGIC AND FAUNAL VARIATION IN THE UPPER WINTERSET UNIT

FEET ABOVE BASE	LIMESTONE TYPE		
	SECTION 4	SECTION 6	SECTION 7
2	Brachiopod-bryozoan biomicrudite	Brachiopod-bryozoan biomicrudite	Covered
4	do.	do.	Covered
9	do.	Crinoidal-bryozoan biomicrudite	Covered
11	Crinoidal-bryozoan biomicrudite	do.	Covered
12	Not sampled	Not sampled	Interlayered fossiliferous micrite and intrasparite
13	Intraclast-bearing bryozoan biomicrudite	Bryozoan biomicrudite	do.
18½	Oölithic-crinoidal bryozoan biosparrudite	Intrasparrudite and intrasparite	do.
24	Interlayered micrite and fossiliferous intrasparrudite & intrasparite	Intraclast-bearing bryozoan biomicrudite	Interlayered intrasparite and intrasparrudite

feet above the base, intraclasts are abundant. Toward the top of these measured sections, as much as 60 percent of the rock is composed of intraclasts of micritic material. This same relationship, the increase in intraclasts upward, occurs at stratigraphic sections 8, 16, and 18, where relatively thick sections of this unit are exposed.

Most thin sections illustrate some recrystallization of micrite to coarse sparry calcite. Folk (1959a, p. 33) stated that to have a sparry calcite cement, a substantial framework of allochems must be present, as sparry calcite fills void spaces in the framework. If no adequate framework exists, the sparry calcite commonly results from the recrystallization of micritic material. Many thin sections contain micritic material with relatively few allochems (an insufficient number for a framework in which sparry calcite could be precipitated as a cement). The sparry calcite is the result either of recrystallization or of fracture filling. Examples of rim cementation show that some coarse spar results from cavity filling. In many cases where recrystallization is suspected, it is possible to find areas where micritic material grades into coarser spar. Many areas of micrite, completely surrounded by coarse sparry calcite, suggest that the micrite represents remnants of micritic material that once comprised the portion now recrystallized to coarse sparry calcite. The areas of recrystallization in the upper Winterset thin sections illustrate the criteria for recognizing recrystallization discussed by Bathurst (1958, p. 25-27), such as relict structures completely surrounded by coarser sparry calcite, irregularity of intergranular boundaries, and variation in grain shape and grain size. Fracture and void fillings, evidenced by rim cementation, are common and occur as irregular bands of coarse sparry calcite parallel to bedding in the unit.

Faunal associations—Brachiopods, bryozoans, crinoids, and algae dominate the faunal assemblage of the upper Winterset. Ostracodes and foraminifers occur in trace amounts. The percentage of skeletal material ranges from 1 to 50 percent, with most units containing approximately 20 to 30 percent. Lower percentages are associated with beds characterized by large percentages of intraclasts. The upper Winterset commonly contains less skeletal material than does the underlying lower Winterset unit. Much of the skeletal material in the upper unit is 3 to 5 mm in diameter. Small unidentifiable skeletal fragments are also in this unit. The larger skeletal fragments are unabraded, and many brachiopod shells bear spines. Bryozoans similar to those pictured by Johnson (1951, p. 93, pl. 48, fig. 1) commonly encrust brachiopod shells. Encrusting bryozoans are found only in the upper Winterset unit. Algal material is minor in this sequence and occurs as irregular areas now composed of coarse sparry calcite scattered through a micrite matrix (similar to the structures pictured by Folk, 1959a, p. 27).

Synthesis of above data—Decreases in amount and coarseness of terrigenous material from the lower to the upper Winterset unit are indicative of changes in energy factors controlling the deposition of these two units. Micrite, unabraded condition of larger skeletal material, and faunal assemblage of the upper Winterset suggest a low-energy environment. When the characteristics of the upper Winterset unit are compared to those of the lower unit (such as sparry calcite cement, abraded and fragmented skeletal material, fauna indicative of high energy, and large percentages of terrigenous material), it is reasonable to assume that the energies occurring during the deposition of the lower unit were greater than those in the depositional environment of the upper unit. The unabraded condition and size (3 to 5 mm) of the skeletal material in the upper unit suggest that these organisms lived in the low-energy environment and have not been transported.

An increase in the percentage of intraclasts occurs upward in the upper Winterset sequence (table 8). The increase in intraclasts upward possibly resulted from a decrease in water depth. With a decrease in depth, previously deposited micrite beds were possibly disturbed by wave action, thus producing the intraclasts.

In the southern part of the area the upper Winterset thins and is absent at stratigraphic section 32. No evidence exists for an unconformity between the Winterset Member and the siltstones and shales of the Nellie Bly. While thick micritic sequences, such as found at stratigraphic section 4, accumulated in the northern part of the area, clastics were deposited in the southern part (Nellie Bly lithology). The upper Winterset micritic sequence in the northern part of the area probably represents a facies of the lower Nellie Bly clastics in the southern part.

Reef Facies of the Winterset Member

Two reef developments occur in the area. The larger and more complete reef structure is north of Ramona, Oklahoma, below the Santa Fe Railway trestle over the South Fork of Double Creek. At this locality, the reef core and its lateral facies are well exposed along the south bank for approximately 200 yards. The other reef is in NW¼ SE¼ NW¼ sec. 31, T. 26 N., R. 14 E., Washington County, where a small reef core is exposed in a stream bank. Three anomalous stratigraphic sequences are in the northern part of the area, and these sequences are also discussed.

Thickness and lithology—Ten stratigraphic sections were measured in the vicinity of the reef development north of Ramona. These sections are incomplete, as the contact with the Nellie Bly Formation was not observed. The purpose in measuring these sections, which are relatively close together, was to determine the lateral and vertical lithologic changes in the vicinity of the reef.

Two well-defined reef cores, composed of unbedded micrite, are exposed immediately below the railroad trestle. Laterally away from the cores, a change in lithology occurs, as the sequence (18.5 feet thick) is composed primarily of interbedded shales with skeletal debris and biosparrudite with a few thin micritic beds. The boundaries of the reef cores are distinct and abut against the interbedded shales and limestones of the lateral units.

Figure 6 shows the relationships in the vicinity of the reef. The Lost City Limestone Member is present in this area; it is thickest beneath the reef cores and thins in all directions away from the cores. At stratigraphic section 5, the only other locality where the Lost City Member was found, the Winterset Member overlies the Lost City Member. The smaller reef development (stratigraphic section 28) overlies the Stark Shale Member. At stratigraphic sections 1, 2, 3, 15, 19, and 40, the Winterset Member overlies the Stark Shale Member. Laterally from the smaller reef core (approximately 30 feet), the lower Winterset overlies the Stark Member. Upon this evidence, the assumption is made that the reef developments, because they overlie units that are elsewhere overlain by the Winterset

Member, are in part stratigraphically equivalent to the Winterset Member.

The lateral variations in gross lithology occurring in the reef facies near Ramona are shown in figure 6. The core complex is approximately 100 feet wide, with a maximum measured vertical thickness of 12 feet. The limestones composing the cores are micritic with no distinct bedding and relatively few fossils. The sequence occurring laterally away from the core complex is strikingly different. As is shown in figure 6, the stratigraphic sections closest to the cores have a greater predominance of shale units (with skeletal debris) than have those farther removed from the cores. These shale units are composed primarily of loose skeletal material, with abundant colonial (tabulate) corals, and probably represent reef talus. These units thicken toward the source of the talus, the reef cores. This is the only locality where corals are abundant. One hundred yards west of the cores, most coralline material disappears. The corals probably inhabited the reef cores and flanks. As the shale units thin to the west, the limestone units thicken. The basal limestone unit at stratigraphic section 33, which is 6.5 feet thick, is absent within 80 feet. No basal limestone unit occurs at stratigraphic section 34, and 4.5 feet of shale occupies the same stratigraphic interval as that of the limestone at stratigraphic section 33.

The limestones near Ramona are predominantly biosparrudites. A few thin micritic beds occur and become slightly more abundant toward the reef cores. Three micrite beds, adjacent to the core at stratigraphic section 37, may represent lateral extensions of the reef core. At stratigraphic sections 33 and 35, only one thin micritic unit is present. The remaining limestone units are composed of a skeletal framework cemented with sparry calcite. This sequence, with a maximum measured thickness of 18.5 feet, is the same stratigraphic interval which is elsewhere called the Winterset Member and which is dominated by micritic material. Biosparrudites occur at stratigraphic section 9. To the northeast at stratigraphic section 11, micritic beds become more abundant, with a corresponding decrease in the biosparrudite beds. Less than 2 miles northeast of stratigraphic section 11 at stratigraphic section 13, no sparry calcite-cemented beds occur above the basal lower Winterset unit.

A peculiar relationship exists between the reef cores and

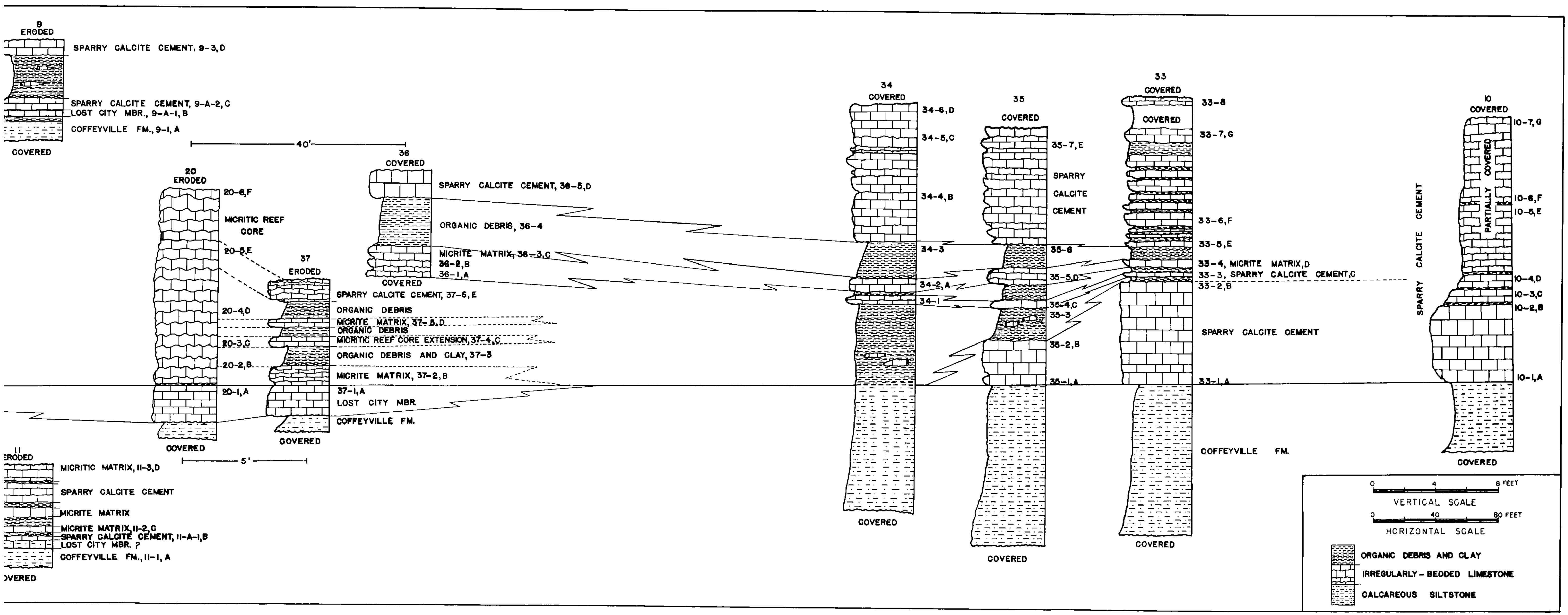

Figure 6. Reef facies in the vicinity of Ramona, Oklahoma.

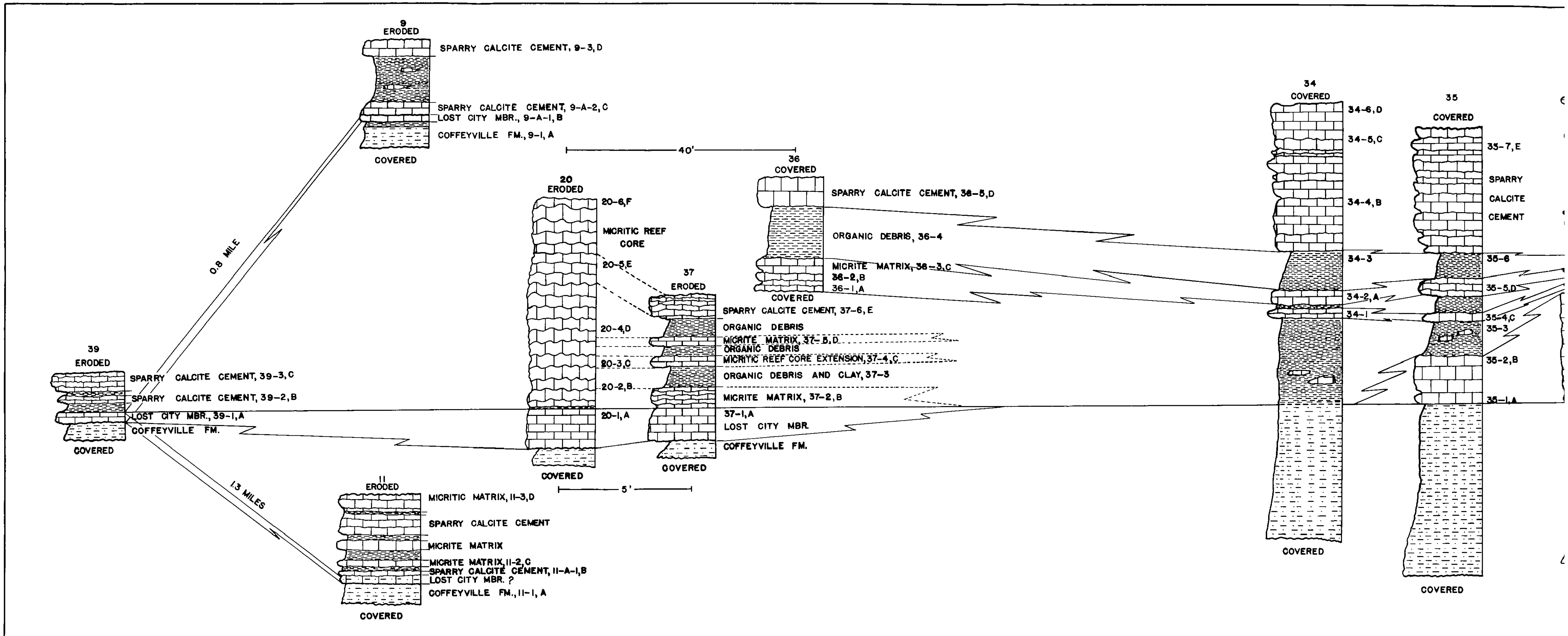

Figure 6. Reef facies in the vicinity of Ramona, Oklahoma.

the underlying beds. At stratigraphic section 20, where the cores overlie the Lost City Limestone Member, the Lost City has sagged beneath the weight of the reef core (fig. 7). The Lost City Limestone unit dips beneath the reef cores at angles of up to 40 degrees. The limestone bed was probably being deformed as the reef core grew, for several stratified beds adjacent to the cores have also been bent downward. This same relationship occurs at stratigraphic section 28 where the core overlies the Stark Shale Member. The Stark sags beneath the reef core. Twenhofel (1950b, p. 184) stated that if reefs develop on incompetent beds, such as clay or silt, the weight of the core may be sufficient to cause the underlying beds to dip toward and beneath the reef. This is probably true for the Hogshooter reefs, because at both stratigraphic sections 20 and 28, the upper part of the underlying Coffeyville consists of relatively thick sequences of siltstone (more than 15 feet), which represent an incompetent unit beneath the reef cores. The dip on the Lost City Limestone Member beneath the cores is to the east and west (depending on which side of the reef core the angle is determined) with a northward component of dip also. This possibly indicates that the main reef development was farther to the north and that the cores observed now along the creek represent southern extensions of the main reef.

Lithologic types associated with the less extensive reef core at stratigraphic section 28 are different from those at Ramona. The lithology of the core itself is similar to that of the larger cores, as it is composed of sparsely fossiliferous micritic material with no pronounced bedding. The units abutting the core lack the predominance of biosparrudites. Instead, the lateral units are similar to the lower and upper Winterset units that have been previously described at this locality. The bulk of the lateral sequence is composed of micritic material. Algal material is more abundant in the micritic beds adjacent to the core than elsewhere in the area.

Insoluble content—Fifty-eight samples from the reef facies were digested in hydrochloric acid, and 20 samples were digested in acetic acid. The insoluble content from the hydrochloric acid digestions ranges from 3 to 17 percent. No definite trend for the distribution or composition of insoluble material can be established for the reef facies. Samples from the reef cores contain little insoluble material (4 to 11 percent). The range in insoluble material from 3 to 17 percent is similar to that found for the insoluble material in the upper Winterset unit (3 to 15 percent). Traces of muscovite and opal occur in the residues; glauconite occurs in the hydrochloric acid residues of the biosparrudites but is absent in the residues of the micritic beds and reef cores.

The acetic acid residues contained several additional constituents. The residues derived from the digestion of the biosparrudite beds invariably contained phosphate particles, phosphatic internal molds of gastropods, conodonts, and fish teeth. The micritic beds contained no phosphate particles, conodonts, or gastropods, but did contain a few fish teeth. The mineral and fossil assemblage in the thick sequence of biosparrudites is similar to the assemblage of the lower Winterset unit (maximum of 13 inches thick), which is also primarily a biosparrudite. The depositional environment of the thick biosparrudite sequence around the reef cores was probably similar to that of the lower Winterset biosparrudite.

Terrigenous grain size—Terrigenous material of the reef facies is dominantly less than 4.5 phi in diameter. The amount of coarser material ranges from 2 to 12 percent, a range similar to that of the upper Winterset unit (2 to 16%). No trends can be established for the distribution of terrigenous grain size.

Petrographic properties—Thirty-two thin sections and 27 acetate peels of samples from the reef cores and lateral facies were examined. The reef cores are composed primarily of micritic material associated with 1 to 25 percent skeletal material. The skeletal material consists of brachiopods, bryozoans, probable algae, crinoids, ostracodes, and rare gastropods. Well-preserved examples of rim cementation occur, indicating void spaces in the micritic material. The basal reef-core sample at Ramona contains approximately 30 percent intraclasts, which suggest partial destruction of the reef core as it was growing.

An unbedded sequence, approximately 6 feet thick, overlies the lower intraclast-bearing unit. An algal? microsparite, containing abundant organic matter (the insoluble residue of this sample developed an oil film during digestion), occurs near the base of the sequence. Irregular areas of sparry calcite, scattered through microspar matrix, may represent recrystallized algal material. These areas are similar to those illustrated by Folk (1959a, pls. 3-25, 27, 28). No additional skeletal material is associated with these algal? structures. Several feet above the microsparite, definite algal structures occur. In this unit,

Figure 7. Photographs showing the relationship between the reef core and the underlying Lost City Member at stratigraphic section 20 near Ramona, Oklahoma. The reef core is directly above the downwarped Lost City Member. The stratified reef facies is shown to the right of the reef core.

algae similar to *Solenopora filiformis* (Dybowski), as described and pictured by Johnson and others (1959), are abundant and compose approximately 80 percent of the sample. Minor percentages of fenestrate bryozoans, crinoid columnals, brachiopods, and gastropods occur with the algae. The associated skeletal material is not abraded. Some algal material has been recrystallized and resembles the fibrous calcite structures discussed by Black (1952). Wolfenden (1958, p. 882) observed similar fibrous calcite structures in algal reef limestones from northwestern Derbyshire, England. Excellent examples of void fillings occur in this sample. Several rim-cemented cavities, approximately 3 mm in diameter, are present. Along the margins of the cavities, fine-grained calcite has been precipitated; the interiors of the cavities are partly filled with long, slender crystals of calcite, which have grown inward perpendicular to the sides of the cavities. Some of these crystals are more than 1 mm long. Those portions of interiors not occupied by radiating crystals are filled with poikilitic calcite. Reef limestones from northwestern Derbyshire, England, have this type of cavity filling (Wolfenden, 1958, p. 882).

Above the algal sequence is a poorly bedded one-foot-thick unit composed of approximately 80 percent skeletal material. Crinoid columnals constitute 65 percent of the rock. Minor percentages of fenestrate bryozoans, brachiopods, pelecypods, and gastropods are also present. Sparry calcite cement and microspar both occur; the microspar probably represents recrystallized micrite, as suggested by recrystallization of skeletal material to microspar. Similar to several beds in the stratified reef facies, this unit probably represents a poorly washed sequence and possibly represents one of the highly crinoidal beds that accumulated over the reef core proper.

An unbedded unit, 3.5 feet thick, overlies the highly crinoidal unit. Unlike the massive algal sequence below the crinoidal unit, this sequence is dominated by fenestrate bryozoans. Approximately 20 percent of this upper unit is composed of relatively unbroken bryozoan material. Minor percentages of crinoidal material and gastropods also occur. Petrographically, this unit is similar to the core facies discussed by Pray (1958, p. 263-266). In this unit, the reef framework was probably fenestrate bryozoans. The upper portion of the core has been eroded.

The lithologic sequence of the smaller bioherm in sec. 31,

T. 26 N., R 14 E., Washington County, differs from that of the core at Ramona. Skeletal material is sparse throughout the reef core (12 feet thick). Fenestrate bryozoans are the main skeletal constituent but constitute only 5 to 10 percent of the rock. Minor percentages of brachiopods, crinoids, pelecypods, ostracodes, and gastropods also occur. No distinct algae are recognizable in the samples. Examples of gradational recrystallization of micrite to microspar are scattered throughout the samples from the reef cores. Localized areas of dolomitization are present also; dolomite rhombs occur in cavities, which were formed by solution of fossil material.

Adjacent to the cores at Ramona are two distinct limestone types: phosphatic, algal-crinoidal biosparrudites and crinoidal-bryozoan biomicrudites. The biomicrudites are minor in the immediate vicinity of the cores, but at stratigraphic section 11 (approximately 1.2 miles northeast of the reef cores) they dominate the stratigraphic sequence. The biosparrudites near the cores have a framework consisting of from 60 to 70 percent skeletal fragments (crinoid plates and columnals, *Osagia*, fenestrate bryozoans, pelecypods, gastropods, brachiopods, and arthropod fragments). The skeletal material is fragmented and abraded, but the abrasion is not so pronounced as that of skeletal material in the lower Winterset. Minor amounts of micritic material, scattered through some of the sparry calcite-cemented biosparrudites, is possibly present because of rapid deposition that prohibited complete removal of the micrite. A few intraclasts composed of micritic material are in the biosparrudites and probably represent material that was eroded from the micritic cores or stratified micrite beds.

Faunal associations—The reef cores contain less skeletal material than do the adjacent bedded units. The main skeletal constituents in the cores are indistinct algae, *Solenopora*-type algae, fenestrate bryozoans, crinoidal material, brachiopods, and gastropods. These skeletal constituents show no abrasion. The fauna of the micrite beds adjacent to the cores is similar to that of the cores and contains fish teeth and ostracodes. The stratified biosparrudites contain a different fauna from that of the micrite beds, as conodonts, encrusting algae, *Epimastopora*, gastropods, pelecypods, fish teeth, fenestrate bryozoans, brachiopods, and crinoid material occur. Crinoidal material is the dominant faunal element, with *Osagia* second in abundance. In most thin sections and acetate peels of the biosparrudites immediately surrounding the reef cores, algae have encrusted parallel to the bedding as well as around skeletal material. The encrustations parallel to the bedding may have cemented much of the skeletal material; algae rapidly cemented the skeletal fragments, and abrasion of the skeletal material was reduced. Rapid cementation by the filamentous algae may have caused the poorly washed appearance of the biosparrudites and encrusting algae may have trapped some micritic material.

In the talus beds extending from the cores, colonial corals (*Pleurodictyum* sp., *Coenites* sp., and *Aulopora* sp.) and horn corals (*Lophophyllidium*-type) are abundant. *Pleurodictyum*-type corals occur only within 10 feet of the reef cores, whereas *Coenites* and *Aulopora*-type occurrences extend approximately 150 yards from the reefs. Thorp (1939, p. 288) observed that in the Florida and Bahama region coral material is restricted to the area immediately around a reef. Coral material is not resistant to abrasion and is rapidly destroyed. Conularids, fenestrate bryozoan fragments, crinoidal material, and fish teeth also occur in the talus beds.

Synthesis of above data—The sequence near Ramona represents an excellent example of reef development and of lithologic changes that occur around such an organic structure. The reef facies is, in part, stratigraphically equivalent to the Winterset Member because of its stratigraphic position and relationship to underlying units. The "typical" Winterset Member found in most of the area consists of two units: the lower, a thin (3 to 13 inches thick) sparry calcite-cemented bed, and the upper, a thick (up to 24 feet thick) micritic sequence. Near Ramona, an anomalous sequence occurs in the same stratigraphic position as that of the lower and upper Winterset units in other areas. Instead of being dominated by micritic material, the section is composed primarily of sparry calcite-cemented beds similar to those of the thin lower Winterset unit of other localities. The stratigraphic sections adjacent to the reef cores are dominated by sparry calcite-cemented beds that were probably deposited in a relatively high-energy environment from which most of the micritic material was removed. It is feasible that a reef should develop in a well-aerated, high-energy environment, such as is indicated by the presence of sparry calcite-cemented beds. At stratigraphic section 11, approximately 1.2 miles northeast of the reef cores at Ramona, sparry calcite-cemented beds are reduced in volume and micritic beds are thicker. Still farther north at stratigraphic section 13, the "typical" sequence of the Winterset Member occurs with the lower part of the Winterset being the only bed with sparry calcite cement. The high-energy environment surrounding the reef cores was not widespread, and, as the distance away from the reef increased, the energy decreased and micrite was then stabilized.

The fauna associated with the lower Winterset unit is similar to that of the sparry calcite-cemented beds surrounding the reef cores. This similarity probably indicates that the fauna is environmentally controlled, with the organisms favoring a high-energy environment being present around the reef cores. Phosphate, glauconite, and conodonts that occur only in the lower Winterset unit of other localities are abundant in the sparry calcite-cemented beds near the reef cores. This suggests that phosphate and glauconite occur only in high-energy environments where organisms producing or responsible for these minerals are present.

Several similarities exist between the reef facies at Ramona and the reef facies discussed by Pray (1958), Wolfenden (1958), and Newell and others (1953). In general, each of these reef complexes (the Winterset reef facies, the Mississippian reefs of southern New Mexico, the Upper Mississippian reefs of Derbyshire, England, and the Capitan reef complex) exhibits similar lateral variations away from the reef core. The units adjacent to the micritic reef core are composed of organic detritus (commonly crinoidal material) cemented with sparry calcite. Farther from the core, an interlayering of sparry calcite-cemented detritus beds and micritic beds occurs. Still farther from the cores, the stratigraphic sequence is composed mostly of micrite. Disregarding the reef cores composed primarily of micritic material, the progression away from the cores through a sparry calcite-cemented sequence to an interlayered sequence of both sparry calcite-cemented and micritic beds, to a sequence composed entirely of micritic beds, suggests a lowering of the energy in the depositional environment away from the cores. In the sparry calcite-cemented sequences, the micritic material was removed by the winnowing effect of currents. In the sequences characterized by both micrites and sparry calcite-cemented beds, the energy was not constant, and periods of winnowing and quiescence occurred. In the sequences where only micrite occurs, the energy was low. The absence of micritic material in the sparry calcite-cemented detritus sequence adjacent to the reef cores was probably caused by strong currents in the vicinity of the reef cores. Relatively strong and persistent currents are necessary to supply nutrients to a growing reef.

If strong currents are near a reef core, it is difficult to visualize a micritic core's being preserved in such a high-energy environment. Ginsburg and Lowenstam (1958, p. 312-314) discussed the effectiveness of grass baffles in stabilizing and accumulating micritic material in relatively high-energy environments. They observed (p. 314) that baffled areas might actually become stabilized to the extent that mound-shaped accumulations of micritic material are formed and are elevated as much as 4 to 8 feet above the surrounding sea floor. If grasses are adequate baffles to stabilize micritic material in recent seas, it is conceivable that similar growths, such as *Solenopora*-type algae or fenestrate bryozoans, could have acted in like manner to produce the moundlike reefs or bioherms in a high-energy environment.

Stratigraphic Sections with Possible Reef Affiliations

In the northern part of the area, three anomalous sequences, occurring at stratigraphic sections 14, 22, and 23, are different from the "typical" Winterset Member. Relatively thick sequences of sparry calcite-cemented beds, 20 inches and 7 feet, occur at stratigraphic sections 14 and 22, respectively. The lithology of these sequences is similar to the sparry calcite-cemented beds near the reef development at Ramona. At stratigraphic section 22, the insoluble content resembles that in the beds surrounding the reef cores. The fauna is similar to that in the lateral facies of the Ramona reef (fish teeth, conodonts, gastropods, crinoids, encrusting algae, pelecypods, and brachiopods). The only other area where fish teeth were found is the vicinity of the Ramona reef. Glauconite and phosphate are abundant at stratigraphic section 22. As both the lithology and skeletal content are approximately the same at stratigraphic sections 14 and 22 and in the lateral facies of the Ramona reef, it is possible that a similar environment existed in these different areas. Although a reef core is not exposed in the northern part of the area, the thicker biosparrudite sequences may represent lateral facies of a reef. In any case, the increased thickness of the biosparrudites indicates a higher energy environment in the vicinity of stratigraphic sections 14 and 22.

Hansen (1958) subdivided the Winterset Member into lower, middle, and upper units because of an anomalous sequence in the vicinity of stratigraphic section 23, where a partial vertical section is exposed along a small creek. In this partial section, interbedded micrite-bearing and sparry calcite-cemented beds occur. Hansen considered this sequence sufficiently different from the "typical" upper Winterset of other areas to designate this anomalous sequence as the upper unit. The "typical" upper Winterset unit of the other areas was then changed to the middle unit. Hansen found this same anomalous sequence near stratigraphic section 11. As previously mentioned, the sequence at stratigraphic section 11 has been influenced by the Ramona reef environment. The reef facies near Ramona is a lithofacies of the Winterset Member. The similarity of the sequence at stratigraphic section 23 to that at stratigraphic section 11 suggests the possibility of a reef development in the vicinity of stratigraphic section 23. The upper unit as suggested by Hansen is a lithofacies of the "typical" upper Winterset unit, and therefore no further need for dividing the Winterset sequence into three units exists.

NELLIE BLY FORMATION

Two contacts were observed between the Hogshooter Formation and the overlying Nellie Bly Formation (stratigraphic sections 12, 32). Elsewhere, the Nellie Bly has been eroded away.

The lower part of the Nellie Bly Formation consists of thin-bedded calcareous siltstones with a few black shale beds. At stratigraphic section 12, the Nellie Bly overlies the upper Winterset unit, which is less than two feet thick at this locality. Two miles to the south (stratigraphic section 32), the Nellie Bly overlies the lower Winterset unit. No evidence of an unconformity exists between the Hogshooter and Nellie Bly Formations. If no unconformity exists, then the lower part of the Nellie Bly Formation in the southern part of the area represents a facies of the Winterset Member because it occupies the same stratigraphic interval as does the Winterset Member farther to the north. Oakes (1952, p. 65) mentioned the occurrence of deltaic facies in the Nellie Bly Formation in southern Osage County. The northward extrusion of this deltaic facies of the Nellie Bly Formation was probably deposited contemporaneously with the deposition of the Winterset Member farther north.

APPLICABILITY OF FOLK'S CLASSIFICATION TO THE LIMESTONES OF THE HOGSHOOTER FORMATION

In 1959, R. L. Folk published a descriptive petrographic classificaton for limestones. Table 1 illustrates a simplified presentation of the purely descriptive terms Folk applied to carbonate rocks. From this descriptive classification, he postulated genetic relationships. According to him, a framework cemented with sparry calcite is indicative of strong or persistent currents and a high-energy environment. Limestones consisting of a micritic matrix with or without allochemical constituents are indicative of low-energy environments in which the currents were insufficient to remove the fine-grained micritic material. During the investigation of the Hogshooter Formation, several relationships were observed that support Folk's genetic implications.

Relationship Between Terrigenous Material and Limestone Type

Seventy-one insoluble residues of the Winterset Member (not including the reef facies) were wet-sieved on a 4.5-phi screen to determine the percentages of each sample coarser and finer than 4.5 phi in diameter. In figure 8, the percentage of insoluble material was plotted against the percentage of terrigenous material coarser than 4.5 phi, and a line separating the samples containing sparry calcite cement and micritic material was drawn. This line separates the lower from the upper Winterset unit. Samples (sparry calcite-cemented) above this line contain a higher percentage of coarse material than do the micrite-bearing samples below the line. An increase in the percentage of material coarser than 4.5 phi may be indicative of an increase in energy in the depositional environment. The higher percentages of coarse material in the lower Winterset unit, the sparry calcite cement-bearing samples, indicate a higher energy environment for these samples. In the micrite-bearing samples, the percentages of material coarser than 4.5 phi are less, indicating a lower energy in the depositional environment for these samples. Finer material occurs in the micritic samples because the currents were capable of transporting only the finer terrigenous material into the area of deposition. In many samples, an increase in the amount of terrigenous material occurs with an increase in the percentage of coarse material. This relationship further suggests that coarser material may result from higher energy factors than those occurring in the micrite-accumulating environment.

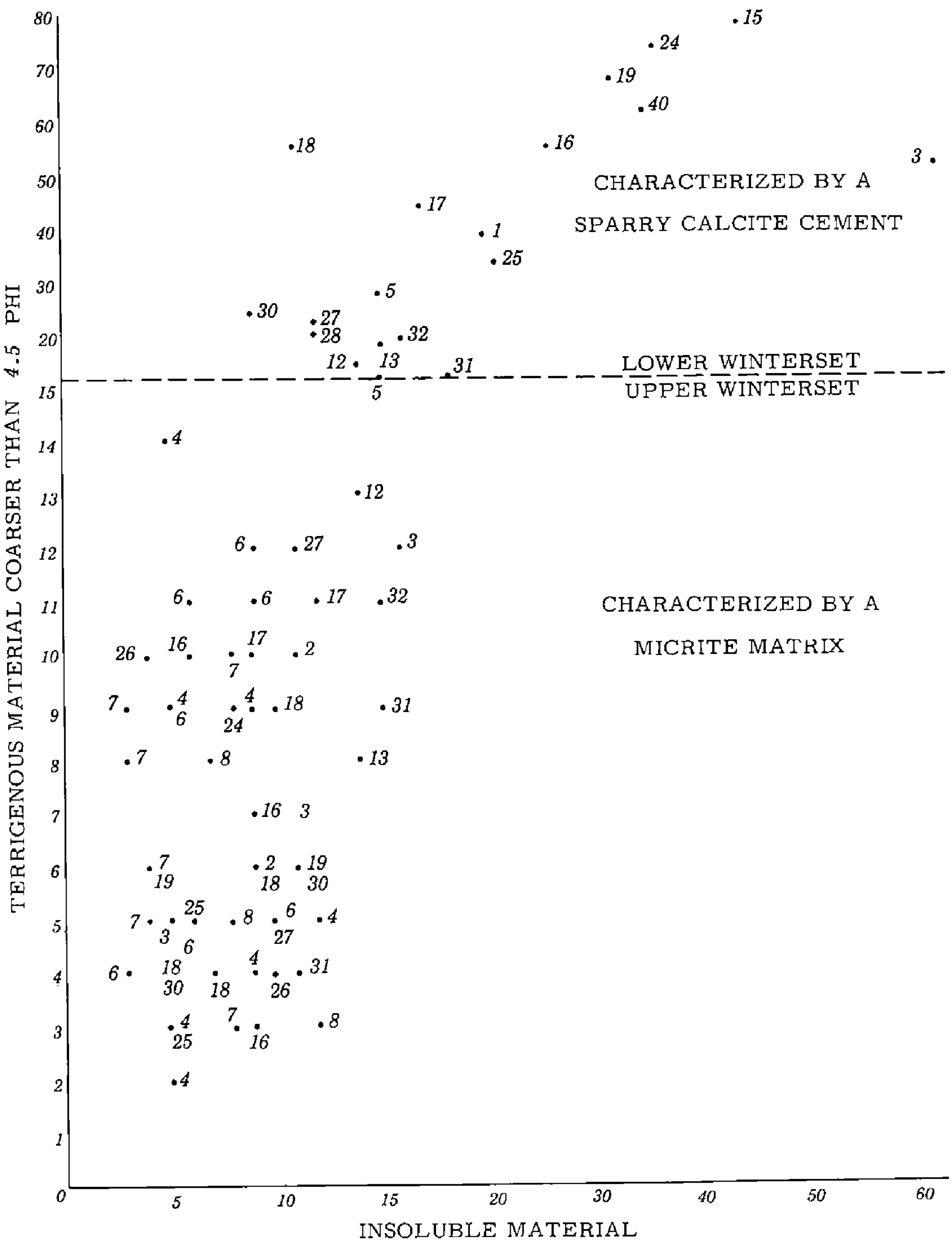

Figure 8. Relationship between percentage and coarseness of insoluble material and limestone types in the Winterset Member.

Relationship Between Fauna and Limestone Type

The faunal assemblages of the lower and upper Winterset units are strikingly different. The lower Winterset fauna consists of pelecypods, encrusting algae, crinoids, conodonts, bryozoans, and a few brachiopods. This fauna is similar to that found by Illing (1954) and Newell and others (1959) inhabiting the shallow, well-aerated (3 to 60 feet deep) waters of the Bahama Banks. The upper Winterset is characterized by a fauna dominated by brachiopods and bryozoans, with traces of ostracodes, foraminifers, and few crinoids. According to Elias (1937), this faunal assemblage is characteristic of deeper water, or lower energy, environments than is the fauna of the lower Winterset. Agreement between the fauna and the presence or absence of sparry calcite cement exists. In the lower Winterset unit, where sparry calcite cement is present, the fauna suggests a vigorous environment. In the upper Winterset unit, where micritic material is dominant, the fauna suggests a lower energy environment.

Relationship Between Abrasion of Skeletal Fragments and Limestone Type

The lower Winterset unit normally contains more and coarser terrigenous material than does the overlying upper Winterset (table 7). In thin sections, the degree of abrasion can be determined by examining the condition of skeletal fragments. In the lower Winterset, the skeletal fragments show a relatively high degree of abrasion, with most fragments being broken and fractured. In the upper Winterset, the skeletal material is less abraded. Large unabraded brachiopods and bryozoans (more than 1 mm in length) are abundant in the upper Winterset unit; spines are commonly still attached to the brachiopod shells. An environment in which the skeletal fragments are not abraded or fractured is probably characterized by low energy. In the upper unit, skeletal fragments are relatively unbroken and unabraded, indicating a low-energy environment. Micritic material also occurs in these same thin sections. If one component, such as the fauna, indicates a low-energy environment, the other components also were formed under the same environmental characteristics, and thus a micritic matrix is indicative of low-energy environments. Conversely, the extremely abraded fragments in the lower Winterset unit are indicative of relatively high energy. Therefore the sparry calcite cement in this unit is indicative of high-energy conditions.

Near the reef complex at Ramona, the insoluble content in the interbedded micrite-bearing and sparry calcite cement-bearing units remains reasonably constant. However, even at this locality, the abrasion characteristics of skeletal fragments provide an explanation for the presence or absence of micritic material. In the micritic beds, skeletal material is not as abraded as in the sparry calcite cement-bearing beds, thus again indicating that micrite accumulates in an environment of lower energy than that of beds characterized by abraded skeletal fragments and sparry calcite cement.

The presence of a fauna characteristic of a high-energy environment, an increase in the coarseness of the terrigenous material, and a relatively high degree of abrasion of skeletal fragments all suggest a relatively high-energy environment. Sparry calcite cement is also associated with these other components and, therefore, suggests high-energy conditions. Unabraded skeletal fragments, a fauna characteristic of a low-energy environment, and a decrease in the amount and coarseness of terrigenous material all suggest a relatively low-energy environment. A micritic matrix is associated with these components, and, therefore, micrite suggests low-energy conditions.

SUMMARY

Figure 9 illustrates the general relationships between the facies of the Hogshooter, Coffeyville, and Nellie Bly Formations.

Examination of the upper part of the Coffeyville Formation provided sufficient information (such as nearshore or shallow-water organisms, rounded muscovite flakes, carbonaceous material, and sparry calcite cement) to suggest that the Coffeyville siltstones and silty biosparrudites were deposited in shallow, high-energy, nearshore environments. The Canville and Lost City Limestone Members represent limestones that accumulated contemporaneously with the upper part of the Coffeyville terrigenous facies in adjacent areas. These two limestone facies of the Coffeyville Formation may represent micritic accumulations that were concentrated in areas baffled and stabilized by primitive plants (possibly algal growths). In the areas stabilized by primitive plants (similar to those discussed by Ginsburg and Lowenstam, 1958), micritic material was trapped and secured by the plant growths; in areas surrounding the stabilized regions, terrigenous material was deposited in a high-energy environment. Evidence for this interpretation occurs in the Canville and the Lost City. These units are composed predominantly of micritic material, which is thickest in a central area and which thins away from the central portion. In the thicker central portion, a lower terrigenous content occurs than in the thinner marginal areas. A fauna suggestive of relatively low-energy conditions (brachiopods, calcareous sponges, bryozoans, and foraminifers) is associated with the lower terrigenous content in the thicker central areas. In thin sections from the central areas, the skeletal material shows little fracturing and abrasion; the unabraded skeletal material suggests a low-energy environment. In the thinner marginal areas, sparry calcite cement is associated with faunal elements that also occur in the upper Coffeyville terrigenous sequence. The skeletal material in these marginal areas has been fractured and abraded to a higher degree than has that from the thicker central portion. The increase in terrigenous material toward the margins, associated with the faunal change and increase in abrasion of skeletal material suggests a higher energy environment along the margins. It is reasonable to expect such lithologic and faunal changes toward the periphery where plant growth was sparser and the higher energy environment exerted more influence upon deposition.

Thin sections of the Lost City and the Canville sequences contained large particles (more than 1 mm in diameter) composed of terrigenous material similar to that of the Coffeyville terrigenous facies. These large terrigenous particles may be fragments of the adjacent terrigenous facies that were torn up and redeposited in the low-energy environment of the stabilized areas. At one location (stratigraphic section 19), the Canville Limestone Member lenses out into Coffeyville terrigenous material, again suggesting contemporaneous deposition of the Canville and Lost City Limestones with the upper part of the Coffeyville terrigenous facies.

The Coffeyville terrigenous facies and the Canville and Lost City limestone facies show upward decreases in amount and size of terrigenous material. This fact may indicate a decrease in energy in the depositional environment or a gradual deepening of the water (associated with an increase in distance from shore) from the time the lower units were deposited until the upper portion was deposited.

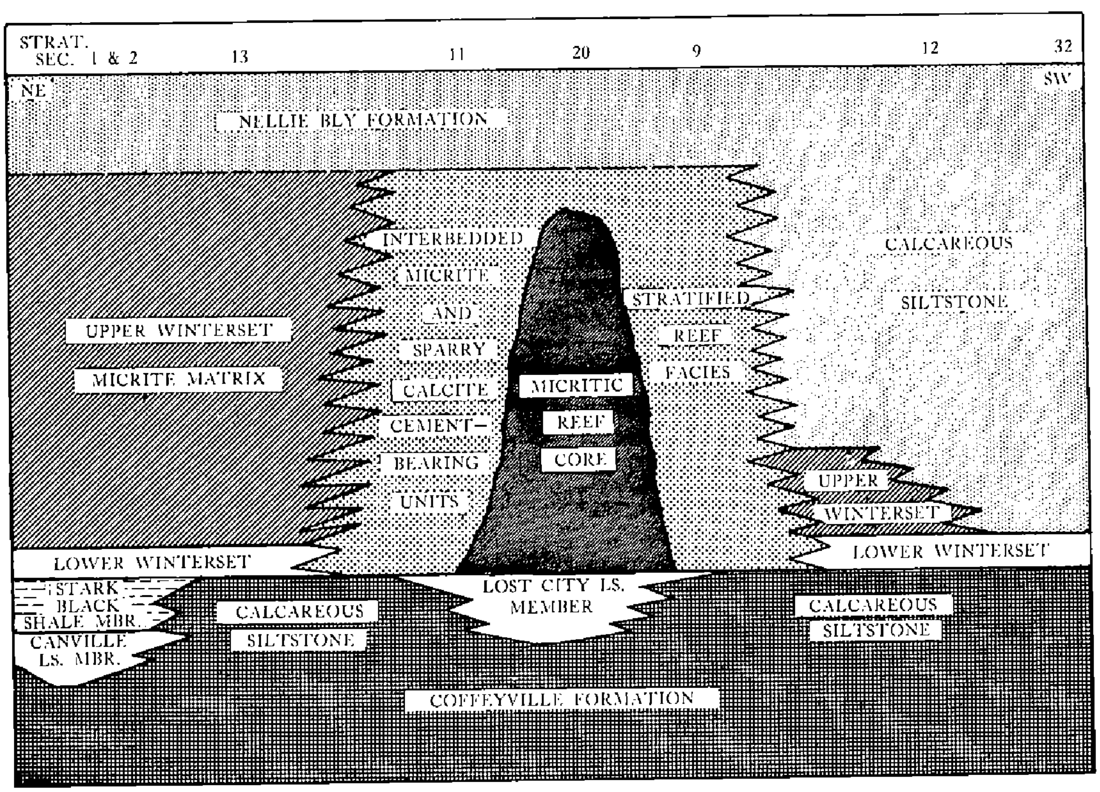

Figure 9. Diagrammatic cross section of the Hogshooter facies.

The Canville Member is overlain by the Stark Shale Member. The Stark consists primarily of fissile, carbonaceous black shale that probably represents an accumulation of organic material (possibly the organic remains of the primitive plants responsible for the stabilization of the underlying sequences) in a reducing environment below the depositional interface. In areas where the Lost City Member was deposited, conditions necessary for black shale accumulation did not exist.

A slight increase in water depth (as suggested by the upward decrease in coarseness of terrigenous material of the Coffeyville, Canville, and Lost City) produced the lower Winterset lithotope and resulted in the widespread deposition of sediments of relatively uniform lithology. The energy in the depositional environment of the lower Winterset was relatively high because micritic material is absent (cemented with sparry calcite). The biological constituents of this unit also suggest a relatively shallow, high-energy environment (encrusting algae, fenestrate bryozoans, crinoidal material, gastropods, pelecypods, and arthropods). Fossil material in the lower Winterset unit has been abraded to some degree, indicating that it was deposited in a high-energy environment. The terrigenous content in this unit is not constant but ranges from 9 to 62 percent of the total rock. This variability in terrigenous content probably results from variations in the energy occurring in the depositional environment (supply of terrigenous material may not have been uniform). Grain size of the terrigenous material shows a trend of increasing coarseness from south to north (3.0 phi to 1.5 phi), suggesting a source for this material to the north of the area. In the central part of the area (in the vicinity of stratigraphic sections 1, 3, 40) an anomalous increase in coarseness of terrigenous material occurs. At stratigraphic section 40, the percentage of terrigenous material coarser than 4.5 phi is 62 percent, an increase of 40 percentage points in the amount of coarse material found approximately 1.5 miles to the northeast. This anomalous increase in coarseness is probably the result of greater current velocities. A reef structure is adjacent to stratigraphic section 40, and it is probable that the currents supplying the nutrients to the reef structure also carried coarser terrigenous material into this area.

In the southern part of the area (stratigraphic section 32) the lower Winterset unit is overlain by the Nellie Bly Formation; at this locality, the unit is thickest (13 inches as compared with an average of 6 inches elsewhere). In this area, a vigorous environment was probably present for a longer period of time and part of this thicker sequence may be contemporaneous with the micritic upper Winterset unit farther north. The intraclast content in this sequence increases upward and is possibly indicative of shallowing in the sea associated with the encroachment of the Nellie Bly facies into the area.

Two reef structures (stratigraphic sections 20, 28) developed contemporaneously with the deposition of the lower Winterset unit, as the basal portions of these structures occupy the same stratigraphic position as the lower Winterset. Both reef structures are above sequences (Lost City and Stark) that accumulated in stabilized areas. These stabilized areas may have been favorable environments for reef-building organisms. These reef structures are probably patch reefs, as they do not have a linear trend and influence of the reef environment is local.

With a slight increase in water depth (or lowering of energy in the depositional environment), the upper Winterset lithotope developed over most of the area. The upper Winterset micritic sequence with unabraded skeletal material, consisting of spine-bearing brachiopod shells, large fenestrate bryozoan fragments, and traces of foraminifers and octracodes, is indicative of a low-energy environment. From the central part of the area (stratigraphic section 4) to the north, shale units are more numerous and thicker. This northwest increase in amount of terrigenous material indicates a source to the north of the area. In the southern part of the area, calcareous siltstones and shales (Nellie Bly lithology) were deposited contemporaneously with the micrite deposition farther to the north. Oakes (1952, p. 65) discussed the occurrence of a deltaic sequence in the Nellie Bly Formation in the southern part of Osage County, Oklahoma. The terrigenous influx observed in the southern part of the area is probably the extension of this deltaic environment into the area where the lower and upper Winterset rock types were being deposited.

The reef structures that were initiated during the same time interval as the deposition of the lower Winterset unit continued to grow during the upper Winterset interval. Near Ramona, Oklahoma, three distinct facies are associated with the reef structures. The reef cores are composed of a framework of *Solenopora*-type algae at the base and fenestrate bryozoans at the top. The algae and bryozoans acted as baffles that trapped micritic material that was swept into this vicinity by strong currents. Lithologic units composed of reef detritus, sparry calcite-cemented skeletal material, and a few beds composed of micritic material are adjacent to the reef cores. The reef detritus zones thin rapidly away from the reef, and the sparry calcite-cemented units become thicker. The sparry calcite-cemented units immediately surrounding the reef cores suggest high-energy conditions near the reef. Away from the reef to the north, the sparry calcite-cemented units become thinner and finally disappear (except for the thin lower Winterset unit), indicating a lowering of the energy away from the reef structures. The rocks not influenced by the high-energy reef environment are characterized by micrite. Figure 9 shows the relationship between the facies associated with the reef structures.

At stratigraphic section 4 (thickest section of the upper Winterset), variations in limestone types indicate relative depths of water. In the lower portion of the vertical section, irregular beds range in thickness from 4 to 6 inches. Associated with these irregular, thin beds are biomicrudites and few intrasparites. Above this irregularly bedded lower unit is a thick-bedded sequence (individual beds average 2 feet thick). No intraclast-bearing units are in this sequence, which is dominated by brachiopod-bryozoan biomicrudites. An irregularly bedded sequence (beds range in thickness from 1 to 2 inches), in which 60 percent of the rocks is composed of micritic intraclasts, overlies the thick-bedded unit.

This stratigraphic sequence, beginning at the base with irregularly bedded, slightly intraclastic units and passing through a thick-bedded biomicrudite sequence into an intraclastic sequence of thin, irregular beds, possibly indicates an initial relatively shallow depth followed by a deepening of the water with subsequent shallowing of the water again. The energy during the deposition of the lower irregularly bedded sequence was higher than during the deposition of the thick-bedded biomicrudite, as no intraclasts occur in the thick-bedded interval. Shallowing of the water or an increase in the energy is again indicated by the intraclastic sequence overlying the thick-bedded unit. Intraclast-bearing sequences are also found in the upper parts of stratigraphic sections 8, 17, and 18. After the deposition of the Coffeyville terrigenous facies, and the Canville, Lost City, and Stark facies, the water depth increased, and the widespread lower Winterset unit was deposited. With a further deepening of water (or lowering of energy by baffle stabilization), energy in the depositional environment decreased, and the accumulation of micritic material occurred. The water depth was not sufficient to prohibit occasional disturbances of micritic material, and intraclasts were formed. With a continued increase in water depth, the energy decreased, and the micritic material was deposited below wave base; thus no major disturbances of this material occurred. The water depth then decreased, and the micritic material was subjected to higher energy conditions, with large numbers of intraclasts being formed (intraclastic sequence found near the top of stratigraphic section 4). This shallowing of the water is probably indicative of shallowing associated with the transgression of the Nellie Bly terrigenous sequence over the Hogshooter Formation.

Intraclasts in this sequence are indicative of an environment shallower than that of the biomicrudite, as wave action disturbed a previously deposited micrite. Before intraclasts can form, the micritic material comprising the intraclasts must be cohesive or partly lithified (Folk, 1959a, p. 4-5). If the water depth were shallow during the initiation of the upper Winterset deposition (as is suggested above), the initially deposited micritic units could have been subjected to subaerial conditions under which the micrite became semiconsolidated. Assuming that this first event took place, the following sequence of events might have ensued. The partially lithified micritic material was subjected to wave action (water depth was sufficiently shallow so that the micritic material was above wave base), and intraclasts were formed. As the depth of the water increased, the massive unit (biomicrudite) was deposited below wave base and was lithified by compaction instead of subaerial exposure. As the water depth again decreased, micritic material was subjected to subaerial conditions with a resulting partial lithification of the micrite. This material was subjected to wave action (micritic material was again above wave base) and intraclasts were formed.

The fauna in the lower part of the stratigraphic sequence at stratigraphic section 4 (the lower intraclastic unit and the thick-bedded sequence) is dominated by fenestrate and encrusting bryozoans, which average approximately. 18 to 20 percent of the total rock. Brachiopods, ostracodes, and foraminifers are associated with the bryozoans and together constitute approximately 5 percent of the rock. In the upper intraclastic sequence, approximately 3 to 10 percent skeletal material occurs and is much more fragmented than that found in the lower sequences. The higher energy environment associated with the formation of the intraclasts may not have been favorable for most organisms, and therefore skeletal material is scarce. This upper intraclastic sequence possibly represents a mud-flat accumulation, and therefore skeletal remains should be sparse.

Most of the upper Coffeyville sequence and the Hogshooter Formation was deposited under transgressive conditions (rock types suggest increasing depth of water), but the upper part of the upper Winterset unit probably represents a shallowing of the water depth and the beginning of a regressive phase.

REFERENCES

Adams, G. I., Girty, G. H., and **White, David,** 1903, Stratigraphy and paleontology of the Upper Carboniferous rocks of the Kansas section: U. S. Geol. Survey, Bull. 211, 123 p.

Ames, L. L., Jr., 1959, The genesis of carbonate apatites: Econ. Geology, vol. 54, p. 829-841.

Bathurst, R. G. C., 1958, Diagenetic fabrics in some British Dinantian limestones: Liverpool & Manchester Geol. Jour., vol. 2, p. 11-36.

————1959, Diagenesis in Mississippian calcilutites and pseudobreccias: Jour. Sed. Petrology, vol. 29, p. 365-376.

Black, W. W., 1952, The origin of the supposed tufa bands in Carboniferous reef limestones: Geol. Magazine, vol. 89, p. 195-200.

Bloesch, Edward, 1928, Nowata and Craig Counties, **in** Oil and gas in Oklahoma: Okla. Geol. Survey, Bull. 40-EE, 30 p., **also in** Okla. Geol. Survey, Bull. 40, vol. 3, p. 353-376.

Bushinsky, G. I., 1935, Structure and origin of phosphorites in the U.S.S.R.: Jour. Sed. Petrology, vol. 5, p. 81-92.

Curtis, N. M., Jr., and **Ham, W. E.,** 1957, Physiographic map of Oklahoma: Okla. Geol. Survey, Educ. Ser., Map 4.

deLaubenfels, M. W., 1957, Marine sponges, **in** Treatise on marine ecology and paleoecology, vol. 1: Geol. Soc. America, Mem. 67, p. 1083-1086.

Duncan, Helen, 1957, Bryozoans, **in** Treatise on marine ecology and paleoecology, vol. 2: Geol. Soc. America, Mem. 67, p. 783-800.

Elias, M. K., 1937, Depth of deposition of the Big Blue (Late Paleozoic) sediments in Kansas: Geol. Soc. America, Bull., vol. 48, p. 403-432.

Folk, R. L., 1959a, Practical petrographic classification of limestones: Amer. Assoc. Petroleum Geologists, Bull., vol. 43, p. 1-38.

————1959b, Petrology of sedimentary rocks: Austin, Texas, Hemphill's, 154 p.

Ginsburg, R. N., and **Lowenstam, H. A.,** 1958, The influence of marine bottom communities on the depositional environment of sediments: Jour. Geology, vol. 66, p. 310-318.

Hansen, B. V., 1958, The stratigraphy and petrogenesis of the Hogshooter formation in northeastern Oklahoma: Tulsa, Univ., unpublished Master of Science thesis.

Illing, L. V., 1954, Bahaman calcareous sands: Amer. Assoc. Petroleum Geologists, Bull., vol. 38, p. 1-95.

Jewett, J. M., 1932, Brief discussion of the Bronson group in Kansas: Kans. Geol. Soc., Guidebook, 6th Ann. Field Conf., p. 99-103.

Johnson, J. H., 1943, Geologic importance of calcareous algae, with annotated bibliography: Colo. School Mines, Quart., vol. 38, no. 1, 102 p.

————1942, Permian lime-secreting algae from the Guadalupe Mountains, New Mexico: Geol. Soc. America, Bull., vol. 53, p. 195-226.

————1945, Calcareous algae of upper Leadville limestone near Glenwood Springs, Colorado: Geol. Soc. America, Bull., vol. 56, p. 828-847.

————1946, Lime-secreting algae from the Pennsylvanian and Permian of Kansas: Geol. Soc. America, Bull., vol. 57, p. 1087-1120.

————1951, An introduction to the study of organic limestones: Colo. School Mines, Quart., vol. 46, no. 2, 185 p.

Johnson, J. H., Konishi, Kenji, and **Rezak, Richard,** 1959, Studies of Silurian (Gotlandian) algae: Colo. School Mines, Quart., vol. 54, no. 1, 173 p.

Krumbein, W. C., and **Garrels, R. M.,** 1952, Origin and classification of chemical sediments in terms of pH and oxidation-reduction potential: Jour. Geology, vol. 60, p. 1-33.

Krumbein, W. C., and **Pettijohn, F. J.,** 1938, Manual of sedimentary petrography: New York, Appleton-Century-Crofts, Inc., 549 p.

Mitchell, R. H., 1935, Residues of some Pennsylvanian limestones: Amer. Assoc. Petroleum Geologists, Bull., vol. 19, p. 412-417.

Moore, R. C., 1929, Environment of Pennsylvanian life in North America: Amer. Assoc. Petroleum Geologists, Bull., vol. 13, p. 459-487.

——————1935, Stratigraphic classification of the Pennsylvanian rocks of Kansas: Kans., State Geol. Survey, Bull. 22, 256 p.

Newell, N. D., Rigby, J. K., Fischer, A. G., Whiteman, A. J., and **Hickox, J. E.,** 1953, The Permian reef complex of the Guadalupe Mountains region, Texas and New Mexico: San Francisco, W. H. Freeman & Co., 236 p.

Newell, N. D., and **Rigby, J. K.,** 1957, Geological studies on the Great Bahama Bank: Soc. Econ. Paleontologists Mineralogists, Spec. Pub. 5, p. 15-72.

Newell, N. D., Imbrie, John, Purdy, E. G., and **Thurber, D. L.,** 1959, Organism communities and bottom facies, Great Bahama Bank: Amer. Museum Nat. History, Bull., vol. 117, art. 4, p. 181-228.

Oakes, M. C., 1940, Geology and mineral resources of Washington County, Oklahoma: Okla. Geol. Survey, Bull. 62, 208 p.

——————1952, Geology and mineral resources of Tulsa County, Oklahoma: Okla. Geol. Survey, Bull. 69, 234 p.

Ohern, D. W., 1910, The stratigraphy of the older Pennsylvanian rocks of northeastern Oklahoma: State University of Oklahoma, Research Bull. 4, 40 p.

Osburn, R. C., 1957, Marine Bryozoa, **in** Treatise on marine ecology and paleoecology, vol. 1: Geol. Soc. America, Mem. 67, p. 1109-1112.

Pettijohn, F. J., 1957, Sedimentary rocks, 2d ed.: New York, Harper and Brothers, 718 p.

Pray, L. C., 1958, Fenestrate bryozoan core facies, Mississippian bioherms, southwestern United States: Jour. Sed. Petrology, vol. 28, p. 261-273.

Thorp, E. M., 1939, Florida and Bahama marine calcareous deposits, **in** Recent marine sediments, a symposium: Tulsa, Amer. Assoc. Petroleum Geologists, p. 283-297.

Trask, P. D., 1939, Organic content of Recent marine sediments, **in** Recent marine sediments, a symposium: Tulsa, Amer. Assoc. Petroleum Geologists, p. 428-453.

Twenhofel, W. H., 1950a, Principles of sedimentation, 2d ed.: New York, McGraw-Hill Book Co., Inc., 674 p.

——————1950b, Coral and other organic reefs in the geologic column: Amer. Assoc. Petroleum Geologists, Bull., vol. 34, p. 182-202.

Weeks, L. G., 1957, Origin of carbonate concretions in shales, Magdalena Valley, Colombia: Geol. Soc. America, Bull., vol. 68, p. 95-102.

Wolfenden, E. B., 1958, Paleoecology of the Carboniferous reef complex and shelf limestones in northwest Derbyshire, England: Geol. Soc. America, Bull., vol. 69, p. 871-898.

PLATES I - V

Photomicrographs of Coffeyville and Hogshooter Rocks

Explanation of Plate I

Coffeyville Formation

Figures 1-3. Coffeyville Terrigenous Facies

1. Measured section 5-A-1. Fine sand-silty, algal-bryozoan biosparrudite; darker areas are algal encrustations (Osagia sp.) primarily around pelecypod fragments.
2. Measured section 9-1. Fine sandstone to siltstone: sparry calcite-cemented submature pelecypod-bryozoan orthoquartzite; large algally encrusted pelecypod fragments are parallel to bedding in unit; large bryozoan in lower third of photomicrograph; darker area at top is limonite-stained zone.
3. Measured section 11-1. Fine sand-bearing pelecypodal-algal biosparrudite; Osagia sp. encrusted primarily around recrystallized pelecypod fragments; darker areas are algal encrustations.

Figures 4-6. Canville Member

4. Measured section 1-3. Silty, spiculiferous biomicrosparite; darker areas of matrix are micrite; lighter areas are microspar; monaxon sponge spicules common; some of the spicules have been recrystallized to microspar; approximately 20 percent skeletal material.
5. Measured section 3-1. Silty, bryozoan-algal biosparrudite; Osagia encrusted around pelecypod and bryozoan fragments; large crinoid columnal on right side of photomicrograph; fine-crystalline sparry calcite cement; bryozoan and algal structures are characterized by large concentrations of pyrite.
6. Measured section 19-1. Fine sand-silty, pyritic-limonitic bryozoan-algal biomicrudite; limonite disseminated through micrite matrix; long algally encrusted skeletal fragment near center of photomicrograph is punctate-brachiopod fragment; helically coiled gastropod in lower left of photograph; cross section of bryozoan colony in upper part; pyrite concentrated in bryozoan and algal fragments.

(All photographs x4.8. field diameter 10 mm. All photographs were taken with crossed nicols.)

Plate I

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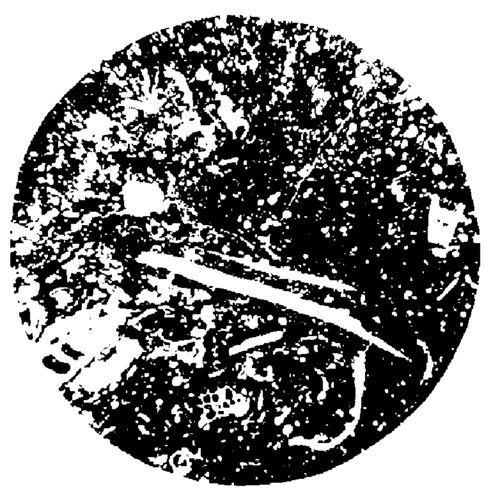

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Explanation of Plate II

Coffeyville Formation

Figure 1. Stark Member

1. Measured section 1-4. Limestone concretion; matrix is microspar; lighter areas are coarse-crystalline sparry calcite; thin, dark bands are composed of organic material; lighter matrix at top of photomicrograph is fine-crystalline sparry calcite.

Figures 2, 3. Lost City Member

2. Measured section 5-A-2. Silty, algal-bryozoan-crinoidal biosparrudite; relatively large Epimastopora fragment in lower portion of photograph; large terrigenous fragment in center of photograph (may represent fragment of highly terrigenous Coffeyville terrigenous facies that was being deposited contemporaneously in adjacent areas); encrusting algae common.
3. Measured section 9-A-1. Silty, algal-pelecypodal biomicrudite; interbedded zones of small skeletal fragments and large fragments; Osagia encrusted only on upper surfaces of larger skeletal fragments (primarily pelecypod fragments); terrigenous material concentrated in layers containing small skeletal fragments; gastropods common.

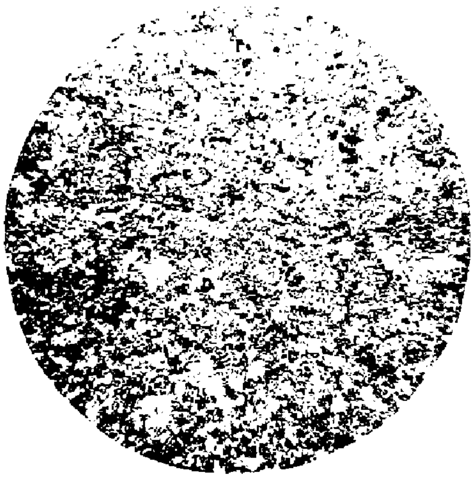
Hogshooter Formation

Figures 4-6. Lower Winterset Unit

4. Measured section 1-5. Silty, phosphatic-glauconitic fossiliferous oösparite; concentrically layered oöliths common; dark spots are phosphate particles; dark matrix is limonite-stained sparry calcite; some oöliths have been replaced by phosphate; scattered crinoid fragments (abraded); field diameter 4.5 mm, x10.7.
5. Measured section 3-5. Fine sandstone to siltstone; sparry calcite-cemented submature phosphatic-glauconitic algal-bearing orthoquartzite; Osagia occurs as dark areas; algae have encrusted parallel to bedding, and probably trapped terrigenous material; dark particles in lower part of photograph are crinoid fragments and phosphate particles.
6. Measured section 13-1. Silty, phosphatic crinoidal-algal biosparrudite; skeletal material not deeply abraded; darker matrix is limonite-stained sparry-calcite cement.

(All photographs x4.8, field diameter 10 mm, except where noted otherwise. All photographs were taken with crossed nicols.)

Plate II



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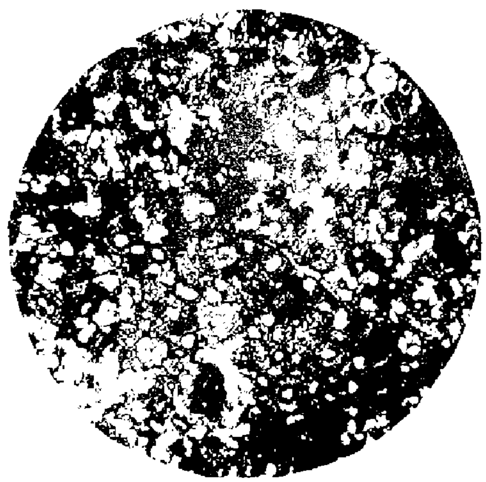

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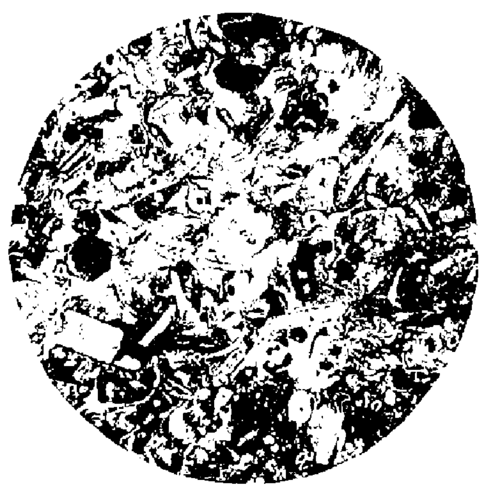

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Explanation of Plate III

Hogshooter Formation

Figures 1-3. Lower Winterset Unit

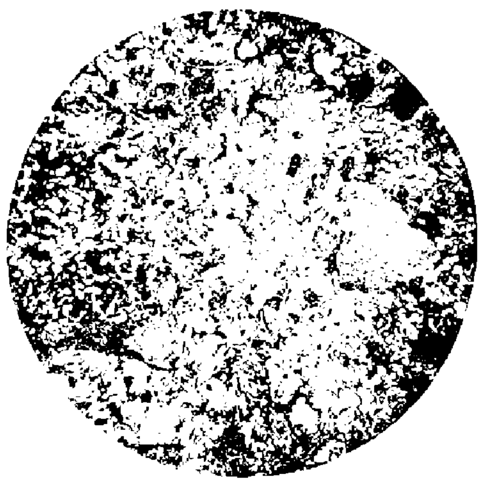
1. Measured section 24-1. Medium sand-silty, phosphatic crinoidal-algal biosparrudite; skeletal material deeply abraded, and associated with high terrigenous content (36 percent).
2. Measured section 25-1. Fine sand-silty, phosphatic crinoidal-algal biosparrudite; skeletal material much less abraded than in 24-1; encrusting algae occur as dark elliptical structures.
3. Measured section 32-1. Fine sand-silty, phosphatic algal-bryozoan biosparrudite; large bryozoan colony encrusted with algae in lower part of photograph; skeletal material not deeply abraded; relatively large crinoidal material scattered through section.

Figures 4-6. Upper Winterset Unit

4. Measured section 3-7. Brachiopod-bryozoan biomicrudite; rim-cemented cavities and pore-filling sparry calcite common; excellent geopetal structure in center of photograph.
5. Measured section 4-1. Brachiopod-bryozoan biomicrudite; unabraded brachiopod shell in center of photograph; much small fragmented skeletal material.
6. Measured section 4-3. Brachiopod-bryozoan biomicrudite; large brachiopod fragment with spine still attached in lower part of photograph; some pore-filling and recrystallization spar; lighter areas in matrix are due to recrystallization of micrite to fine-crystalline sparry calcite; some recrystallization in lower right of photograph with sparry calcite completely surrounding remnants of micrite matrix.

(All photographs x4.8, field diameter 10 mm. All photographs were taken with crossed nicols.)

Plate III



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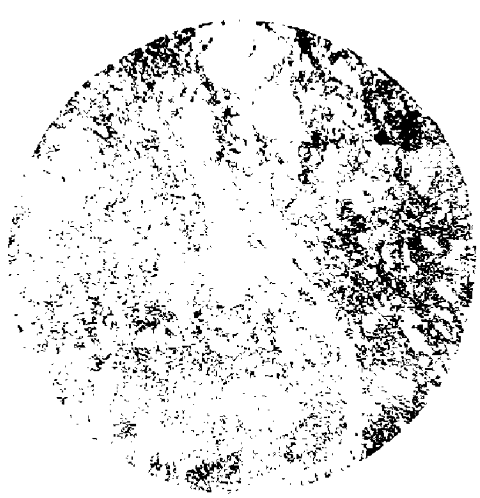

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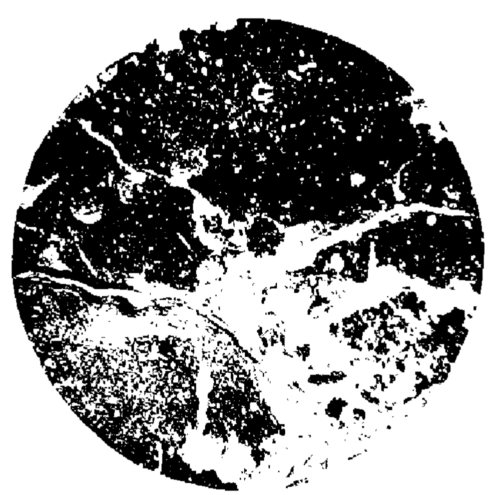

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Explanation of Plate IV

Hogshooter Formation

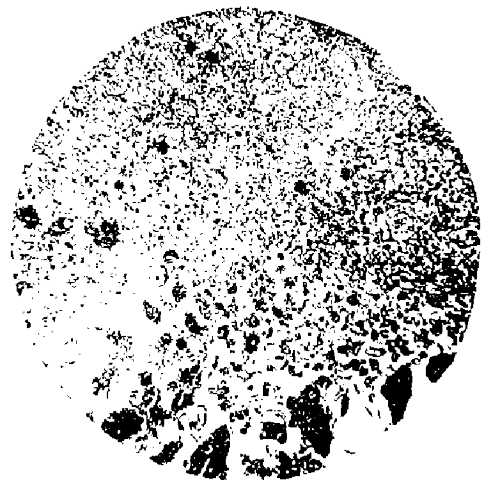
Figures 1-6. Upper Winterset Unit

1. Measured section 4-5. Crinoidal-bryozoan-brachiopod biomicrudite; pseudopunctate brachiopod shell in center of photograph; larger skeletal material unabraded; recrystallization spar in lower right portion, as sparry calcite surrounds portions of the micrite matrix; some pore-filling sparry calcite occurs in cavities.
2. Measured section 4-8. Intrasparite; intraclasts composed of fossiliferous micrite; some superficial oöliths occur; grades upward from coarser intraclasts at base to smaller at top; larger intraclasts probably not transported far, as they are still angular.
3. Measured section 4-9. Interlayered micrite, fossiliferous intrasparrudite, and intrasparite; small-scale channel-and-fill structures; fractures filled with sparry calcite; dark areas in right-central part of photograph are large intraclasts of micritic material.
4. Measured section 6-5. Bryozoan biomicrudite; fenestrate bryozoan colonies may still be in growth position; no abrasion or fracturing of bead-type bryozoan structure has occurred; bryozoans may have trapped much of smaller skeletal material and micrite.
5. Measured section 7-1. Interbedded micrite and intrasparite; excellent examples of pore-filling sparry calcite in fractures; rim cementation common; intrasparite below fractures, with micrite between and above fractures.
6. Measured section 16-3. Partially recrystallized brachiopod biomicrudite; lighter areas of matrix have been recrystallized to fine-crystalline sparry calcite; matrix in upper portion of photograph is still micrite; some pore-filling sparry calcite occurs as white areas in photograph.

(All photographs x4.8, field diameter 10 mm. All photographs were taken with crossed nicols.)

Plate IV

1



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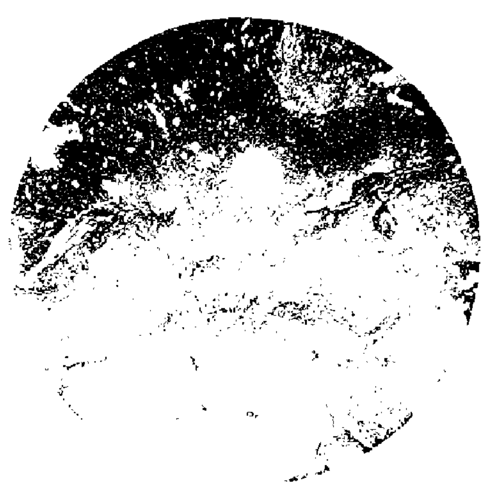

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Explanation of Plate V

Hogshooter Formation

Figures 1-4. Core Reef Facies of the Winterset Member

1. Measured section 20-4. Algal biolithite; reef core; Solenopora-type algae as radiating structures in lower part and upper half of photograph; recrystallization of algal material common, producing a blurred effect; large cavity in left-central portion of photograph illustrating excellent examples of rim cementation; large calcite crystals have grown into the central portion of the cavity; remainder of cavity has been filled with poikilitic calcite.
2. Measured section 20-4. Part of figure 1, x19.2; radiating structures are Solenopora-type algae; diameter of photomicrograph is 2.5 mm.
3. Measured section 20-5. Crinoidal biomicrudite and biosparrudite; skeletal material dominated by crinoid fragments; minor bryozoan material; darker areas of matrix are micrite, and lighter areas are sparry-calcite cement; several large unbroken fenestrate-bryozoan structures suggest that the bryozoans may have been stabilizing the depositional environment; micrite may have been trapped before complete winnowing could occur.
4. Measured section 20-6. Partially recrystallized bryozoan biomicrudite; darker areas of matrix are micrite; lighter areas are fine-crystalline sparry calcite that has formed by recrystallization of micrite; large unbroken fenestrate bryozoans occur in lower half of photograph; some pore-filling sparry calcite appears as white areas; bryozoans probably stabilized depositional environment.

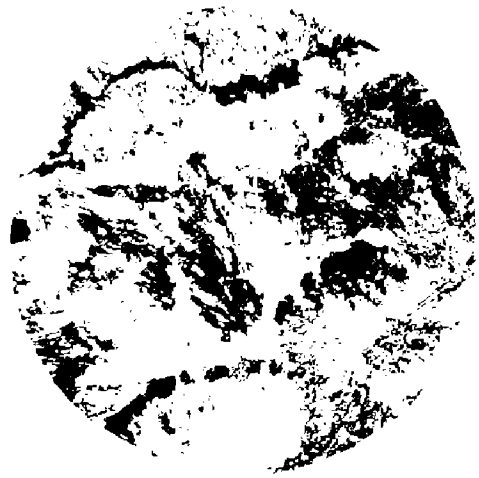
Figures 5, 6. Stratified Reef Facies of the Winterset Member

5. Measured section 9-A-2. Phosphatic algal-crinoidal biosparrudite; large algally encrusted particle in center of photograph is phosphate nodule composed of numerous smaller particles of phospsatic material; this unit is stratigraphically equivalent to the reef cores 0.8 mile north.
6. Measured section 10-3. Phosphatic intraclast-bearing crinoidal-algal biosparrudite; darker areas of matrix are micrite; encrusting algae occur around skeletal material and disseminated through entire photograph; algae may have acted as a cementing agent; micritic material may have been trapped by encrusting algae before complete winnowing occurred; darker rounded particles are intraclasts composed of micritic material.

(All photographs x4.8, field diameter 10 mm, except where noted otherwise. All photographs were taken with crossed nicols.)

Plate V

1



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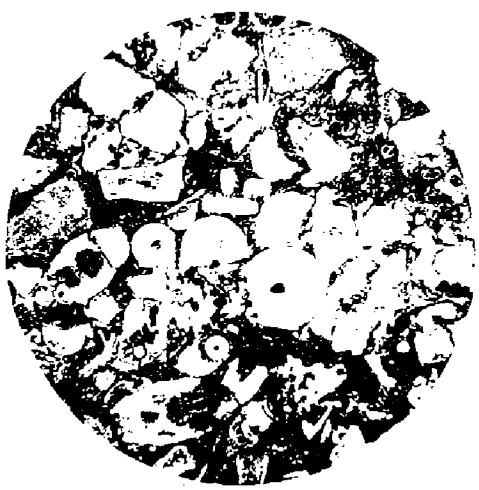

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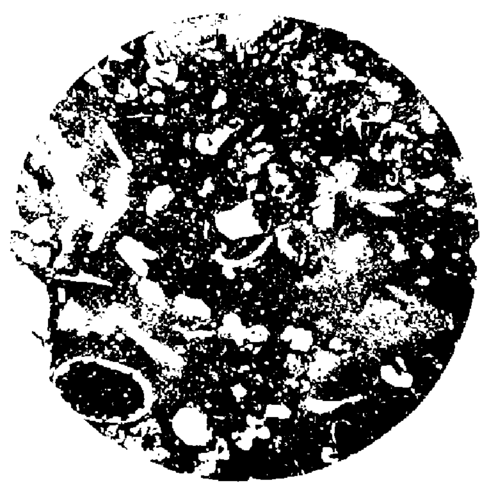

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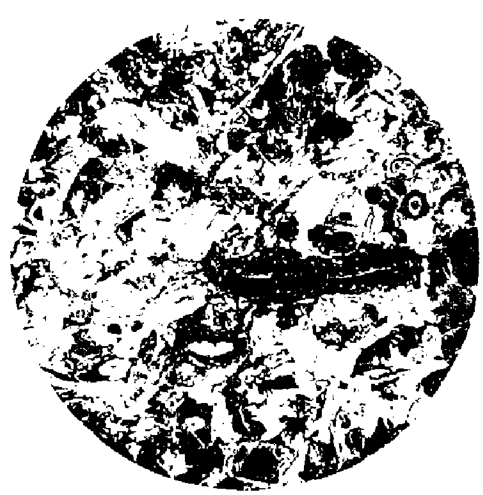

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APPENDIX

Procedures Employed to Determine the Insoluble-Residue Characteristics

A procedure similar to that discussed by Krumbein and Pettijohn (1938, p. 494-495) was used to obtain 156 insoluble-residue analyses. For each of these residues, the amount of material coarser and finer than 4.5 phi was determined. A series of checks was run to calculate the amount of insoluble material lost during the period between the initial residue determination and the coarseness calculation. The main steps employed in determining the amount of material lost are presented below.

1. The weight of the residue removed from the filter paper was subtracted from the initial weight of the residue.
2. After the residue was removed, the filter paper was weighed, and the initial filter-paper weight was subtracted from the value obtained from the second weighing of the paper. This difference represents the amount of fine material impregnated in the filter paper.
3. The value obtained in step 2, which represents the fine fraction remaining on the paper, was subtracted from the value obtained in step 1, which represents the difference in weight between the initial residue and the material removed from the paper. If no material is lost, the difference between these two values is 0. However, in many cases, a difference often exists, and this difference represents the amount of material lost during the removal of the material from the paper.
4. The difference obtained in step 3 was divided by both the initial-sample and initial-residue weights.

If the residue loss was greater than 10 percent, the sample was discarded and a new residue analysis was prepared. The greatest loss in residue occurred when the residue weight was approximately 0.3 or 0.4 grams, as a loss of only 0.04 of a gram represents a loss of more than 10 percent of the residue. In this case, where the loss is more than 10 percent, the amount of the total sample lost was approximately 0.5 percent.

The steps used to determine the percentages of the residue coarser and finer than 4.5 phi are listed below.

1. The insoluble residue was removed from the filter paper and weighed.
2. The removed residue was washed through a 4.5 phi screen until all the material finer than 4.5 was removed.
3. The material remaining on the sieve was washed into a previously weighed beaker, and then placed in an oven.
4. The material and the beaker were then weighed; the original weight of the beaker was subtracted from the combined weight, the difference representing the amount of material coarser than 4.5 phi.
5. The weight value from step 4 was subtracted from the value found in step 1 (the weight of material after removal from the filter

paper). The weight obtained from this subtraction is the amount of material finer than 4.5 phi, which was washed through the screen.

6. The weight of the fine material found in step 5 was added to the weight of the fine material remaining on the filter paper (this value was previously determined in the calculation of the percentage of residue lost) to obtain the total amount of fine material.

7. The additional fine material from the paper was added to the initial weight of the residue removed from the filter paper. This was done to obtain the total residue weight to be used in the calculation of the amounts coarser and finer than 4.5 phi.

8. The total weight of the material larger than 4.5 phi (value from step 4) was divided by the total residue (step 7) to obtain the percentage of material coarser than 4.5 phi. The remaining percentage represents the amount of material finer than 4.5 phi.

In the following table, the initial insoluble-residue percentages are listed with the percentages of the residue material that are coarser and finer than 4.5 phi.

INSOLUBLE-RESIDUE DATA

SAMPLE	UNIT	PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI	PERCENT FINER THAN 4.5 PHI
CH-1-3	Canville	16	30	70
CH-1-4	Stark	11	9	91
CH-1-5	Lower Winterset	20	39	61
CH-2-1	Canville	18	42	58
CH-2-2	Canville	12	22	78
CH-2-4	Stark	12	4	96
CH-2-5	Upper Winterset	11	10	90
CH-2-6	Upper Winterset	9	6	94
CH-3-1	Canville	39	22	78
CH-3-2	Canville	20	23	77
CH-3-4	Stark	88	1	99
CH-3-5	Lower Winterset	62	52	48
CH-3-6	Upper Winterset	16	12	88
CH-3-7	Upper Winterset	5	5	95
CH-4-1	Upper Winterset	9	4	96
CH-4-3	Upper Winterset	9	9	91
CH-4-4	Upper Winterset	12	5	95
CH-4-5	Upper Winterset	5	14	86
CH-4-7	Upper Winterset	5	9	91
CH-4-8	Upper Winterset	5	3	97
CH-4-9	Upper Winterset	5	2	98
CH-5-1	Coffeyville	35	59	41
CH-5-2	Coffeyville	73	69	31
CH-5-3	Coffeyville	29	50	50
CH-5-A-1	Coffeyville	39	53	47
CH-5-A-2	Lost City	12	20	80
CH-5-A-3	Lower Winterset	15	28	72
CH-5-6	Upper Winterset	15	16	84
CH-6-1	Upper Winterset	5	9	91
CH-6-2	Upper Winterset	10	5	95
CH-6-3	Upper Winterset	9	12	88
CH-6-4	Upper Winterset	6	11	89
CH-6-5	Upper Winterset	9	11	89
CH-6-6	Upper Winterset	3	4	96

SAMPLE	UNIT	PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI	PERCENT FINER THAN 4.5 PHI
CH-6-7	Upper Winterset	6	4	96
CH-7-1	Upper Winterset	3	8	92
CH-7-2	Upper Winterset	4	5	95
CH-7-3	Upper Winterset	8	3	97
CH-7-4	Upper Winterset	8	10	90
CH-7-5	Upper Winterset	4	6	94
CH-7-6	Upper Winterset	3	9	91
CH-8-1	Upper Winterset	8	5	95
CH-8-2	Upper Winterset	7	8	92
CH-8-3	Upper Winterset	12	3	97
CH-9-1	Coffeyville	55	68	32
CH-9-A-1	Lost City	21	22	78
CH-9-A-2	Reef Facies	9	8	92
CH-9-3	Reef Facies	9	12	88
CH-10-1	Reef Facies	9	15	85
CH-10-2	Reef Facies	7	21	79
CH-10-3	Reef Facies	7	12	88
CH-10-4	Reef Facies	5	7	93
CH-10-5	Reef Facies	13	2	98
CH-10-6	Reef Facies	12	7	93
CH-10-7	Reef Facies	7	6	94
CH-11-1	Coffeyville	49	65	35
CH-11-A-1	Reef Facies	10	9	91
CH-11-2	Reef Facies	6	8	92
CH-11-3	Reef Facies	13	7	93
CH-12-1	Lower Winterset	14	17	83
CH-12-2	Upper Winterset	14	13	87
CH-13-1	Lower Winterset	15	19	81
CH-13-2	Upper Winterset	14	8	92
CH-14-1	Reef Facies	26	77	23
CH-14-2	Reef Facies	7	43	57
CH-14-3	Reef Facies	17	58	42
CH-14-4	Reef Facies	7	11	89
CH-15-1	Stark	17	8	92
CH-15-2	Lower Winterset	44	78	22
CH-16-2	Lower Winterset	26	55	45
CH-16-3	Upper Winterset	9	7	93
CH-16-4	Upper Winterset	9	3	97
CH-16-5	Upper Winterset	6	10	90
CH-17-1	Upper Winterset	12	11	89
CH-17-2	Lower Winterset	17	44	56
CH-17-3	Upper Winterset	9	10	90
CH-18-1	Coffeyville	76	24	76
CH-18-2	Lower Winterset	11	55	45
CH-18-3	Upper Winterset	7	4	96
CH-18-4	Upper Winterset	6	4	96
CH-18-5	Upper Winterset	10	9	91
CH-18-6	Upper Winterset	9	6	94
CH-19-1	Canville	26	13	87
CH-19-2	Stark	8	2	98
CH-19-3	Lower Winterset	32	68	32
CH-19-4	Upper Winterset	11	6	94
CH-19-5	Upper Winterset	4	6	94
CH-20-1	Reef Core	11	16	84
CH-20-2	Reef Core	5	1	99
CH-20-3	Reef Core	6	2	98
CH-20-4	Reef Core	7	4	96
CH-20-5	Reef Core	4	3	97
CH-20-6	Reef Core	9	4	96
CH-22-1	Reef Facies	8	17	83
CH-22-2	Reef Facies	9	38	62

SAMPLE	UNIT	PERCENT INSOLUBLE CONTENT	PERCENT COARSER THAN 4.5 PHI	PERCENT FINER THAN 4.5 PHI
CH-22-3	Reef Facies	7	4	96
CH-22-4	Reef Facies	6	4	96
CH-23 4	Reef Facies	9	5	95
CH-23-1	Reef Facies	7	3	97
CH-23-2	Reef Facies	8	21	79
CH-23-3	Reef Facies	40	53	47
CH-24-1	Lower Winterset	36	74	26
CH-24-2	Upper Winterset	8	9	91
CH-25-1	Lower Winterset	21	34	66
CH-25-2	Upper Winterset	6	5	95
CH-25-3	Upper Winterset	5	3	97
CH-26-1	Lower Winterset	12	20	80
CH-26-2	Upper Winterset	10	4	96
CH-26-3	Upper Winterset	4	10	90
CH-27-1	Lower Winterset	12	22	78
CH-27-2	Upper Winterset	11	12	88
CH-27-3	Upper Winterset	10	5	95
CH-28-1	Reef Core	6	4	96
CH-28-2	Reef Core	11	4	96
CH-28-3	Reef Core	8	8	92
CH-29-1	Canville	29	13	87
CH-29-2	Canville	7	4	96
CH-30-1	Lower Winterset	9	24	76
CH-30-2	Upper Winterset	11	6	94
CH-30-3	Upper Winterset	6	4	96
CH-31-1	Lower Winterset	18	16	84
CH-31-2	Upper Winterset	15	9	91
CH-31-3	Upper Winterset	11	4	96
CH-32-1	Lower Winterset	16	19	81
CH-32-2	Lower Winterset	15	11	89
CH-33-1	Reef Facies	10	12	88
CH-33-2	Reef Facies	6	12	88
CH-33-3	Reef Facies	6	5	95
CH-33-4	Reef Facies	11	4	96
CH-33-5	Reef Facies	14	5	95
CH-33-6	Reef Facies	10	3	97
CH-33-7	Reef Facies	10	3	97
CH-34-1	Reef Facies	16	2	98
CH-34-2	Reef Facies	16	2	98
CH-34-4	Reef Facies	14	4	96
CH-34-5	Reef Facies	6	3	97
CH-35-1	Reef Facies	13	7	93
CH-35-2	Reef Facies	11	8	92
CH-35-4	Reef Facies	7	3	97
CH-35-5	Reef Facies	17	2	98
CH-35-7	Reef Facies	6	3	97
CH-36-1	Reef Facies	3	4	96
CH-36-2	Reef Facies	6	5	95
CH-36-3	Reef Facies	9	3	97
CH-36-5	Reef Facies	9	5	95
CH-37-1	Lost City	15	27	73
CH-37-2	Reef Facies	7	5	95
CH-37-4	Reef Facies	8	2	98
CH-37-5	Reef Facies	7	1	99
CH-37-6	Reef Facies	9	1	99
CH-39-1	Lost City	16	26	74
CH-39-2	Reef Facies	8	3	97
CH-39-3	Reef Facies	9	4	96
CH-40-1	Lower Winterset	35	62	38
CH-42-3	Lower Winterset	15	36	64

Acetic Acid Insoluble-Residue Analyses

Forty acetic acid determinations were performed on samples from the Hogshooter and Coffeyville Formations to concentrate any minerals soluble in hydrochloric acid and insoluble in acetic acid. The only additional mineral observed in the acetic acid residues was calcium phosphate. The phosphate is present as irregularly shaped pellets, botryoidal lumps, and internal molds of gastropods and pelecypods. The lumps and pellets range from approximately 1 to ⅛ mm in diameter, but in hand specimens, phosphate nodules an inch in diameter are common. The larger lumps and nodules are composed of smaller individual particles of phosphate. Because phosphate is the only additional mineral in the acetic acid residues, the approximate percentage of phosphate was calculated by subtracting the weight percentage of the hydrochloric acid residue from the weight percentage of the acetic acid residue for the same sample. This value is only an approximation, but in most cases it agrees closely with the thin-section analyses.

Several generalizations presented below are based on the acetic acid insoluble-residue analyses.

1. The lower Winterset unit contains the largest percentages of phosphatic material; the amount of phosphate in this unit ranges from 3 to 8 percent. Pellets and lumps of phosphatic material are common, and are commonly associated with conodonts and internal molds of gastropods and pelecypods composed of phosphatic material. (This unit is characterized by a sparry calcite cement.)
2. The upper Winterset unit contains no trace of phosphate either as pellets or as internal fillings in gastropod or pelecypod shells. (This unit is characterized by a micritic matrix.)
3. In the reef and possible reef facies of the Winterset Member, the units that have a sparry calcite cement also have a relatively high concentration (from 1 to 8 percent) of phosphatic material as compared with the micritic units; the units with a micritic matrix are devoid of phosphatic material in any form other than rare fish teeth. The sparry calcite-bearing units contain lumps, pellets, conodonts, fish teeth, and internal molds of gastropods and pelecypods, all composed of phosphatic material.
4. The Canville Member contains no phosphatic material in the form of pellets or lumps, and only minor traces of molds of gastropods and pelecypods. No conodonts are present.
5. The Lost City Member contains minor percentages (from traces to 2 percent) of lumps, pellets, and internal molds of gastropods and pelecypods. No conodonts are present.

Acetic Acid Insoluble-Residue Descriptions

Canville Member:

CH-2-1 Glauconite and pyrite in minor percentages; no phosphate, conodonts, or other skeletal material.

Lost City Member:

CH-5-A-2 Approximately 2 percent phosphate (pellet-shaped material); trace of glauconite; no conodonts or other skeletal material.

CH-9-A-1 Trace of pellet-shaped phosphate material and glauconite; internal molds of pelecypods, and planispirally and helically coiled gastropods composed of phosphate.

CH-27-1 Approximately 2 percent phosphate; internal molds of gastropods composed of phosphate; no glauconite or conodonts.

CH-39-1 Trace of glauconite and internal molds of planispirally coiled gastropods composed of phosphatic material; no phosphate pellets or conodonts.

Stark Member:

CH-1-4 Approximately 5 percent pyrite; no skeletal material, glauconite, or phosphate.

Lower Winterset unit:

CH-1-5 Approximately 8 percent phosphate; 1 percent glauconite; phosphate as irregular pellets and as internal molds of gastropods; conodonts (platform type).

CH-5-A-3 Approximately 5 percent phosphate as irregular pellets; 1 percent glauconite; conodonts.

CH-12-1 Approximately 5 percent phosphate as irregular pellets; 2 to 3 percent pyrite; internal molds of gastropods composed of phosphate; conodont fragments.

CH-13-1 Approximately 3 percent phosphatic material as pellets; helically and planispirally coiled gastropod molds composed of phosphatic material; 1 percent glauconite; conodonts.

CH-15-2 Approximately 8 percent phosphate; 2 percent glauconite; conodonts only skeletal material.

CH-16-2 Approximately 4 percent phosphate pellets; 1 percent glauconite; conodonts; no additional skeletal material.

CH-17-2 Approximately 6 percent phosphate material; 2 percent glauconite; internal molds of gastropods composed of phosphate; conodonts.

CH-18-2 Approximately 5 percent phosphate; trace of glauconite; conodonts only skeletal material.

CH-19-3 Approximately 5 percent phosphatic material; trace of glauconite; conodont fragments only skeletal material.

CH-32-1 Approximately 5 percent phosphate; trace of glauconite; internal molds of gastropods composed of phosphate; conodonts.

CH-32-2 Approximately 1 percent phosphate; trace of glauconite; internal molds of helically and planispirally coiled gastropods and pelecypods composed of phosphatic material; conodonts.

Upper Winterset unit:

CH-2-5 Minor percentage of pyrite; no glauconite, phosphate, or skeletal material.

CH-4-1 No phosphate, glauconite, or skeletal material.
CH-5-6 Slight trace of glauconite; no phosphate or skeletal material.
CH-12-2 Minor percentage of pyrite; no glauconite, phosphate, or skeletal material.
CH-18-3 No glauconite, phosphate, or skeletal material.
CH-19-4 No glauconite, phosphate, or skeletal material.

Reef facies of the Winterset Member:

Units with a sparry calcite cement:
CH-9-A-2 Approximately 7 percent phosphate; minor percentage of glauconite; internal molds of pelecypods and planispirally and helically coiled gastropods composed of phosphatic material; conodonts.
CH-10-1 Approximately 5 percent phosphate; trace of glauconite; planispirally and helically coiled gastropods as internal molds composed of glauconite and phosphate; conodonts.
CH-33-7 Minor percentage of phosphate; helically coiled gastropods as internal molds composed of phosphatic material; conodonts and fish teeth.
CH-35-1 Approximately 8 percent phosphate; 1 percent glauconite; internal molds of planispirally and helically coiled gastropods composed of phosphatic material; conodonts.
CH-39-2 Approximately 2 percent phosphate; trace of glauconite; fish teeth and planispirally coiled gastropods.

Units with a micritic matrix:
CH-33-4 Fragments of fish teeth; no conodonts, phosphate, glauconite, or gastropods.
CH-34-2 No phosphate, glauconite, or skeletal material.
CH-35-5 No phosphate, glauconite, or skeletal material.
CH-36-2 No phosphate, glauconite, or skeletal material.
CH-37-4 No phosphate, glauconite, or skeletal material.

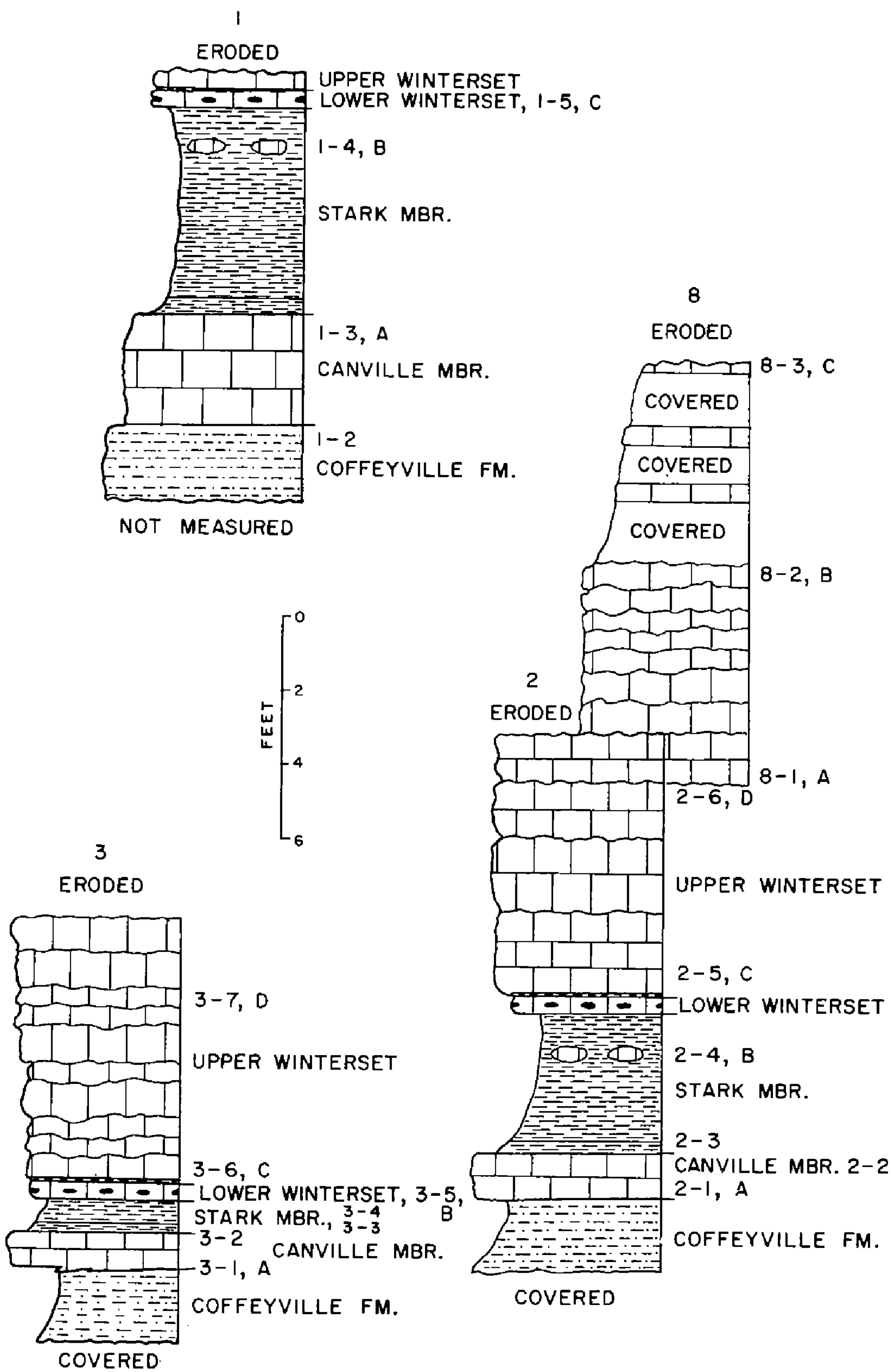
Possible reef facies of the Winterset Member:

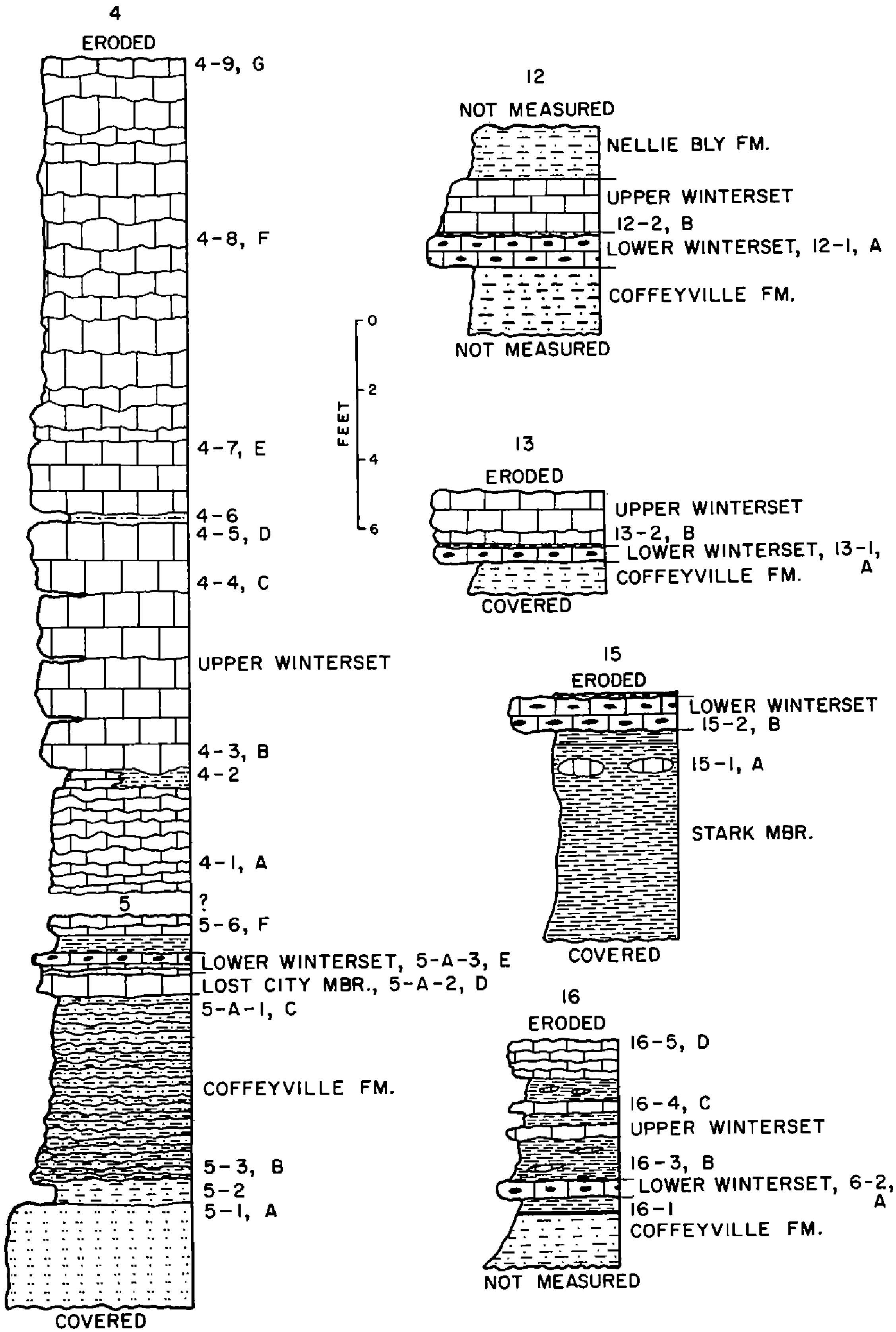
Units with a sparry calcite cement:
CH-14-1 Approximately 3 percent phosphate; trace of glauconite; pelecypods and helically and planispirally coiled gastropods as internal molds composed of glauconite and phosphatic material.
CH-22-2 Approximately 5 percent phosphate; 3 percent glauconite; conodonts abundant; fish teeth and internal molds of gastropods.
CH-23-3 Minor percentages of phosphate and glauconite; fish teeth and conodonts.
CH-23-4 Minor percentages of phosphate and fish teeth.

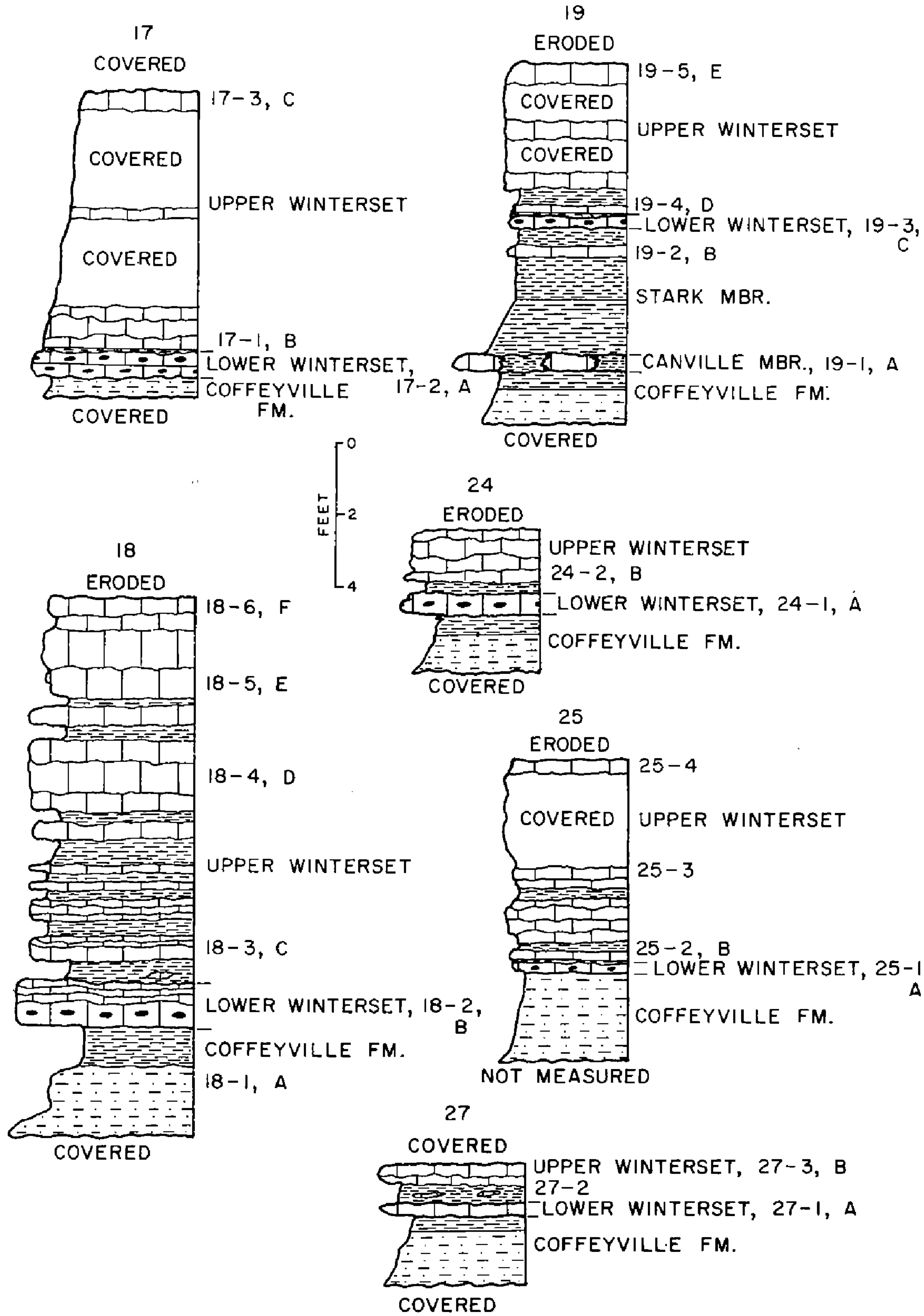
Units with a micritic matrix:
CH-22-3 No phosphate, glauconite, or skeletal material.
CH-23-1 No phosphate, glauconite, or skeletal material.

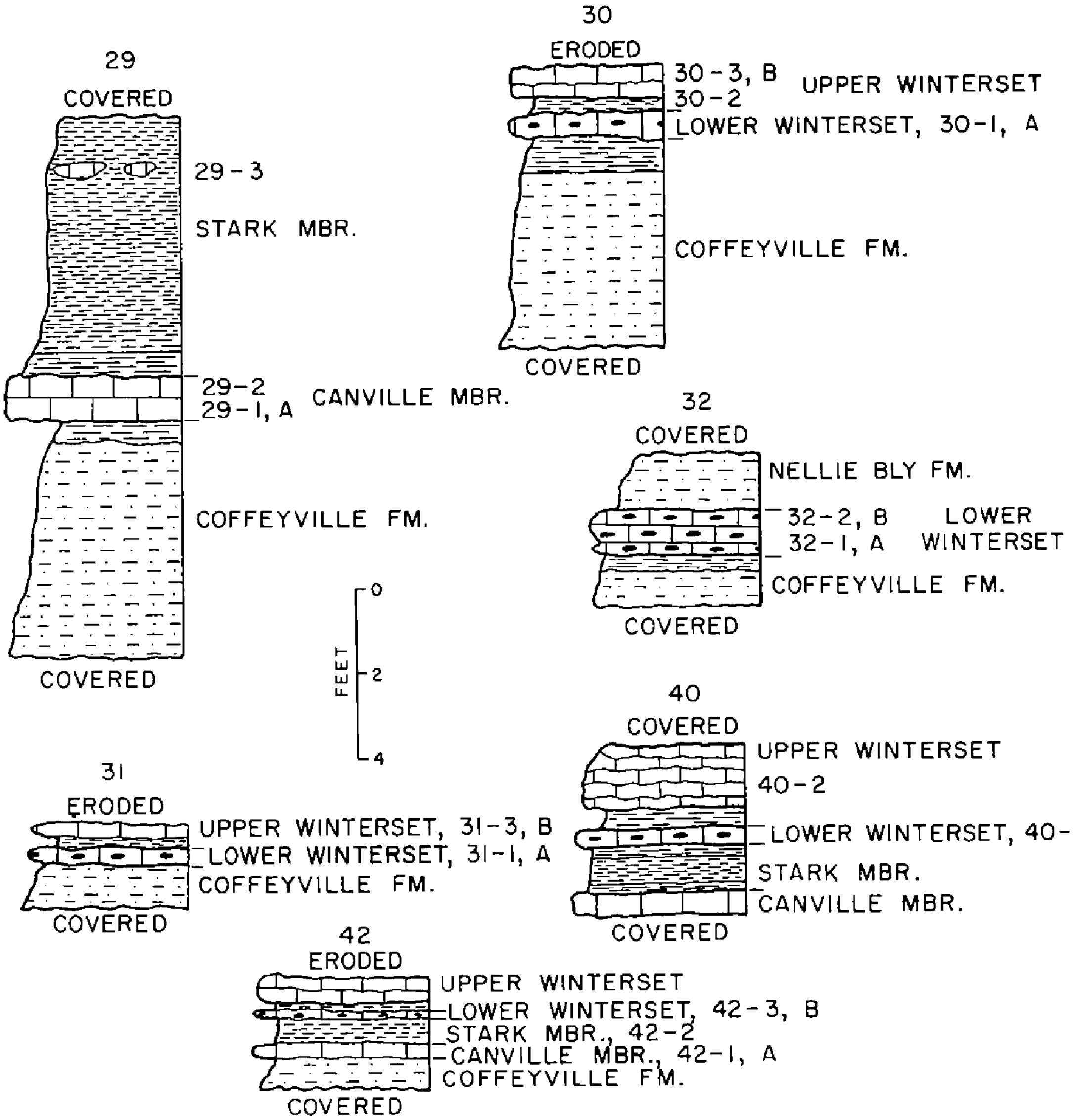
Measured Stratigraphic Sections

Thirty-nine stratigraphic sections were measured in the area. Each of these sections is described below; columnar sections have been made for thirty-six of the measured sections (see fig. 6 for the columnar sections of the units measured in the vicinity of Ramona, Oklahoma). The vertical location of a sample in a particular stratigraphic section is designated by a number such as 1-5, where 1 refers to the stratigraphic section and 5 refers to the fifth sample collected above the base of the section. Wherever a thin section or an acetate peel of a particular sample was made, a letter such as A, B, C, etc., is placed next to the sample location on the columnar section. Each of the samples is representative of a particular stratigraphic unit, and, although only one sample may have been collected from a unit 3 feet thick, the description of the sample is considered as the description of the unit. Samples were collected at all significant lithologic changes. The color, both weathered and unweathered, of the units examined in the area remains constant, and therefore the color of a particular unit is presented only once.

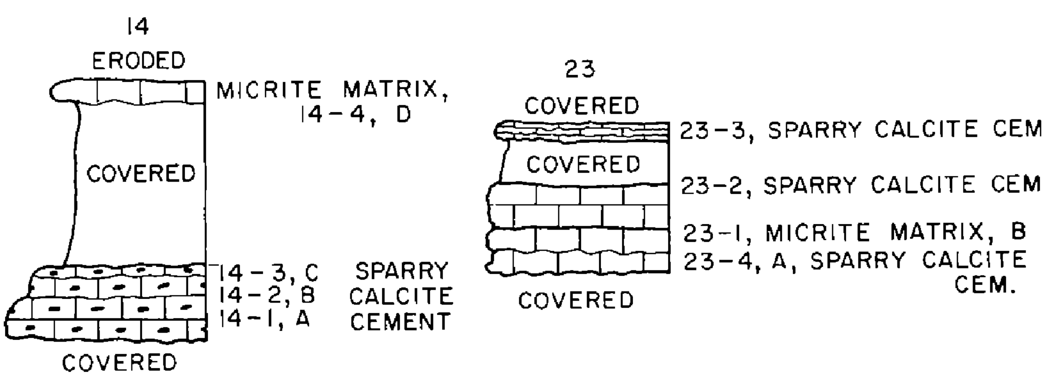

1
ERODED
UPPER WINTERSET
LOWER WINTERSET, 1-5, C
1-4, B
STARK MBR.
1-3, A
CANVILLE MBR.
1-2
COFFEYVILLE FM.
NOT MEASURED
8
ERODED
8-3, C
COVERED
COVERED
COVERED
8-2, B
8-1, A
0
2
4
6
FEET
2
ERODED
2-6, D
UPPER WINTERSET
2-5, C
LOWER WINTERSET
2-4, B
STARK MBR.
2-3
CANVILLE MBR. 2-2
2-1, A
COFFEYVILLE FM.
COVERED
3
ERODED
3-7, D
UPPER WINTERSET
3-6, C
LOWER WINTERSET, 3-5, B
STARK MBR., 3-4 3-3
3-2
CANVILLE MBR.
3-1, A
COFFEYVILLE FM.
COVERED

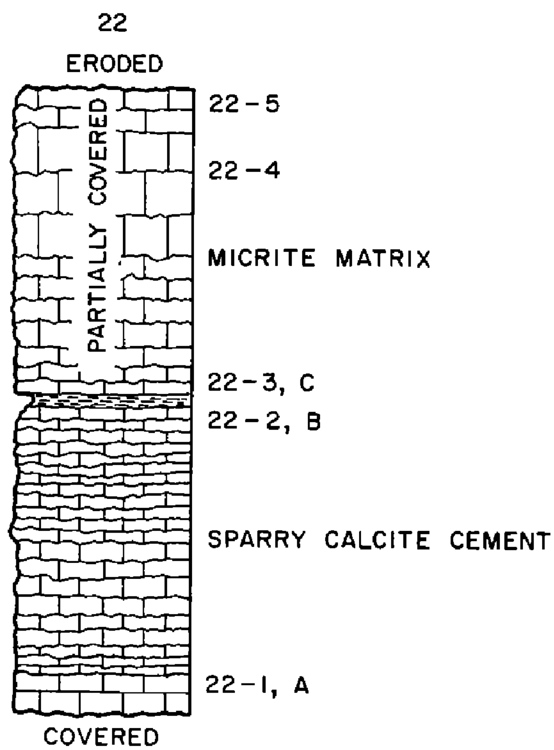

4
ERODED
4-9, G
4-8, F
4-7, E
4-6
4-5, D
4-4, C
UPPER WINTERSET
4-3, B
4-2
4-1, A
?
5
5-6, F
LOWER WINTERSET, 5-A-3, E
LOST CITY MBR., 5-A-2, D
5-A-1, C
COFFEYVILLE FM.
5-3, B
5-2
5-1, A
COVERED
FEET
0
2
4
6
12
NOT MEASURED
NELLIE BLY FM.
UPPER WINTERSET
12-2, B
LOWER WINTERSET, 12-1, A
COFFEYVILLE FM.
NOT MEASURED
13
ERODED
UPPER WINTERSET
13-2, B
LOWER WINTERSET, 13-1, A
COFFEYVILLE FM.
COVERED
15
ERODED
LOWER WINTERSET
15-2, B
15-1, A
STARK MBR.
COVERED
16
ERODED
16-5, D
16-4, C
UPPER WINTERSET
16-3, B
LOWER WINTERSET, 6-2, A
16-1
COFFEYVILLE FM.
NOT MEASURED

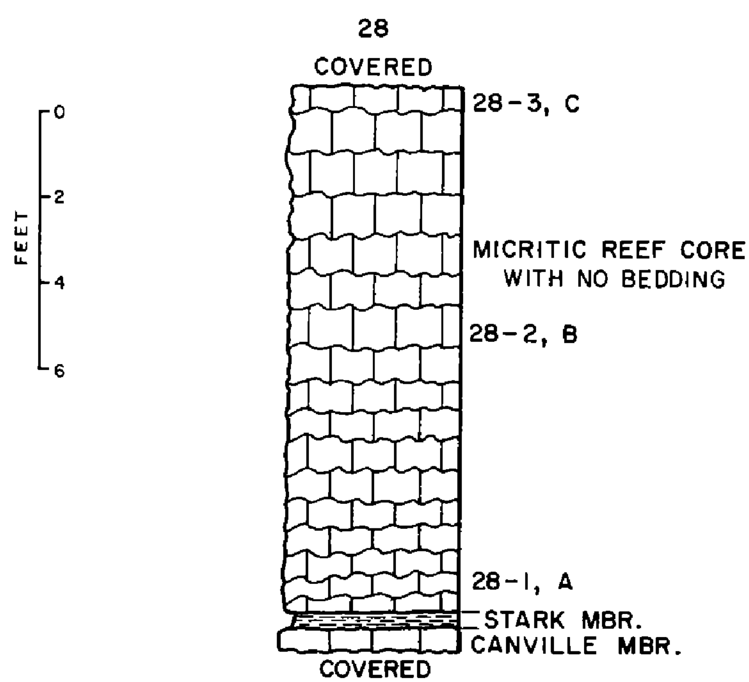

17
COVERED
17-3, C
COVERED
UPPER WINTERSET
COVERED
17-1, B
LOWER WINTERSET, 17-2, A
COFFEYVILLE FM.
COVERED
19
ERODED
19-5, E
COVERED
UPPER WINTERSET
COVERED
19-4, D
LOWER WINTERSET, 19-3, C
19-2, B
STARK MBR.
CANVILLE MBR., 19-1, A
COFFEYVILLE FM.
COVERED
FEET
0
2
4
24
ERODED
UPPER WINTERSET
24-2, B
LOWER WINTERSET, 24-1, A
COFFEYVILLE FM.
COVERED
18
ERODED
18-6, F
18-5, E
18-4, D
UPPER WINTERSET
18-3, C
LOWER WINTERSET, 18-2, B
COFFEYVILLE FM.
18-1, A
COVERED
25
ERODED
25-4
COVERED
UPPER WINTERSET
25-3
25-2, B
LOWER WINTERSET, 25-1, A
COFFEYVILLE FM.
NOT MEASURED
27
COVERED
UPPER WINTERSET, 27-3, B
27-2
LOWER WINTERSET, 27-1, A
COFFEYVILLE FM.
COVERED



STRATIGRAPHIC SECTIONS WITH POSSIBLE REEF FACIES




22
ERODED
22-5
22-4
PARTIALLY COVERED
MICRITE MATRIX
22-3, C
22-2, B
SPARRY CALCITE CEMENT
22-1, A
COVERED


28
COVERED
28-3, C
FEET
0
2
4
6
MICRITIC REEF CORE
WITH NO BEDDING
28-2, B
28-1, A
STARK MBR.
CANVILLE MBR.
COVERED

1. SW¼ SW¼ NE¼ sec. 31, T. 26 N., R. 14 E., Washington County, in south bank of small stream approximately 250 yards east of the north-south road along the half-section line of section 31. (See columnar section, page 98.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top eroded):	
Brachiopod-bryozoan biomicrudite; weathers dark yellowish orange, light gray on unweathered surface; irregular beds approximately 3 inches thick; productid brachiopods and bryozoans abundant, with minor percentages of crinoid columnals, ostracodes, and foraminifers; skeletal material only slightly fragmented with no abrasion; coarse-crystalline sparry calcite as areas of recrystallization and as void fillings evidenced by rim cementation; less than 10% terrigenous material; 25% skeletal material.	0.5
Lower Winterset unit:	
1-5, C. *silty phosphatic glauconitic fossiliferous oösparite;* weathers dark yellowish brown, light brownish gray on unweathered surface; one bed 6 inches thick; phosphate nodules 1 inch and less in diameter; encrusting algae (*Osagia*) and crinoid fragments abundant with minor brachiopod and bryozoan fragments; trace of conodonts; abraded fossil fragments; 20% terrigenous material; 30% skeletal material; 30% oöliths; 8% phosphate and glauconite (see pl. II, fig. 4).	0.5
Coffeyville Formation.	
Stark Member:	
Gray and brown clay.	0.3
Fissile black shale.	0.5
1-4, B, *limestone concretions;* weathers light brownish gray, black on unweathered surface; concretions up to 1 foot long and 3 to 5 inches wide, flattened parallel to bedding in black shale; bedding continues through concretion; chert and pyrite in concretion (see pl. II, fig. 1).	0.4
Fissile black shale.	4.0
Gray and brown clay.	0.3
Canville Member:	
1-3, A, *silty spiculiferous biomicrosparite;* weathers pale dark yellowish orange, light olive gray to pale yellowish brown on unweathered surface; 1 bed 3 feet thick; spicules (sponge) common with minor percentages of foraminifers, crinoid columnals, brachiopods, and ostracodes; matrix and much of the skeletal material recrystallized to microspar; approximately 15% angular quartz particles; 20% skeletal material (see pl. I, fig. 4).	3.0
Coffeyville terrigenous facies (2 feet measured):	
1-2, *calcareous siltstone;* dark yellowish orange on weath-	2.0

	Feet
ered surface, and pale yellowish brown on fresh surface; irregular beds, 0.5 to 1 inch thick; angular quartz particles and rounded flakes of muscovite; scattered, fragmented pelecypods and encrusting algae.	
Total section measured	11.5

2. SW¼ SW¼ NE¼ sec. 31, T. 26 N., R. 14 E., Washington County, 200 yards west of stratigraphic section 1 in south creek bank. (See columnar section, page 98.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top eroded):	
2-6, D, *crinoidal-bryozoan biomicrudite;* irregular beds 3 to 8 inches thick; crinoid columnals, plates, spines (15%) and bryozoans (10%) common, minor percentages of brachiopods, ostracodes, and foraminifers; coarse-crystalline sparry calcite along fractures; some rim cementation indicating void fillings; several bands of concentrated terrigenous material associated with fine-crystalline sparry calcite; less than 10% terrigenous material; 30% skeletal material, no abrasion of skeletal material.	1.5
2-5, C, *brachiopod-bryozoan biomicrudite;* irregular beds 3 to 4 inches thick; brachiopods (10%) and bryozoans (10%) common, minor percentages of crinoid columnals, ostracodes, and foraminifers; skeletal material slightly fragmented with no abrasion; some brachiopods with spines still attached to shell; some void fillings by sparry calcite, and some recrystallization of micrite to coarse sparry calcite; approximately 10% terrigenous material; 25% skeletal material.	5.5
Lower Winterset unit:	
Deeply weathered; not sampled; contains phosphate nodules.	0.4
Coffeyville Formation.	
Stark Member:	
Gray and brown clay.	0.3
Fissile black shale.	0.3
2-4, B, *limestone concretions;* same description as 1-4, except no chert or pyrite.	0.4
Fissile black shale.	2.5
Gray and brown clay.	0.4
Canville Member:	
2-2, sampled at top of unit; same lithology as 2-1, except for decrease in terrigenous material from 18% at 2-1 to 12% at 2-2.	1.2

Feet

2-1, A, *silty spiculiferous intraclast-bearing biomicrosparite;* one bed 1.2 feet thick; spicules (20%) common, minor percentages of brachiopods, pelecypods, crinoids, ostracodes, and foraminifers; intraclasts contain less skeletal material than does adjacent microspar; many spicules have been replaced by microspar and pyrite; 18% terrigenous material; 25% skeletal material; 5% intraclasts.

Coffeyville terrigenous facies (base covered):

Calcareous siltstone (same description as 1-2). 2.5

Total section measured 15.0

3. SW¼ NW¼ NE¼ sec. 6, T. 25 N., R. 14 E., Washington County, in small stream bank approximately 100 yards south of the north quarter-corner. (See columnar section, page 98.)

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

3-7, D, *brachiopod-bryozoan biomicrudite;* irregular beds 3 to 5 inches thick; brachiopods (12%) and bryozoans (10%) common, traces of ostracodes, crinoid columnals, and foraminifers; coarse sparry calcite recrystallized from micrite but not skeletal material; where recrystallization has occurred, fossils are floating in sparry calcite, but adjacent to fossils is a thin zone of micrite still preserved; fossil fragments not abraded, with spines still attached to some brachiopod shells; 5% terrigenous material; 25% skeletal material (see pl. III, fig. 4). 2.0

3-6, C, *silty brachiopod bryozoan biomicrudite;* irregular beds 3 to 5 inches thick; brachiopods (10%) and bryozoans (7%) common with traces of crinoid columnals, plates, and spines, ostracodes, and foraminifers; no abrasion of skeletal material; coarse recrystallized spar; sparry calcite formed by recrystallization of micrite and skeletal material; 16% terrigenous material; 20% skeletal material. 5.0

Lower Winterset unit:

3-5, B, *fine sandstone to siltstone; sparry calcite cemented submature phosphatic glauconitic algal-bearing orthoquartzite;* one bed 6 inches thick; definite laminations due partially to algal stringers; algae (*Osagia*, 13%), crinoid fragments (10%) common, traces of bryozoans and foraminifers; sparry calcite cement; 62% terrigenous material; 25% skeletal material; 8% phosphate and trace of glauconite; skeletal fragments abraded and broken (see pl. II, fig. 5). 0.5

Coffeyville Formation.

Stark Member:

	Feet
Brown and gray clay?	0.1
3-4, *fissile black shale.*	0.4
3-3, *brown and gray clay.*	0.4
Canville Member:	0.9

3-2, sampled at top of single bed of the Canville Member; same lithology as 3-1, except terrigenous content is 20% instead of 39% as in sample from 3-1.

3-1, A, *silty bryozoan algal biosparrudite;* 39% angular quartz particles; bryozoans (15%), encrusting algae (7%) common, minor percentages of crinoid fragments, pelecypods, and gastropods; pyrite concentrated as replacements in algal and bryozoan structures; 30% skeletal material; worm burrows present; cement is fine-crystalline sparry calcite (see pl. I, fig. 5).

Coffeyville terrigenous facies (1.5 feet exposed):

Calcareous siltstone; same lithology as 1-2.	1.5
Total section measured	10.8

4. SW¼ SE¼ SW¼ sec. 9, T. 26 N., R. 14 E., Washington County, in west bank of Hogshooter Creek. This is the location of the type section of the Hogshooter Formation. (See columnar section, page 99.)

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

Upper part of the upper Winterset unit at this locality consists of a unit 11 feet thick, composed of irregularly bedded units, 1 to 4 inches thick; two samples collected from this interval. 11.0

4-9, G, *interlayered micrite, fossiliferous intrasparrudite and intrasparite;* sampled at top of interval 11 feet thick; skeletal material (crinoidal material, bryozoans, brachiopods, and ostracodes) associated with the zones characterized by sparry calcite cement; micrite zones with no skeletal material; intraclasts associated with sparry calcite-cemented zones and range from 0.66 to 1 mm in diameter; intraclasts grade from coarser at base of a zone to finer at top; small-scale channel-and-fill structures; 5% terrigenous material; 10% skeletal material; 35% intraclasts; 2% oöliths (see pl. IV, fig. 3).

4-8, F, *interlayered micrite and intrasparite;* sampled 5.5 feet below 4-9 in the interval 11 feet thick; bryozoans only skeletal material; allochems (intraclasts, fossils, and oöliths) restricted to zones characterized by sparry calcite cement; intraclasts become smaller from the bases of sparry calcite-cemented zones to the top; intraclasts 0 to 4.5 phi

	Feet
in diameter; 5% terrigenous material; 25% intraclasts; 3% fossils; 2% oöliths (see pl. IV, fig. 2).	
4-7, E, *bryozoan biomicrudite;* sampled 5.5 feet below 4-8; one bed 2 feet thick; bryozoans (18%) common, minor traces of brachiopods, ostracodes, and crinoid columnals; some pseudopellet structures formed by partial recrystallization of the micrite matrix; pseudopellets most abundant adjacent to areas illustrating coarse crystalline spar; 5% terrigenous material; 20% skeletal material; 5% pseudopellet structures.	2.0
4-6, *calcareous siltstone,* brown; contains fragments of brachiopods and crinoid columnals; blocky; directly below 4-7.	0.3
4-5, D, *crinoidal-bryozoan biomicrudite;* sampled directly below 4-6; sample collected at top of a unit 7 feet thick; bryozoans and crinoid columnals, plates, and spines (10% each for crinoidal and bryozoan material) common, minor percentages of brachiopods, ostracodes, and foraminifers; approximately 20% of the micritic material recrystallized to coarse-crystalline sparry calcite completely surrounding some fossil fragments, with fossils seemingly floating in spar; 5% terrigenous material; 25% skeletal material not abraded (see pl. IV, fig. 1).	7.0
4-4, C, *slightly silty bryozoan biomicrudite;* sampled 2 feet below 4-5 in unit 7 feet thick; bryozoans (17%) and brachiopods (5%), minor percentages of crinoid columnals and spines, ostracodes, and foraminifers; recrystallization common with 20% of micritic material recrystallized to coarse sparry calcite; remnants of micrite completely surrounded by sparry calcite; geopetal structures; 2% intraclasts; 12% terrigenous material; 25% skeletal material.	
4-3, B, *brachiopod bryozoan biomicrudite;* sampled 5 feet below 4-4 at base of unit 7 feet thick; brachiopods (10%) and bryozoans (8%) common, traces of crinoidal material, ostracodes, and foraminifers; rim cementation common within centers of skeletal fragments; recrystallization common; 9% terrigenous material; 20% skeletal material (see pl. III, fig. 6).	
4-2, *calcareous siltstone,* gray; interfingers with limestone; sampled directly beneath 4-3.	0.6
4-1, A, *brachiopod-bryozoan biomicrudite;* sampled 2 feet below 4-2; irregular beds, 6 to 8 inches thick; brachiopods (8%), bryozoans (8%) common, traces of crinoidal material, ostracodes, and foraminifers; sparry calcite as void fillings and as recrystallized spar; 9% terrigenous material; 20% skeletal material; lower 14 inches covered (see pl. III, fig. 5).	2.0
Lower Winterset unit is beneath surface of Hogshooter Creek.	
Total section measured	22.9

5. NE¼ SE¼ SW¼ sec. 9, T. 26 N., R. 14 E., Washington County, 200 yards upstream from stratigraphic section 4, in the east bank of Hogshooter Creek. (See columnar section, page 99).

Hogshooter Formation.	Feet
Upper Winterset unit (top eroded):	
5-6, F, *silty crinoidal biomicrudite;* one bed 0.5 foot thick; crinoid columnals and plates (12%) common, minor percentages of brachiopods, bryozoans, foraminifers, ostracodes, and pelecypods; recrystallization of micritic material and skeletal fragments to coarse sparry calcite common; geopetal structures in some brachiopod shells; 15% terrigenous material; 20% skeletal material; 2% intraclasts.	0.5
Gray and brown clay.	0.5
Lower Winterset unit:	
5-A-3, E, *silty phosphatic crinoidal algal biosparrudite;* crinoidal material (35%) and algal material (encrusting, 25%) common, traces of bryozoans, pelecypods, ostracodes, fusulinids, conodonts, and brachiopods; skeletal material abraded; phosphate pellets and nodules, —1 to 4 phi in diameter; 15% terrigenous material; 65% skeletal material; 5% phosphate pellets and nodules; trace of glauconite.	0.3
Coffeyville Formation.	
Lost City Member:	
5-A-2, D, *silty algal bryozoan crinoidal biosparrudite;* weathers dark yellowish brown; light olive gray on unweathered surface; 1 bed 8 to 14 inches thick, thickens toward stratigraphic section 4; encrusting algae and *Epimastopora* (algae 20% of rock), bryozoans (15%), and crinoidal material (10%) common, few foraminifers; terrigenous rock fragments, no weathering zone around rock fragments; 12% terrigenous material; 50% skeletal material; 1% rock fragments; 2% phosphate (see pl. II, fig. 2).	0.7
Coffeyville terrigenous facies:	
5-A-1, C, *fine-sand algal bryozoan biosparrudite;* sampled directly below Lost City Member; unit 5.5 feet thick; irregular beds one-half to three-quarters of an inch thick; dark yellowish orange on weathered surface and light gray to pale yellowish brown on fresh surface; encrusting algae (15%), bryozoans (10%) common, crinoidal and pelecypod fragments (each 5% of rock); flakes of black carbonaceous material throughout unit; approximately 40% terrigenous material; 40% skeletal material (abraded); traces of phosphate, glauconite, muscovite (see pl. I, fig. 1).	5.5
5-3, B, *fine-sand silty pelecypod biosparrudite;* sampled at base of unit 5.5 feet thick; fragmented pelecypod material (approximately 25%) common, minor percentages of ostra-	

Feet

codes, bryozoans, and questionable algae; skeletal material layered parallel to the bedding; approximately 30% terrigenous material; 25% skeletal material; trace of carbonaceous material.

5-2, *calcareous siltstone;* weathers dark yellowish orange, light gray on fresh surface; sampled directly below the 5.5-foot unit. 0.6

5-1, A, *fine-sand silty pelecypod biosparrudite;* sampled at top of bed 3 feet thick; weathers moderate yellowish brown, light gray on unweathered surface, pelecypod fragments (15%) common, minor percentages of encrusting algae, bryozoans, brachiopod and crinoid fragments; layering caused by stringers of algae parallel to bedding surface of unit; skeletal material abraded and fragmented; 35% terrigenous material; 20% skeletal material; trace of phosphatic material. 3.0

Total section measured 11.1

6. SW¼ SE¼ SW¼ sec. 9, T. 26 N., R. 14 E., Washington County, 100 feet south of stratigraphic section 4, in west stream bank along Hogshooter Creek. The same stratigraphic sequence is found at stratigraphic section 6 as is present at stratigraphic section 4. This section was sampled to determine any lateral variations within the upper Winterset unit in a relatively short distance. Because the thicknesses are the same as those at stratigraphic section 4, a discussion of only sampled units is presented below. (Columnar section not drawn; this section is identical in over-all appearance to 4.)

Hogshooter Formation.

Upper Winterset unit (top eroded):

6-7, G, equivalent to 4-9, *intraclast-bearing crinoidal biomicrudite;* large crinoid columnals (5%) and bryozoans (4%) with a trace of ostracodes; intraclasts 4 to 5 phi in diameter, with no distinct boundaries; limonite common along fractures in rock and associated with coarse-crystalline sparry calcite; 6% terrigenous material; 10% skeletal material (unabraded); 10% intraclasts.

6-6, F, equivalent to 4-8, *interlayered intrasparrudite and intrasparite;* traces of bryozoans, crinoids, and brachiopods; intraclasts concentrated according to size with the larger intraclasts (0-2 phi) associated with skeletal material; intraclasts range in size down to 4 phi, the smaller intraclasts resembling those in 6-7; some of the intraclasts illustrating concentric layering around the margins;

3% terrigenous material; 2% skeletal material; 60% intraclasts; 20% oöliths.

6-5, E, equivalent to 4-7, *bryozoan biomicrudite;* byrozoans (23%) common, traces of crinoidal material, ostracodes, and brachiopods; microspar formed by recrystallization of micritic material; some coarse-crystalline sparry calcite along fractures; 9% terrigenous material; 25% skeletal material; 2% intraclasts (see pl. IV, fig. 4).

6-4, D, equivalent to 4-5, *bryozoan-crinoidal biomicrudite;* bryozoans (10%), crinoids (7%), minor percentages of brachiopods; pseudoallochems (intraclast-appearing structures) formed by isolation of micritic material during recrystallization of micritic material to coarse sparry calcite; these pseudoallochems seem to be secondary in origin; 6% terrigenous material; 20% skeletal material; 10% pseudoallochems.

6-3, C, equivalent to 4-4, *intraclast-bearing crinoidal bryozoan biomicrudite;* crinoidal material (15%) and bryozoans (15%) common, brachiopods (8%) and traces of gastropods and ostracodes; some recrystallization to sparry calcite; 9% terrigenous material; 40% skeletal material; 5% intraclasts.

6-2, B, equivalent to 4-3, *brachiopod bryozoan biomicrudite;* brachiopods (19%) and bryozoans (10%) common, crinoidal material (4%); recrystallization has formed pseudoallochems similar to those in 6-4; skeletal material not abraded; 10% terrigenous material; 25% skeletal material; 3% pseudoallochems.

6-1, A, equivalent to 4-1, *bryozoan brachiopod biomicrudite;* bryozoans (15%), brachiopods (10%), and crinoidal material (3%), trace of ostracodes; one-third of rock recrystallized to coarse sparry calcite; pseudoallochems formed by isolation of micritic material during recrystallization of micrite to sparry calcite; most recrystallization in zones where skeletal material is concentrated; 5% terrigenous material; 30% skeletal material; 2% pseudoallochems.

Base of upper Winterset unit covered.

7. NE¼ NW¼ NW¼ sec. 16, T. 26 N., R. 14 E., Washington County, in quarry partly filled with water, 150 yards south of stratigraphic section 4.

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

7-6, F, approximately equivalent to 4-8, *interlayered fossiliferous micrite, intrasparite, and intrasparrudite;* sampled 4.0

Feet

at top of unit 4 feet thick; irregular beds, 0.5 to 2 inches thick; dark yellowish orange on weathered surface with abundant limonite staining; light gray on fresh surface; definite layering of micrite and intraclast-bearing zones within a single irregular bed; intraclasts from 1.5 to 4 phi in diameter; some minor cross-bedding illustrated by different sizes of intraclasts; 2% crinoids and bryozoans, trace of ostracodes; 3% terrigenous material; 35% intraclasts; 2% oöliths; most micritic material recrystallized to microspar.

7-5, E, approximately equivalent to 4-7, *interlayered fossiliferous intrasparite and intrasparrudite;* sampled at base of one bed 2 feet thick; excellent examples of coarse intraclastic rock (intraclasts — 0 to 5 phi in diameter) overlain by a zone containing much smaller intraclasts; bryozoans (4%), crinoidal material (4%), traces of foraminifers and brachiopods; some of larger intraclasts similar to grapestone lumps described by Illing (1954); 4% terrigenous material; 10% skeletal material; 60% intraclasts; 2% oöliths. 2.0

Calcareous siltstone, gray. 0.1

7-4, D, approximately equivalent to 4-5, *interlayered fossiliferous micrite, intrasparite, and intrasparrudite;* sampled at the top of unit 7 feet thick; traces of bryozoans and ostracodes; definite layers of intraclastic material interlayered with zones of slightly fossiliferous micrite; some chert replacement along fractures; some recrystallization of micrite to microspar; 8% terrigenous material; trace of skeletal material; 35% intraclasts; 1% oöliths. 7.0

7-3, C, *interlayered slightly fossiliferous micrite and intrasparite;* sampled 2 feet below 7-4, and still in the unit 7 feet thick; small percentages of crinoids, bryozoans, and foraminifers; intraclasts reduced in number and size as compared to those in the above-mentioned samples; some recrystallization of micrite to microspar; intraclasts concentrated in distinct layers; microchanneling and cross-bedding; 8% terrigenous material; 5% skeletal material; 15% intraclasts.

7-2, B, *interlayered fossiliferous micrite and intrasparite;* sampled at base of massve unit 7 feet thick; minor percentages of brachiopods, bryozoans, ostracodes, foraminifers, and crinoids; intraclasts concentrated in definite layers; coarse sparry calcite along fractures; 4% terrigenous material; 10% skeletal material; 10% intraclasts; 1% oöliths.

Calcareous siltstone, gray. 0.1

7-1, A, *interlayered fossiliferous micrite and intrasparite;* 0.5

Feet

sampled directly beneath calcareous siltstone and just above water level in quarry; minor percentages of bryozoans, crinoidal material, brachiopods, and ostracodes; 20% of rock recrystallized to coarse sparry calcite; intraclasts in definite layers; rock was fractured soon after deposition, as intraclasts are not rounded and were probably not transported any large distance; layers of micrite apparently were fractured and then coarse sparry calcite was precipitated in the fracture voids as rim cementation is present; micrite zones overlie fractured layers; 3% terrigenous material; 10% skeletal material; 25% intraclasts; 2% oöliths (see pl. IV, fig. 5).

Covered by water in quarry.

Total section measured 13.7

8. NW¼ SW¼ NE¼ sec. 31, T. 26 N., R. 14 E., Washington County, in east bank of small stream approximately 75 yards north of stratigraphic section 2. (See columnar section, page 98.)

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

8-3, C, *silty intraclast-bearing bryozoan biomicrudite;* sampled at top of partly covered interval 5.5 feet thick; irregular beds 3 to 5 inches thick; bryozoans (15%) common, traces of brachiopods, crinoidal material, ostracodes, and foraminifers; majority of intraclasts have surrounding band of limonite; intraclasts seem to have suffered weathering, and may represent calclithitic material; approximately 30% of the rock recrystallized to microspar or coarse-crystalline sparry calcite; micritic matrix and fossils recrystallized to microspar; intraclasts — 1 to 2 phi in diameter; 12% terrigenous material; 20% skeletal material; 10% intraclasts. 5.5

8-2, B, *interlayered fossiliferous micrite and intraclast-bearing bryozoan biosparrudite;* sampled at top of irregularly bedded unit 5.5 feet thick; beds 2 to 3 inches thick; bryozoans (20%) common, minor percentages of brachiopods, crinoids, ostracodes, and foraminifers; within individual beds are interlayers of intraclast-bearing biosparrudites and micrite; micrite layers contain much less fossil material than do intraclastic layers; approximately 10% of the rock recrystallized to sparry calcite; 7% terrigenous material; 30% skeletal material; 10% intraclasts. 5.5

8-1, A, *bryozoan brachiopod biomicrudite;* sampled approximately 5.5 feet above the base of the upper Winterset unit; sample is approximately equivalent to 2-6; base of unit covered; bryozoans (15%), brachiopods (5%), minor 5.5

	Feet
percentages of crinoidal material, pelecypods, and ostracodes, irregular beds 4 to 7 inches thick; some recrystallization of micrite to microspar and coarse sparry calcite; geopetal structures inside shell fragments; 8% terrigenous material; 30% unabraded skeletal material.	
Base of upper Winterset unit covered.	
Total section measured	16.5

9. NW¼ NE¼ NW¼ sec. 34, T. 24 N., R. 13 E., Washington County, in west side of railroad cut approximately 300 feet south of the east-west section-line road. (See columnar section, facing page 56.)

	Feet
Hogshooter Formation.	
Reef facies of the Winterset Member (top eroded):	
9-3, D, *phosphatic algal crinoidal biosparrudite;* one bed 1 foot thick; weathers grayish orange, light olive gray on fresh surface; encrusting algae (*Osagia*, 30%) and crinoidal material (20%) with minor percentages of bryozoans, gastropods, pelecypods, brachiopods, and ostracodes; skeletal material abraded; gastropod shells filled with phosphatic material; 9% terrigenous material; 60% skeletal material; 5% phosphatic material; trace of glauconite.	1.0
Reef talus interval composed primarily of gray clay; interval partly covered.	2.8
9-A-2, C, *phosphatic algal crinoidal biosparrudite;* one bed 0.7 foot thick; weathers same as 9-3; encrusting algae (*Osagia*, 30%), crinoids (20%), minor percentages of bryozoans, brachiopods, conodonts, gastropods, and pelecypods; larger phosphate nodules composed of numerous small, round phosphate particles; 9% terrigenous material; 60% fossil material; 7% phosphate; trace of glauconite (see pl. V, fig. 5).	0.7
Coffeyville Formation.	
Lost City member:	
9-A-1, B, *silty algal pelecypod biomicrudite;* one bed 0.5 foot thick; algae (*Osagia* and *Epimastopora*, 20%), pelecypods (10%), minor percentages of brachiopods, gastropods, bryozoans, fusulinids, other foraminifers, crinoids, and ostracodes; fragmented fossil material in distinct layers where terrigenous material is concentrated; foraminifers with surrounding weathered zone; worm burrows present; 21% terrigenous material; 40% skeletal material; slight trace of phosphate (see pl. II, fig. 3).	0.5
Coffeyville terrigenous facies:	
9-1, A, *fine sandstone to siltstone; sparry calcite-cemented*	1.6

	Feet
submature pelecypod bryozoan-bearing orthoquartzite; irregular beds 0.5 to 3 inches thick; pelecypods (8%), bryozoans and algae (each 3%), traces of brachiopods and crinoidal material; larger fossil fragments parallel to bedding in individual beds; skeletal material fragmental with much abrasion; 55% terrigenous material; 15% skeletal material (see pl. I, fig. 2).	
Covered.	
Total section measured	6.6

10. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, in east bank of South Fork of Double Creek, 75 yards northwest of the old high school gymnasium at Ramona, Oklahoma. (See columnar section, facing page 56.)

Hogshooter Formation.	Feet
Reef facies (top covered):	
10-7, G, *partially recrystallized crinoidal bryozoan biosparrudite;* irregular beds 2 to 3 inches thick; recrystallized crinoidal material (20%), bryozoans (13%), algae (6%), trace of brachiopods; the rock mostly recrystallized to sparry calcite; original cement apparently sparry calcite; no evidence of micritic material; 7% terrigenous material; 40% skeletal material; 2% limonite; trace of phosphate.	3.5
10-6, F, *silty partially recrystallized crinoidal algal biosparrudite;* irregular beds 2 to 3 inches thick; recrystallized crinoidal material (35%), encrusting algae (12%), bryozoans (10%), trace of brachiopods; no evidence of micritic material; 12% terrigenous material; 60% skeletal material; trace of phosphatic material.	2.0
10-5, E, *silty partially recrystallized bryozoan algal crinoidal biosparrudite;* irregular beds 2 to 3 inches thick; bryozoans (20%), encrusting algae (20%), crinoidal material (10%), traces of pelecypods, brachiopods, and foraminifers; foraminifers with weathering rim surrounding the tests; intraclasts of micritic material scattered through the rock; bryozoan material not too fragmented or abraded; micritic material possibly derived from reef core approximately 200 yards east; this may represent a poorly washed unit; 13% terrigenous material; 50% skeletal material.	4.5
10-4, D, *crinoidal bryozoan biosparrudite;* irregular beds 2 to 3 inches thick; crinoidal material (50%), bryozoans (13%), minor percentages of brachiopods and algae, traces of ostracodes, foraminifers, and arthropod fragments; skeletal material fragmented and abraded; small percentage of micrite intraclasts; 5% terrigenous material; 70% skeletal material; trace of intraclasts and phosphatic material.	1.0

Feet

10-3, C, *phosphatic intraclast-bearing crinoidal algal biosparrudite;* one bed 1 foot thick; crinoidal material (50%), encrusting algae (10%), bryozoans and gastropods (each 3%), traces of brachiopods, foraminifers, and ostracodes; unit may represent a poorly washed sequence as several large accumulations of micritic material are present; 7% terrigenous material: 70% skeletal material; 8% phosphatic material (nodules and fillings in gastropod shells); 3% micritic intraclasts (see pl. V, fig. 6). 1.0

10-2, B, *phosphatic crinoidal biosparrudite;* sampled at top of unit 5 feet thick; crinoidal material (60%), brachiopods (5%), minor percentages of bryozoans, algae, pelecypods, gastropods, and conodonts; terrigenous material confined mostly to the phosphate particles; 7% terrigenous material; 70% skeletal material; 8% phosphatic material; trace of glauconite. 5.0

10-1, A, *phosphatic crinoidal algal biosparrudite;* sampled at base of unit 5 feet thick; crinoidal material (30%), encrusting algae (10%), bryozoans (8%), with pelecypods and brachiopods (5% each), gastropods (4%), trace of conodonts; phosphatic material as individual particles and as fillings in gastropod shells; larger phosphate nodules composed of numerous smaller phosphate particles; 9% terrigenous material; 65% skeletal material; 8% phosphate; trace of glauconite.

Coffeyville Formation (5 feet exposed).

Coffeyville terrigenous facies:

Calcareous siltstone, gray, thin-bedded. 5.0

Covered.

Total section measured 22.0

11. SW¼ SE¼ SE¼ sec. 16, T. 24 N., R. 13 E., Washington County, in roadcut on north side of east-west section-line road. (See columnar section, facing page 56).

Hogshooter Formation. Feet

Reef facies (top eroded):

11-3, D, *intraclast-bearing bryozoan crinoidal biomicrudite;* one bed; bryozoans (20%), crinoidal material (4%), minor percentages of pelecypods, brachiopods, foraminifers, ostracodes, and encrusting algae; much of micritic material recrystallized to microspar; intraclasts confined to areas where larger skeletal material is also present; some coarse sparry calcite as fracture filling material; 13% terrigenous material; 30% skeletal material; 7% intraclasts; 2% limonite. 1.1

Brown clay. 0.1

Crinoidal algal biosparrudite; crinoidal and algal material 1.2

	Feet
abundant, with bryozoans common and traces of brachiopods, gastropods, and ostracodes; similar in lithology to 11-A-1.	
Brown clay and shale.	0.3
Bryozoan crinoidal biomicrudite; similar in lithology to 11-3.	0.6
Brown clay and shale.	0.6
11-2, C, *intraclast-bearing bryozoan crinoidal biomicrudite;* one bed; bryozoans (20%); crinoids (12%), brachiopods (6%), traces of algae (encrusting), foraminifers, pelecypods, and ostracodes; intraclasts restricted to zones where larger skeletal fragments occur; 6% terrigenous material; 40% skeletal material; 3% intraclastic material; trace of limonite.	0.3
Brown and gray clay and shale.	0.2
11-A-1, B, *silty phosphatic crinoidal algal biosparrudite;* one bed; crinoidal material (30%), encrusting algae (*Osagia*, 17%), bryozoans (15%), minor percentages of brachiopods, ostracodes, and gastropods; phosphate as fillings in gastropod shells and as individual particles; 10% terrigenous material; 65% skeletal material; 5% phosphate; trace of glauconite.	0.4
Coffeyville Formation (1.2 feet exposed).	1.2
Coffeyville terrigenous facies:	
11-1, A, *highly terrigenous fine-sand-bearing pelecypodal algal biosparrudite;* sampled directly beneath 11-A-1; the more calcareous development directly below 11-A-1 is 0.5 foot thick and possibly represents a lateral facies of the Lost City Member 1 mile south of this stratigraphic section; pelecypods (10%), encrusting algae (10%), bryozoans (6%), brachiopods (3%), trace of crinoids; larger skeletal fragments parallel; shell fragments abraded and fragmented; 49% terrigenous material; 30% skeletal material (see pl. I, fig. 3).	
Covered.	
Total section measured	6.0

12. NW¼ SE¼ SW¼ sec. 10, T. 23 N., R. 13 E., Washington County, in stream channel of Bevan Creek. (See columnar section, page 99.)

	Feet
Nellie Bly Formation (top eroded).	
Calcareous siltstone; light gray and thinly bedded with beds approximately 0.5 inch thick; some thin beds of black shale 5 to 8 feet above base of the formation.	10.0

	Feet
Hogshooter Formation.	
Upper Winterset unit:	
12-2, B, *silty intraclast-bearing bryozoan biomicrudite;* irregularly bedded; bryozoans (20%), crinoidal material (7%), brachiopods (5%), traces of ostracodes and foraminifers; 20% of rock recrystallized to coarse sparry calcite; some evidence of void fillings (rim cementation); intraclasts angular and apparently subjected to little transportation; 14% terrigenous material; 35% skeletal material; 4% intraclasts.	1.5
Lower Winterset unit:	
12-1, A, *silty phosphatic algal crinoidal bryozoan biosparrudite;* encrusting algae (25%), crinoidal material (15%), bryozoans (14%), pelecypods (5%), traces of conodonts, brachiopods, ostracodes, gastropods, foraminifers, and arthropod fragments; pyrite concentrated in algal structures and bryozoan fragments; 14% terrigenous material; 65% skeletal material; 5% prosphatic material; trace of glauconite; 2 to 3 % pyrite; trace of intraclasts.	1.0
Coffeyville Formation (not measured).	
Coffeyville terrigenous facies:	
Calcareous siltstone, light gray, thin-bedded.	
Total section measured	12.5

13. SW¼ NE¼ NW¼ sec. 10, T. 24 N., R. 13 E., Washington County, in man-made trench in pasture a quarter of a mile south of the east-west section-line road. (See columnar section, page 99.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top eroded):	
13-2, B, *silty brachiopod biomicrudite;* brachiopods (14%), traces of ostracodes and crinoidal material; irregular beds 2 to 4 inches thick; intraclasts present; skeletal material only slightly fractured and unabraded; 14% terrigenous material; 15% skeletal material; 3% intraclasts; 10% recrystallized spar; trace of limonite.	1.5
Gray and brown clay.	0.1
Lower Winterset unit:	
13-1, A, *silty phosphatic crinoidal algal biosparrudite;* one bed; crinoidal material (35%), encrusting algae (12%), bryozoans (8%), pelecypods (5%), gastropods (3%), minor percentages of arthropod fragments, conodonts, ostracodes, *Girvanella*-type algae; approximately 20% of the cement has been replaced by poikilitic barite; 15% terrigenous material; 70% skeletal material; 2% pseudoöliths;	0.8

Feet

3% phosphatic material present as individual particles and fillings in gastropod shells; trace of glauconite; 2 to 3% replacement barite; trace of limonite (see pl. II, fig. 6).

Coffeyville Formation (1 foot exposed).

Coffeyville terrigenous facies:

Calcareous siltstone, gray, thinly bedded. 1.0

Total section measured 3.4

14. SE¼ NE¼ NW¼ sec. 10, T. 28 N., R. 15 E., Nowata County, on side of small hill a quarter of a mile south of the east-west section-line road. (See columnar section, page 101.)

Hogshooter Formation Feet

Possible reef facies (top eroded):

14-4, D, *partially recrystallized intraclast-bearing bryozoan biomicrosparrudite;* sampled at top of partially covered sequence 4.5 feet thick; irregular beds 2 to 5 inches thick; bryozoans (35%), brachiopods (8%), crinoids (6%), trace of ostracodes; skeletal material fragmented; approximately 10% of rock recrystallized to coarse sparry calcite; some recrystallization of micrite to microspar; 7% terrigenous material; 50% skeletal material; 15% intraclasts; trace of limonite; this rock nearly identical to that at 11-3. 4.5

14-3, C, *fine-sand phosphatic crinoidal algal biosparrudite;* one bed; undulating bedding surfaces; crinoidal material (25%), encrusting algae (10%), brachiopods (5%), bryozoans (3%), minor percentages of gastropods and foraminifers; definite zones where terrigenous material is concentrated; no graded bedding; crinoidal material abraded; phosphatic material as fillings in gastropod shells and as nodules composed of smaller particles; 17% terrigenous material; 45% skeletal material; 3% phosphatic material; traces of glauconite and limonite; 3% intraclasts composed of micritic material. 0.5

14-2, B, *phosphatic crinoidal algal biosparrudite;* sampled at top of irregularly bedded unit 1 foot thick; crinoidal material (45%), encrusting algae (20%), bryozoans (3%), brachiopods (2%); crinoidal material abraded; algae associated with a limonite stain; 7% terrigenous material; 70% skeletal material; 8% phosphatic material; traces of glauconite and limonite. 1.0

14-1, A, *fine-sand partially recrystallized phosphatic crinoidal biosparrudite;* sampled at base of above-mentioned unit 1 foot thick; crinoidal material (22%), brachiopods (3%), gastropods and pelecypods (3% each), and a trace of encrusting algae; most fossil material recrystallized; gastropods filled with glauconite and phosphate; 26%

Feet

terrigenous material; 30% skeletal material; 3% phosphatic material; trace of glauconite.

Base is covered, but this may be lowermost limestone unit present, and it is possibly overlying the Coffeyville Formation.

Total section measured 6.0

15. SE¼ SW¼ SW¼ sec. 14, T. 29 N., R. 15 E., Nowata County, in north side of railroad cut. (See columnar section, page 99.)

Hogshooter Formation. Feet

Lower Winterset unit (Upper Winterset unit has been eroded):

15-2, B, *sandy phosphatic crinoidal biosparrudite;* one bed 1 foot thick; crinoidal material (20%), minor percentages of gastropods, conodonts, bryozoans, brachiopods, foraminifers, arthropod fragments, and algae; rock fragments of terrigenous material; skeletal material abraded and fragmented; 44% terrigenous material; 30% skeletal material; 8% phosphatic material; 2% glauconite; 1% terrigenous rock fragments. 1.0

Coffeyville Formation.

Stark Member (base is covered):

Gray and brown clay. 0.7

Black fissile shale. 0.3

15-1, A, *pyritic limonitic silty microspar concretion;* concretions localized in a zone approximately 1 foot below the lower Winterset; elongated in the direction of bedding; no skeletal material; faint indication of bedding through concretions; 5% silty terrigenous material; 10% pyrite; trace of limonite. 0.4

Black fissile shale. 5.0

Base covered.

Total section measured 7.4

16. SW¼ SW¼ SW¼ sec. 21, T. 29 N., R. 15 E., Nowata County, in east roadcut of north-south section-line road. (See columnar section, page 99.)

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

16-5, D, *intraclast-bearing bryozoan brachiopod biomicrudite;* irregularly bedded with each bed approximately 3 1.1

	Feet
inches thick; bryozoans (15%), brachiopods (10%), crinoids (8%), minor percentages of pelecypods and foraminifers; larger skeletal fragments and intraclasts associated in the same zones; definite pore-filling sparry calcite; skeletal material mostly unabraded; 6% terrigenous material; 35% skeletal material; 10% intraclasts.	
Brown and gray clay and shale with nodular limestones.	0.7
16-4, C, *brachiopod algal bryozoan biomicrudite;* one bed with undulating bedding planes; brachiopods (20%), algae (similar to *Anchicodium* and *Girvanella,* 15%), bryozoans (10%), crinoids (8%), traces of pelecypods and ostracodes; some parallelism of larger skeletal material; skeletal material fractured but not abraded; 9% terrigenous material; 55% skeletal material; trace of limonite.	0.4
Brown and gray shale.	0.4
Brachiopod biomicrudite; similar in lithology to 16-4.	0.3
16-3, B, *gray and brown shale with limestone nodules;* nodules are *brachiopod biomicrudite;* irregular lenses of limestone; not persistent; brachiopods (20%), minor percentages of bryozoans, crinoids, and questionable algae; skeletal material unabraded; recrystallization of micritic material to fine- and coarse-crystalline sparry calcite; 9% terrigenous material; 25% fossil material (see pl. IV, fig. 6).	1.5
Lower Winterset unit:	
16-2, A, *fine-sand phosphatic crinoidal algal biosparrudite;* one bed; crinoidal material (27%), encrusting algae (10%), minor percentages of bryozoans, gastropods, conodonts, pelecypods, arthropod fragments, and ostracodes; phosphate occurs as individual particles and as fillings in gastropod and ostracode shells; 26% terrigenous material; 40% skeletal material; 3% pseudoöliths; 4% phosphatic material; trace of glauconite and limonite.	0.6
Coffeyville Formation (2.0 feet measured):	
Coffeyville terrigenous facies:	
Gray and brown clay.	0.4
16-1, *coal.*	0.05
Calcareous siltstone, gray, thin-bedded.	1.5
Total section measured	6.95

17. SE¼ NE¼ SE¼ sec. 32, T. 29 N., R. 15 E., Nowata County, in small creek bank 20 yards west of the north-south section-line road. (See columnar section, page 100.)

Hogshooter Formation.

	Feet
Upper Winterset unit (top covered):	
17-3, C, *bryozoan-algal biomicrudite;* sampled at top of covered interval 6.0 feet thick; thin beds 2 to 4 inches thick; bryozoans (20%), possible algal structures in form of coarse sparry calcite accumulations (14%), crinoids (4%), minor percentages of brachiopods, ostracodes, and foraminifers; possible algal material showing some parallelism; 9% terrigenous material; 40% skeletal material, fragmented but unabraded.	6.0
17-1, B, *silty, bryozoan biomicrudite;* unit is 15 inches thick with 3 irregular beds 3 to 8 inches thick, bryozoans (35%), brachiopods and crinoidal material (each 7%), traces of ostracodes, pelecypods, and arthropod fragments; skeletal material fractured; approximately 5% of rock recrystallized to coarse sparry calcite; 12% terrigenous material; 50% skeletal material; slight trace of glauconite; 2% limonite.	1.2
Lower Winterset unit:	
17-2, A, *fine-sand phosphatic crinoidal algal biosparrudite;* one bed; crinoidal material (35%), encrusting algae and *Girvanella* (15%), minor percentages of bryozoans, conodonts, brachiopods, pelecypods, gastropods; gastropods filled with phosphatic material; some shell fragments burrowed by algae; 17% terrigenous material; 65% skeletal material; 6% phosphate; 2% glauconite; 2% pseudoöliths; 1% intraclasts.	0.7
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Calcareous siltstone; gray and brown, thin-bedded; 1 foot measured.	1.0
Not measured.	
Total section measured	8.9

18. SE¼ NW¼ SE¼ sec. 18, T. 28 N., R. 15 E., Nowata County, in south bank of California Creek; excellent exposure. (See columnar section, page 100.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top eroded):	
18-6, F, *partially recrystallized and fractured brachiopod bryozoan biomicrudite;* irregular beds 3 to 5 inches thick; brachiopods (18%), bryozoans (17%), crinoids (3%), minor percentages of ostracodes and foraminifers; rock fractured shortly after deposition as fossil fragments have been fractured and offset slightly; 20% of rock composed of coarse-crystalline sparry calcite; spar concentrated around	3.0

	Feet
fractured areas; geopetal structures; some slight amount of parallelism of larger fossil fragments; 9% terrigenous material; 40% skeletal material; 2% intraclasts; trace of limonite.	
18-5, E, *fractured silty bryozoan brachiopod biomicrudite;* sampled at base of unit 3 feet thick; bryozoans (25%), brachiopods (7%), crinoidal material (5%), minor percentages of ostracodes, foraminifers, and possible algae; sparry calcite associated with fractured areas; 10% terrigenous material; 40% skeletal material; 5% intraclasts; trace of limonite.	
Gray and brown shale.	0.1
Bryozoan brachiopod biomicrudite; similar in lithology to 18-5.	0.5
Gray shale.	0.4
18-4, D, *fractured brachiopod bryozoan biomicrudite;* one bed 2 feet thick; bryozoans (30%), brachiopods (15%), minor percentages of crinoids, ostracodes, and possible algae; 20% of rock recrystallized to sparry calcite; fragments of unrecrystallized micrite and fossil material completely surrounded by coarse sparry calcite; some of spar possibly crystallized in fractures; geopetal structures; slight parallelism of fractured zones; 6% terrigenous material; 50% skeletal material; 4% intraclasts.	2.0
Gray clay and shale.	0.3
Brachiopod bryozoan biomicrudite; similar to 18-4.	0.4
Gray and brown clay.	0.7
Brachiopod bryozoan biomicrudite; similar to 18-4.	0.3
Gray and brown clay.	0.1
Brachiopod bryozoan biomicrudite; similar to 18-4.	0.3
Gray and brown clay.	0.2
Brachiopod bryozoan biomicrudite; similar to 18-4, irregularly bedded.	0.6
Gray and brown clay.	0.5
18-3, C, *brachiopod bryozoan biomicrudite;* irregularly bedded; brachiopods (20%), bryozoans (10%), crinoids (3%), traces of ostracodes and algae; parallelism of larger skeletal material; 10% recrystallized to coarse sparry calcite; 7% terrigenous material; 35% skeletal material; 2% intraclasts; trace of limonite.	0.5
Gray and brown clay with limestone nodules similar to 18-3.	0.6
Lower Winterset unit:	
18-2, B, *fine-sand phosphatic crinoidal algal biosparrudite;*	1.2

Feet

irregularly bedded near top; crinoidal material (40%), encrusting algae (15%), bryozoans (7%), brachiopods (5%), minor percentages of gastropods, pelecypods, conodonts, and arthropods; several areas of concentrated terrigenous material; large skeletal fragments parallel; 11% terrigenous material; 70% skeletal material; 5% phosphatic material; trace of glauconite; 2% intraclasts.

Coffeyville Formation.

Coffeyville terrigenous facies:

Gray silty shale. 1.0

18-1, A, *fine sandstone to siltstone: sparry calcite-cemented submature nonfossiliferous orthoquartzite;* poikilitic sparry calcite cement; well-sorted terrigenous material; bedding present; 76% terrigenous material; 24% sparry calcite cement. 2.0

Covered.

Total section measured 14.7

19. SE¼ NE¼ SW¼ sec. 18, T. 27 N., R. 15 E., Nowata County, in small stream bank (south bank) 50 yards south of oil-lease road and east of relatively large hill with oil-storage tanks at base. (See columnar section, page 100.)

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

19-5, E, *fractured brachiopod biomicrudite;* sampled at top of partly covered sequence 5 feet thick; irregular beds 2 to 5 inches thick; impossible to determine if shale beds are present; brachiopods (15%), bryozoans (4%), trace of crinoidal material; spines attached to several brachiopod shells; little to no abrasion of skeletal material; pseudopellet structure possibly due to recrystallization of micritic material or possibly representing algal structure; rock fractured and recrystallized to coarse sparry calcite along fractures; 4% terrigenous material; 20% skeletal material; 2% intraclasts; 15% pseudopellet structures. 5.0

19-4, D, *silty brachiopod biomicrudite;* sampled at base of partly covered unit 5 feet thick; brachiopod shells and spines (40%), bryozoans (5%), crinoids (4%); some of larger skeletal fragments parallel; zones where micrite recrystallized to microspar, skeletal material also recrystallized in these same zones; limonite associated with microspar; spines still attached to shell fragments; 11% terrigenous material; 50% skeletal material; trace of limonite.

Lower Winterset unit:

19-3, C, *fine-sand phosphatic crinoidal biosparrudite;* 0.4

	Feet
crinoidal material (30%), brachiopods (5%), pelecypods (3%), traces of arthropod fragments, worm burrows, conodont fragments, and encrusting algae; skeletal material fragmental, and crinoidal material deeply abraded; slight indication of bedding; 32% terrigenous material; 40% skeletal material; traces of intraclasts, oölites; 5% phosphatic material; trace of glauconite.	
Coffeyville Formation.	
Stark Member:	
Gray and brown clay.	0.1
Black fissile shale.	0.4
19-2, B, *pyrite-bearing microspar and sparry calcite concretions;* concretions grade into a solid limestone layer 5 inches thick; ostracodes and brachiopod spines (traces) in concretions; high organic content; concretions black; organic material impregnated with microspar and sparry calcite.	0.4
Black fissile shale; conodont fragments along bedding surfaces.	1.2
Gray and brown clay.	1.5
Canville Member:	
19-1, A, *fine-sand pyritic limonitic bryozoan algal biomicrudite;* one bed with undulating beddng planes, 3 to 8 inches thick; bed disappears southeastward, and unit becomes nodular, eventually disappearing into the calcareous siltstone of the Coffeyville terrigenous facies; bryozoans (10%), encrusting algae (8%), pelecypods (3%), brachiopods (3%), gastropods (3%), traces of ostracodes and crinoidal material; pyrite common as a replacement in bryozoan and gastropod material; much small fragmental skeletal material; pyrite present in algal encrustations; some parallelism of larger skeletal material; 26% terrigenous material; 30% skeletal material; 1% pyrite; 2% limonite; trace of glauconite (see pl. I, fig. 6).	0.3-0.6
Coffeyville terrigenous facies:	
Calcareous siltstone, and gray and brown clay; to southeast, Canville Member facies into this lithology.	1.5
Not measured.	
Total section measured	11.1

20. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, in south stream bank of the South Fork of Double Creek directly below and adjacent to the Santa Fe railroad trestle. (See columnar section, facing page 56; also fig. 7.)

Hogshooter Formation. Feet

Reef core (top eroded):

20-6, F, *partially recrystallized bryozoan biomicrudite;* sampled at top of reef core; bryozoans (15%), algae (7%), crinoidal material (5%), gastropods (2%); algae is indistinct type which recrystallized readily to coarse sparry calcite; much of the rock recrystallized to microspar and fine-crystalline sparry calcite; recrystallized areas grade into micrite; nearly all bryozoan material recrystallized to sparry calcite; no bedding; some pore fillings by coarse sparry calcite; 9% terrigenous material; 30% skeletal material; traces of chert and dolomite (see pl. V, fig. 4). 3.5

20-5, E, *crinoidal biomicrudite and biosparrudite;* faint bedding almost entirely of crinoidal material; crinoidal material (spines, plates, columnals, 65%), bryozoans (5%), pelecypods (5%), brachiopods and gastropods (2% each), trace of ostracodes; most of cement is fine-crystalline sparry calcite with possible micrite (limonite obscures some of the matrix material); areas of coarse-crystalline sparry calcite; most of the spar is twinned sparry calcite; 4% terrigenous material; 80% skeletal material; 4% limonite; trace of phosphate (see pl. V, fig. 3). 1.0

20-4, D, *algal biolithite;* reef core without bedding; 70% of rock composed of *Solenopora*-type algae, with radiating structures; structures polygonal in cross section; bryozoans (5%), crinoidal material (5%), brachiopods and gastropods (2% each); 7% terrigenous material; 85% skeletal material; 1% limonite; traces of glauconite and dolomite (see pl. V, figs. 1, 2). 5.0

20-3, C, *algal? biolithite;* no bedding; black; highly organic; organic material disseminated through rock and obscures the structures in the rock; vague indication of algal structure through rock; no other skeletal material; 6% terrigenous material; organic material and algal structures composing the remainder of the rock. 1.5

20-2, B, *intraclast-bearing recrystallized micrite and fossiliferous intrasparrudite;* one bed; excellent contact between two limestone types; skeletal material and intraclasts restricted to one zone; smaller intraclasts scattered through the micrite (recrystallized to microspar) zone; no fossils in micritic zone; small percentages of brachiopods, ostracodes, crinoids, and gastropods in intraclastic zone; intraclasts extremely dark with a high organic content; intraclasts poorly sorted; 5% terrigenous material; 10% skeletal material; 30% intraclasts. 0.5

Coffeyville Formation.

Lost City Member: reef core rests on this member; this unit has been warped downward, and the dip on this unit directly below the core ranges from 35 to 40 degrees.

	Feet
20-1, A, *silty partially recrystallized algal brachiopod biomicrudite;* one bed; encrusting algae (25%), brachiopods (8%), pelecypods and crinoidal material (6% each), bryozoans (5%); most of the matrix now microspar; recrystallization of micrite matrix; some areas of micrite still existing; much of skeletal material recrystallized; 11% terrigenous material; 50% skeletal material; 3% intraclasts; 5% limonite.	2.3
Total section measured	13.8

22. SE¼ SE¼ NE¼ sec. 14, T. 29 N., R. 15 E., Nowata County, in west roadcut of north-south section-line road and on small hill just west of road. This section is partly covered. (See columnar section, page 102.)

Hogshooter Formation.	Feet
Possible reef facies (top eroded):	
22-5, *brachiopod biomicrudite;* similar in lithology to 22-3, sampled at top of the reef facies; irregular beds 2 to 5 inches thick.	2.0
22-4, *brachiopod biomicrudite;* similar in lithology to 22-3, but with more brachiopod material; productid-type brachiopods with abundant crinoidal material (large columnals, rudite-sized); irregularly bedded units 2 to 5 inches thick.	4.5
22-3, C, *fractured partially recrystallized intraclast-bearing brachiopod biomicrudite;* irregularly bedded; brachiopods (15%), crinoids (5%), bryozoans (5%); rock fractured; intraclasts most abundant along fractured zones, possibly a result of fracturing; intraclasts not rounded or sorted; 20% of rock coarse-crystalline sparry calcite; recrystallization spar or replacement spar; fractures parallel; 7% terrigenous material; 25% skeletal material; 15% intraclasts.	1.0
22-2, B, *partially recrystallized phosphatic glauconitic crinoidal biosparrudite;* irregular beds 1 to 3 inches thick; crinoidal material (50%) *Girvanella*-type algae (5%), arthropod fragments (5%), minor percentages of pelecypods, bryozoans, brachiopods, conodonts, and foraminifers; 9% terrigenous material; 65% skeletal material; 5% phosphatic material; 3% glauconite; much skeletal material and cement recrystallized to sparry calcite.	7.0
22-1, A, *recrystallized phosphatic crinoidal bryozoan biosparrudite;* one bed 11 inches thick; crinoidal material (20%), bryozoans (8%), foraminifers (3%), shell fragments (3%); rock mostly recrystallized; difficult to determine original cement; much skeletal material originally present in this rock possibly destroyed by recrystallization;	0.9

Feet

8% terrigenous material; 35% skeletal material; 5% phosphatic material; 1% glauconite; 5% limonite.

Base covered; may be lowermost unit in Hogshooter Formation, or may be additional beds below 22-1.

Total section measured 15.4

23. SW¼ NE¼ NE¼ sec. 21, T. 29 N., R. 15 E., Nowata County, in small stream bank approximately 30 yards south of railroad trestle. (See columnar section, page 101.)

Hogshooter Formation. Feet

Possible reef facies (base covered, top uncertain):

Covered.

23-3, *highly terrigenous crinoidal biosparrudite;* dark gray; thin beds 0.5 to 1 inch thick; crinoidal material abraded; trace of bryozoans; 40% terrigenous material (mostly coarser than 4.5 phi); traces of conodonts and fish teeth; minor percentages of phosphate and glauconite; unit possibly represents the lowermost unit of the Nellie Bly Formation (flaggy blue limestones overlie the Hogshooter Formation in the vicinity of Coffeyville, Kansas; Moore, 1935, p. 98). 0.5

Covered interval (probably shale). 1.0

23-2, *crinoidal bryozoan algal biosparrudite;* one bed 10 inches thick; crinoidal material (15%), bryozoans (15%), encrusting algae (15%), minor percentages of brachiopods, foraminifers, and fish teeth; sparry calcite cement; 8% terrigenous material; 50% skeletal material; 5% limonite. 0.9

23-1, A, *intraclast-bearing bryozoan algal biomicrudite;* one bed 6 inches thick; large skeletal fragments; skeletal material unabraded; bryozoans (30%), encrusting algae (15%), crinoidal material (10%), minor percentages of brachiopods and gastropods; much of micrite matrix recrystallized to coarse sparry calcite; 7% terrigenous material; 60% skeletal material; 5% intraclasts. 0.5

23-4, *intraclast-bearing crinoidal bryozoan algal biosparrudite and biomicrudite;* only upper 3 inches exposed above water level; crinoidal material (15%), bryozoans (10%), encrusting algae (5%), minor percentages of gastropods, brachiopods, ostracodes and fish teeth; cement or matrix mostly microspar with some possible sparry calcite cement; 9% terrigenous material; 35% skeletal material; 15% intraclasts. 0.2

Covered.

Total section measured 3.1

24. NE¼ NE¼ NE¼ sec. 16, T. 28 N., R. 15 E., Nowata County, in small stream bank 100 yards south of the main road to Wann, Oklahoma. (See columnar section, page 100.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top eroded):	
24-2, B, *fractured and partially recrystallized brachiopod biomicrudite;* irregular beds 3 to 5 inches thick; brachiopods (25%), crinoids (8%), minor traces of bryozoans and fragments; recrystallization along fractured areas; intraclasts concentrated along fractured zones; 8% terrigenous material; 35% skeletal material; 3% intraclasts; trace of limonite; brachiopod fragments with spines attached.	1.5
Gray clay with limestone nodules similar in lithology to 24-2.	0.3
Lower Winterset unit:	
24-1, A, *medium-sand phosphatic crinoidal algal biosparrudite;* 5-inch unit; crinoidal material (25%), encrusting algae (7%), bryozoans (4%), brachiopods (3%), minor percentages of ostracodes, foraminifers; crinoidal material abraded; parallelism of large skeletal material; 36% terrigenous material; 40% skeletal material; 3% phosphate; 1% glauconite; trace of limonite (see pl. III, fig. 1).	0.4
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Gray and brown clay and calcareous siltstone.	1.0
Not measured.	
Total section measured	3.2

25. SE¼ SE¼ SW¼ sec. 30, T. 27 N., R. 15 E., Nowata County, in side of small hill 150 yards north of the east-west section-line road, and just above a small stream. (See columnar section, page 100.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top eroded):	
25-4, *bryozoan brachiopod biomicrudite,* similar in lithology to 25-2; sampled at top of interval which is partly covered; irregular beds 2 to 4 inches thick; brachiopods and bryozoans common, minor terrigenous material;-approximately 10% of rock recrystallized to sparry calcite.	3.0
25-3, *brachiopod biomicrudite;* similar in lithology to 25-2; brachiopods abundant (productid-type), minor percentages of crinoid columnals and bryozoan material; approximately 5% terrigenous material; 30% unabraded skeletal material; approximately 1% limonite.	0.6

	Feet
Gray and brown clay.	0.1
Brachiopod biomicrudite; similar in lithology to 25-2; abundant brachiopods, minor percentages of bryozoans and crinoid columnals; approximately 5% terrigenous material.	1.3
Gray and brown clay.	0.2
25-2, B, *fractured and partially recrystallized bryozoan brachiopod biomicrudite;* irregularly bedded; bryozoans (18%), brachiopods (14%), minor percentages of crinoidal material, ostracodes, foraminifers, and possible algae; skeletal material not abraded; spines attached to brachiopod shells; intraclasts and coarse-crystalline sparry calcite localized in definite zones; sparry calcite possibly filled voids formed by fracturing as rim cementation occurs; 6% terrigenous material; 35% skeletal material; 5% intraclasts; 15% pseudopellet structures (algae?).	0.3
Lower Winterset unit:	
25-1, A, *fine-sand, phosphatic crinoidal algal biosparrudite;* one bed 3 inches thick; crinoidal material (30%), encrusting algae (15%), pelecypods (3%), bryozoans (8%) brachiopods (3%); parallelism of larger skeletal fragments; some *Girvanella*-type algae (rare); limonite concentrated in encrusting algae; 21% terrigenous material; 60% skeletal material; 1% intraclasts; 6% phosphate; traces of glauconite and limonite (see pl. III, fig. 2).	0.2
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Brown and gray clay and siltstone.	2.0
Not measured.	
Total section measured	7.7

26. NE¼ SE¼ SW¼ sec. 20, T. 26 N., R. 14 E., Washington County, sampled in north bank of large pond just above water level. Lithologies at this locality are nearly the same as those at same stratigraphic position at stratigraphic section 27, and therefore the rock types of the samples from section 26 are discussed with those from stratigraphic section 27.

27. SW¼ SW¼ SW¼ sec. 20, T. 26 N., R. 14 E., Washington County, in recent excavation just north of east-west section-line road. (See columnar section, page 100.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top covered):	
27-3, B, *silty crinoidal bryozoan algal biomicrudite;* irregular beds 1 to 5 inches thick; crinoidal material (12%),	0.5

Feet

bryozoans (8%), encrusting algae (7%), minor percentages of brachiopods and ostracodes; 25% of rock recrystallized to sparry calcite; recrystallization primarily along styolites; 11% terrigenous material; 30% skeletal material; trace of limonite.

27-2, *brown clay with limestone nodules and crinoidal columnals;* nodules resemble limestone found in 27-3. 0.6

Lower Winterset unit:

27-1, A, *silty phosphatic crinoidal algal biosparrudite;* irregularly bedded unit 4 inches thick; crinoidal material (33%), encrusting algae (20%), bryozoans (8%), pelecypods (4%), minor percentages of brachiopods, ostracodes, arthropod fragments, and *Girvanella*-type algae; parallelism of larger skeletal fragments; 12% terrigenous material; 5% phosphate; trace of glauconite. 0.3

Coffeyville Formation.

Coffeyville terrigenous facies:

Gray and brown clay and calcareous siltstone. 2.0

Covered.

Total section measured 3.4

28. NW¼ SE¼ NW¼ sec. 31, T. 26 N., R. 14 E., Washington County, in west bank of small stream 500 yards west of stratigraphic section 2. (See columnar section, page 102.)

Hogshooter Formation. Feet

Reef core (top covered):

28-3, C, *partially recrystallized crinoidal bryozoan biomicrudite;* sampled at top of partly covered sequence 5.5 feet thick; still in reef core; crinoid columnals (10%), bryozoans (8%), brachiopods, pelecypods, gastropods (each 2%); most of skeletal material recrystallized to coarse sparry calcite; much of micrite matrix recrystallized in microspar; 8% terrigenous material; 25% skeletal material; trace of limonite. 5.5

28-2, B, *partially dissolved and recrystallized silty fossiliferous micrite;* sampled at top of unbedded unit 5 feet thick; ostracodes (10%), bryozoans (4%), crinoidal material (1%); many irregular voids, possibly representing dissolved algal structures; darker areas of rock with a higher organic content possibly algal in origin; most of micrite recrytallized to microspar; some dolomite as replacement of skeletal material; most skeletal material recrystallized to coarse sparry calcite; 11% terrigenous material; 15% skeletal material; traces of limonite and dolomite. 5.0

Feet

28-1, A, *partially dissolved and recrystallized algal brachiopod biomicrudite;* sampled at base of unit 5 feet thick; no bedding; *Girvanella*-type algae (10%), minor percentages of brachiopods, crinoids, bryozoans, and gastropods; cavities and darker areas of rock possibly representing algal developments (possibly an algal biolithite), most of micrite recrystallized to microspar; skeletal material recrystallized to coarse sparry calcite; some cavities partly filled with replacement dolomite; 6% terrigenous material; 15% skeletal material; trace of dark organic material.

Coffeyville Formation.

Stark Member:

Black fissile shale; lies directly beneath reef core and is warped downward beneath the core. 0.9

Canville Member:

Limestone present but not sampled; dips beneath the reef core and the water level.

Base covered.

Total section measured 11.4

29. NW¼ SE¼ SW¼ sec. 6, T. 25 N., R. 14 E., Washington County, in south bank of small stream in southern part of the Carter Oil Company lease. (See columnar section, page 101.)

Coffeyville Formation. Feet

Stark Member (top covered):

29-3, *black pyritic limestone concretion;* bedding in black shale definitely continues through concretion. 0.4

Black fissile shale. 5.0

Brown and gray clay. 0.6

Canville Member:

29-2, *silty brachiopod biomicrosparrudite;* similar to 29-1 except contains much less and smaller terrigenous material than 29-1; sampled at top of unit 1.1 feet thick; spirifers most abundant brachiopods. 1.1

29-1, A, *fine-sand brachiopod biomicrosparrudite;* sampled at base of unit 1.1 feet thick; brachiopods (15%), bryozoans and pelecypods (4% each); most skeletal material recrystallized to coarse sparry calcite; matrix now microspar; 29% terrigenous material; 20% skeletal material; trace of pyrite.

Coffeyville terrigenous facies:

Gray and brown clay. 0.5

	Feet
Gray calcareous siltstone.	5.0
Covered.	
Total section measured	12.6

30. NE¼ SW¼ SE¼ sec. 22, T. 25 N., R. 13 E., Washington County, in south bank of small stream 150 yards north of the east-west section-line road. (See columnar section, page 101.)

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

30-3, B, *fractured intraclast-bearing brachiopod biomicrudite;* irregular bed 3 to 4 inches thick; brachiopods (10%), bryozoans (5%); angular intraclasts formed by fracturing of micritic material; recrystallization or pore-filling by sparry calcite along fractured zones; approximately 20% of rock recrystallized to coarse sparry calcite; parallelism of fractured zones; 6% terrigenous material; 15% skeletal material; 12% intraclasts. 0.3

30-2, *brown clay and nodular limestone;* similar to 30-3. 0.1

Lower Winterset unit:

30-1, A, *phosphatic oölith-bearing crinoidal algal biosparrudite;* one bed; crinoidal material (30%), encrusting algae (20%), bryozoans (5%), brachiopods and gastropods (2% each); gastropods filled with phosphatic material; oöliths illustrate concentric banding; approximately 30% of skeletal material recrystallized; 9% terrigenous material; 60% skeletal material; 15% oöliths; 1% intraclasts; 5% phosphate; trace of glauconite. 0.5

Coffeyville Formation.

Coffeyville terrigenous facies:

Gray and brown clay. 0.9

Calcareous siltstone, gray, thinly bedded. 4.0

Covered.

Total section measured 5.8

31. SW¼ NE¼ SW¼ sec. 34, T. 25 N., R. 13 E., Washington County, in east bank of small stream 10 yards east of the farm road where it crosses the stream. (See columnar section, page 101.)

Hogshooter Formation. Feet

Upper Winterset unit (top eroded):

31-3, B, *fractured and partially recrystallized silty brachio-* 0.2

	Feet
pod biomicrudite; one irregular bed; brachiopods (30%), bryozoans (4%), traces of ostracodes, foraminifers, and crinoids; some brachiopod shells with spines attached and unabraded; 20% of rock recrystallized mostly along fractured zones; intraclasts also along fractured zones; intraclasts formed as result of fracturing; pseudopellet structures possibly due to recrystallization; 11% terrigenous material; 35% skeletal material; 5% pseudopellet structures; 1% angular intraclasts.	
31-2, *brown clay with limestone nodules;* similar in lithology to 31-3.	0.2
Lower Winterset unit:	
31-1, A, *silty phosphatic oölith-bearing crinoidal algal biosparrudite;* unit 3 inches thick with beds 0.5 to 1 inch thick; crinoidal material (25%), encrusting algae (20%), brachiopods and pelecypods (each 4%), gastropods and bryozoans (each 3%), trace of arthropod fragments; well-rounded intraclasts; oölith structures around quartz and skeletal particles; 18% terrigenous material; 60% skeletal material; 5% oöliths; 2% intraclasts; 5% phosphate; 1% glauconite; parallelism of skeletal material; abraded skeletal material.	0.2
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Gray and brown clay.	0.1
Gray calcareous siltstone.	1.0
Covered.	
Total section measured	1.7

32. NE¼ NW¼ NE¼ sec. 28, T. 23 N., R. 13 E., Washington County, in roadcut on south side of east-west section-line road. (See columnar section, page 101.)

	Feet
Nellie Bly Formation.	
Covered.	
Gray and brown calcareous siltstone.	1.0
Lower Winterset unit.	
32-2, B, *fine-sand phosphatic intraclast-bearing crinoidal algal biosparrudite;* one bed 10 inches thick; crinoidal material (15%), encrusting algae (13%), bryozoans (10%), gastropods (8%), pelecypods (5%), minor percentages of brachiopods, ostracodes, conodonts, and arthropod fragments; parallelism of large skeletal material; 15% terrigenous material; 55% skeletal material; 10% intraclasts; 1% phosphate; trace of glauconite.	0.9

	Feet
32-1, A, *fine-sand phosphatic algal bryozoan biosparrudite;* irregularly bedded; encrusting algae (25%), bryozoans (20%), crinoidal material (15%), pelecypods and brachiopods (3% each), gastropods (2%), traces of arthropod fragments and conodonts; parallelism of larger skeletal fragments; skeletal material fractured and abraded; 16% terrigenous material; 73% skeletal material; 1% intraclasts and oöliths; 5% phosphate; trace of glauconite (see pl. III, fig. 3).	0.2
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Gray and brown clay.	0.2
Covered.	
Total section measured	2.3

33. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, 200 yards west of stratigraphic section 20 in the south bank of the South Fork of Double Creek. (See columnar section, facing page 56).

	Feet
Hogshooter Formation.	
Stratified reef facies (top eroded):	
33-8, *silty algal crinoidal biosparrudite;* irregular beds 0.5-1 inch thick; encrusting algae (30%), crinoidal material (25%), bryozoans (3%), brachiopods and pelecypods (1% each), traces of helically coiled gastropods and conodonts; some parallelism caused by algal filaments; most algal filaments weathered to limonite; sparry calcite cement; 10% terrigenous material; approximately 60% skeletal material; slight trace of phosphate; fish teeth abundant; trace of phosphate as internal molds in gastropod shells.	0.5
Covered.	2.0
33-7, G, *partially recrystallized slightly phosphatic algal crinoidal biosparrudite;* irregularly bedded with undulating bedding planes; moderate yellowish brown on weathered surface; dark yellowish brown on unweathered surface; beds 1 to 2 inches thick; encrusting algae (35%), crinoidal material (20%), bryozoans (5%), brachiopods and pelecypods (2% each), traces of ostracodes, arthropod fragments, and conodonts; fish teeth common (2%); definite parallelism of skeletal material caused by filamentous algal encrustations parallel to bedding; algal material encrusting most of skeletal material; 10% terrigenous material; approximately 65% skeletal material; trace of phosphate; most algal material altered to limonite; many crinoid fragments recrystallized to sparry calcite.	0.7

	Feet
Brown clay.	0.9
Biosparrudite; similar in lithology to 33-6.	0.7
Brown clay.	0.1
Biosparrudite; similar in lithology to 33-6.	0.4
Brown clay.	0.1
Biosparrudite; similar in lithology to 33-6; one bed 9.5 inches thick.	0.8
Brown clay.	0.1
Biosparrudite; similar in lithology to 33-6; one bed 5 inches thick.	0.4
Brown clay.	0.1
Biosparrudite; similar in lithology to 33-6; one bed 5 inches thick.	0.4
Brown clay.	0.1
33-6, F, *partially recrystallized crinoidal algal biosparrudite;* beds 2 to 4 inches thick; crinoidal material (40%), encrusting and filamentous algae (*Osagia,* 30%), bryozoans (3%), traces of brachiopod, pelecypod, and crustacean fragments; most of binding material or cement encrusting algae; definite layering caused by the filamentous algae binding the coarser skeletal particles in layers parallel to bedding; much of algal material weathered and replaced by limonite; 10% terrigenous material; 75% skeletal material; 10% limonite; trace of phosphate.	0.8
Brown clay.	0.2
Biosparrudite; similar in lithology to 33-6.	0.2
Brown clay.	0.1
Biosparrudite; similar in lithology to 33-6.	0.2
Brown clay.	0.2
33-5, E, *partially recrystallized crinoidal algal biosparrudite;* undulating bedding planes; crinoidal material (40%), encrusting algae (25%), bryozoans (2%), brachiopod and pelecypod fragments (2% each), traces of *Epimastopora* (algae) and foraminifers; scattered fragments of fish teeth and conodonts; larger skeletal fragments parallel to bedding; 14% terrigenous material; approximately 70% skeletal material; trace of phosphate.	0.2
Brown clay.	0.8
33-4, D, *silty bryozoan biomicrudite;* irregularly bedded; micrite matrix; bryozoans (20%), pseudopunctate and punctate brachiopods (10%), large crinoid fragments (10%), algae (5%), few fish teeth; 11% terrigenous material; 45% skeletal material; skeletal material unabraded.	0.4
Brown clay.	0.3

	Feet
33-3, C, *crinoidal biosparrudite;* one irregular bed; crinoidal material (55%), bryozoans (15%), encrusting algae (5%), brachiopod and pelecypod fragments (2% each); parallelism of larger skeletal material; 6% terrigenous material; approximately 80% skeletal material; little to no phosphate.	0.3
Brown clay.	0.3
33-2, B, *phosphatic crinoidal algal biosparrudite;* sampled at top of unit 6.5 feet thick; crinoidal material (50%), encrusting algae (25%), bryozoans (3%), helically coiled gastropods (2%), brachiopod and pelecypod fragments (2%), traces of conodonts, ostracodes, and *Epimastopora* (algae); gastropods preserved as internal molds of phosphatic material; skeletal material fragmented and abraded; 6% terrigenous material; 82% skeletal material; 4% phosphate; trace of glauconite.	6.5
33-1, A, *silty phosphatic glauconitic crinoidal algal biosparrudite;* sampled at base of unit 6.5 feet thick; crinoidal material (40%), encrusting algae (30%), pelecypod and brachiopod fragments (3%), bryozoan fragments (2%), helically coiled gastropods (2%), trace of conodonts; gastropod shells filled with phosphatic material; phosphate as nodules composed of smaller phosphate particles; limonite concentrated in algal structures; parallelism caused by algal material encrusting skeletal material parallel to bedding planes; 10% terrigenous material; 79% skeletal material; 5% phosphate; trace of glauconite.	
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Gray and brown calcareous siltstone.	10.0
Covered.	
Total section measured	27.8

34. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, 80 feet east of stratigraphic section 33, in the south bank of the South Fork of Double Creek. (See columnar section, facing page 56.)

	Feet
Hogshooter Formation.	
Stratified reef facies (top eroded):	
34-6, D, *crinoidal algal biosparrudite;* irregular beds 1 to 4 inches thick; crinoidal material (40%), encrusting algae (25%), bryozoans, pelecypod and brachiopod fragments (2% each), fish teeth and conodonts (1% each); limonite concentrated in algal encrustations; algae developed parallel to the bedding as well as around skeletal fragments; ap-	1.1

	Feet
proximately 7% terrigenous material; approximately 75% skeletal material; trace of phosphate.	
Brown clay.	0.1
34-5, C, *partially recrystallized crinoidal algal biosparrudite;* one bed 1 foot thick; crinoidal material (40%), encrusting algae (30%), bryozoans (2%), shell fragments of brachoipods and pelecypods (2%), trace of conodonts and fish teeth; limonite concentrated in algal encrustations; 6% terrigenous material; approximately 75% skeletal material; slight traces of phosphate and glauconite.	1.0
Zone of weakness; possibly brown clay.	0.1
Biosparrudite; similar in lithology to 34-4.	0.5
Zone of weakness; possibly brown clay.	0.1
Biosparrudite; similar in lithology to 34-4; two irregular beds.	0.4
Zone of weakness; possibly a bedding plane, or possibly brown clay.	0.1
Biosparrudite; similar in lithology to 34-4; one bed.	0.9
Zone of weakness; possibly brown clay.	0.1
Biosparrudite; similar in lithology to 34-4; one bed.	0.4
Zone of weakness; possibly brown clay.	0.1
Biosparrudite; similar in lithology to 34-4; one bed.	1.0
Zone of weakness; possibly brown clay.	0.1
34-4, B, *phosphatic glauconitic algal crinoidal biosparrudite;* one unit; sampled at top of unit; encrusting algae (40%), crinoidal material (30%), traces of bryozoans, conodonts, and fish teeth; encrusting algae parallel to bedding of rock; zones of concentrated lumps of glauconite and phosphate scattered through unit; these zones composed almost entitrely of phosphate and glauconite weathering more deeply than highly fossilferous zones; limonite concentrated in algal structures; traces of phosphate and glauconite in highly fossiliferous zones only; 14% terrigenous material; 75% skeletal material; concentration of phosphate and glauconite differs depending on which zone is considered.	3.1
34-3, *gray and brown clay;* fenestrate bryozoans, fish teeth, crinoid plates, columnals, planispirally coiled gastropods, productid brachiopods, *Aulopora*-type corals, *Coenites*-type corals present but composing only 10 to 25% of the zone; primarily clay material.	2.2
34-2, A, *silty intraclast-bearing bryozoan biomicrudite;* one bed; bryozoans (15%), crinoidal material (10%), pseudopunctate brachiopods (5%), trace of encrusting algae; some small fragments of skeletal material; large skeletal material unabraded and only slightly fractured; intraclasts same	0.8

	Feet
micritic material as matrix of rock; intraclasts larger than 1-mm; 16% terrigenous material; 32% skeletal material; 5% intraclasts.	
Gray and brown clay.	0.2
34-1, *crinoidal algal biosparrudite;* similar in lithology to 34-4; one bed.	0.3
Gray clay with few limestone nodules; fossiliferous, and contains approximately the same types and amounts as 34-3.	5.2
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Gray and brown calcareous siltstone.	10.0
Covered.	
Total section measured	27.8

35. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, 40 feet east of stratigraphic section 33 and 40 feet west of stratigraphic section 34, in south bank of the South Fork of Double Creek. (See columnar section, facing page 56.)

	Feet
Hogshooter Formation.	
Stratified reef facies (top eroded):	
Biosparrudite; similar in lithology to 35-7.	0.5
Brown clay.	0.1
35-7, E, *crinoidal algal biosparrudite;* one bed; dark yellowish orange on weathered surface; medium gray on fresh surface; crinoidal material (35%), encrusting algae (35%), brachiopod and pelecypod fragments (2%), traces of bryozoans, conodonts, and fish teeth; algae encrusting much of skeletal material and also trending parallel to the bedding in the rocks; 6% terrigenous material; 75% skeletal material; traces of glauconite and phosphate.	0.8
Zone of weakness; possibly brown clay.	0.1
Biosparrudite; similar in lithology to 35-7.	0.1
Zone of weakness; more easily weathered zone; possibly brown clay.	0.1
Biosparrudite; similar in lithology to 35-7; 3 irregularly bedded units separated by more easily weathered thin zones.	1.2
Zone of weakness; more easily weathered zone; possibly brown clay.	0.1
Biosparrudite; similar in lithology to 35-7.	
Zone of weakness; possibly brown clay or more easily weathered zone.	0.1

	Feet
Biosparrudite; similar in lithology to 35-7.	0.4
Zone of weakness; possibly brown clay or more easily weathered zone.	0.1
Biosparrudite; similar in lithology to 35-7; irregularly bedded.	0.9
Zone of weakness; possibly brown clay interval.	0.1
Biosparrudite; similar in lithology to 35-7; 3 irregular beds separated by thin weathered zones, probably weathered bedding planes.	1.1
Zone of weakness; possibly brown clay interval.	0.1
Biosparrudite; similar in lithology to 35-7; two distinct beds, 4 and 7 inches thick.	0.9
35-6, *gray and brown fossiliferous clay;* prolific skeletal accumulation; horn corals and *Coenites*-type corals present but less abundant than crinoidal material, consisting of columnals, individual plates, and cups; *Paragassizocrinus* sp. fused infrabasals common; conularids and productid brachiopods present. *Marginifera* sp. common, but often flattened; *Punctospirifer* sp. present but uncommon; *Aulopora*-type corals abundant; fragments of planispirally or low helically coiled gastropods, fish teeth, internal molds of pelecypods, and much fragmented material; approximately 50% of zone composed of skeletal material.	1.5
35-5, D, *silty crinoidal bryozoan biomicrudite;* one bed; undulating bedding planes; crinoidal material (15%), bryozoans (10%), pseudopunctate brachiopods (5%), trace of arthropod fragments; skeletal material unabraded, with long spines attached to brachiopod shells; micrite matrix; 17% terrigenous material; 30% skeletal material.	1.1
Brown and gray shale, fissile.	0.8
35-4, C, *crinoidal biosparrudite;* one irregular bed; crinoidal material, columnals, spines and plates (65%), bryozoans (10%), encrusting algae (5%); many crinoid columnals still articulated; prolific accumulation of skeletal material; limonite concentrated in algal structures; no orientation of skeletal material; 7% terrigenous material; 80% skeletal material; traces of glauconite and phosphate.	0.3
35-3, *light olive-gray shale;* skeletal material uncommon; some small limestone nodules scattered through shale; shale fissile; bryozoan fronds preserved as impressions on the surfaces of the shale beds; a few scattered and flattened productid brachiopods; scattered crinoid columnals and fragmented bryozoan axes; skeletal material approximately 5 to 10%.	2.1
35-2, B, *silty phosphatic glauconitic crinoidal algal biosparrudite;* one bed; crinoidal material (30%), encrusting	2.2

	Feet
algae (30%), brachiopod and pelecypod fragments (10%), planispirally or low helically coiled gastropods (1%), traces of conodonts, fish teeth, and ostracodes; limonite concentrated in algal structures; 11% terrigenous material; 75% skeletal material; 8% phosphate; 1% glauconite; gastropods filled with phosphatic material; algae encrusting fragments parallel to bedding.	
Zone of weakness.	0.1
35-1, A, *silty phosphatic glauconitic algal crinoidal biosparrudite;* one bed with undulating bedding planes; crinoidal material (30%), encrusting algae (35%) brachiopod and pelecypod fragments (5%), helically and planispirally coiled gastropods (1%), traces of conodonts and fish teeth; gastropods filled with phosphatic material; phosphate nodules of smaller particles of phosphate and glauconite; algae encrusting skeletal material parallel to bedding; 13% terrigenous material; limonite concentrated in algal structures; 70% skeletal material; 8% phosphate; 1% glauconite.	0.4
Coffeyville Formation.	
Coffeyville terrigenous facies:	
Gray and brown calcareous siltstone.	11.0
Covered.	
Total section measured	26.2

36. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, 40 feet west of the reef core at stratigraphic section 20, in the south bank of the South Fork of Double Creek. (See columnar section, facing page 56.)

	Feet
Hogshooter Formation.	
Stratified reef facies (top eroded):	
36-5, D, *crinoidal algal biosparrudite;* thick-bedded unit with one weathered zone approximately 15 inches above base of the unit; weathered zone 0.2 inch thick containing abundant *Aulopora*-type corals; rock other than weak zone has crinoidal material (45%), encrusting algae (30%), bryozoans (3%), and brachiopods and pelecypods (3%); incrusting algae parallel to bedding of unit; algae acting as a cement fixing the loose skeletal material; rock medium gray on fresh surface; limonite concentrated in algal structures; 9% terrigenous material; approximately 80% skeletal material; traces of glauconite and phosphate.	1.9
36-4, *organic-debris zone;* fossil talus from reef; skeletal material 90 to 95 percent of unit; corals (*Coenites* and *Aulopora* types) 90% of the skeletal material; conularids,	3.1

Feet

fish teeth, and small brachiopods; extremely large (some over 4 inches long) fragments of the *Coenites*-type coral; most of skeletal material is fragmented; scattered horn corals and fenestrate bryozoan fronds; much more fossil material than found at stratigraphic sections 34 and 35.

36-3, C, *crinoidal bryozoan biomicrudite;* irregular beds; crinoidal material (25%), bryozoans (10%), irregular patches of coarse sparry calcite possibly algal (5%), impunctate and pseudopunctate brachiopods (3%), helically and planispirally or low helically coiled gastropods (1%); gastropods filled with micritic material; 9% terrigenous material; 45% skeletal material. 0.9

Zone of weakness; possibly thin clay layer. 0.1

36-2, B, *intraclast-bearing bryozoan algal biomicrudite;* irregularly bedded; bryozoans (20%), irregular patches of sparry calcite possibly algal in origin (15%), crinoidal material (10%), encrusting algae and indistinct algal threads (3%), punctate and pseudopunctate brachiopods and pelecypods (2% each); brachiopods with spines attached; 6% terrigenous material; approximately 50% skeletal material. 0.5

Zone of weakness; possible shale break. 0.1

36-1, A, *partially recrystallized intraclast-bearing crinoidal bryozoan biomicrudite;* one bed; crinoidal material (30%), bryozoans (19%), slightly helically coiled gastropods (1%), pelecypod shells (2%), ostracodes (1%); skeletal material unabraded; some irregular patches of sparry calcite possibly representing algal structures; 20% of rock recrystallized to coarse sparry calcite; 3% terrigenous material; 45% skeletal material; 5% intraclasts composed of micritic material similar to matrix of rock. 0.3

Covered.

Total section measured 6.9

37. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, 5 feet west of the reef core of stratigraphic section 20, in the south bank of the South Fork of Double Creek. (See columnar section, facing page 56.)

Hogshooter Formation. Feet

Stratified reef facies (top eroded):

37-6, E, *crinoidal bryozoan biosparrudite;* irregular beds 3 to 5 inches thick; unit dips off reef core at approximately 20°W; crinoidal material (45%), bryozoans with some fenestrate fronds preserved (20%), encrusting algae (20%), traces of brachiopod and pelecypod fragments; 1.5

	Feet
algae-encrusted skeletal material parallel to the bedding; limonite concentrated in algal encrustations; 9% terrigenous material; 85% skeletal material.	
Fossiliferous gray clay; skeletal material in zone composed of crinoid and bryozoan fragments; upper 4 inches composed of thin irregular biomicrudite beds.	1.0
37-5, D, *partially recrystallized, crinoidal bryozoan biomicrudite;* crinoidal material (25%), bryozoans (15%), encrusting algae (10%), recrystallized pelecypod shells with spines attached (3%), pseudopunctate and impunctate brachiopods with spines attached (3%), slightly helically coiled gastropods (1%); skeletal material only slightly fragmented and unabraded; approximately 20% of rock recrystallized to coarse sparry calcite; limonite concentrated in algal structures; 7% terrigenous material; 60% skeletal material.	0.5
Gray shale and marl zone.	0.6
37-4, C, *partially recrystallized, bryozoan biomicrudite;* unit extending laterally from reef core; bed continuous with the core; bed horizontal and does not dip toward the core; bryozoans (10%), crinoidal material (7%), pelecypod and brachiopod shells (5%), ostracodes (3%), traces of slightly helically coiled gastropods and arthropod fragments; micritic material with dark organic patches scattered throughout possibly representing an indistinct type of algal structure; all skeletal material recrystallized to coarse sparry calcite; geopetal structures in ostracodes common; parallelism of large shell fragments with the geopetal structures; 8% terrigenous material; approximately 25% skeletal material; unit may represent an algal biolithite if the indistinct structures are algal.	0.5
37-3, *fossiliferous dark yellowish-orange shale;* crinoid columnals and plates most abundant skeletal material; some brachiopod fragments; colonial coral *Michelinia* sp.; coralline colonies 1 to 5 inches in diameter; skeletal material 30 to 40%.	1.2
37-2, B, *partially recrystallized crinoidal bryozoan biomicrudite;* irregularly bedded; 8 distinct beds 1 to 3 inches thick; beds dip toward the reef core at approximately 5°, indicating the reef was still settling downward after these beds were deposited; crinoidal material (30%), bryozoans (10%), brachiopod and pelecypod shells (3%); most of the skeletal material (except for a minor portion of the crinoidal material) recrystallized to coarse sparry calcite; possible algal structures constituting approximately 40% of the rock; possible algal structure composed of darker areas scattered throughout a micrite matrix; limonite concentrated in some of the possible algal structures; 7%	1.3

Feet

terrigenous material; 43% skeletal material.

Zone of weakness; possibly gray clay. 0.1

Coffeyville Formation.

Lost City Member:

37-1, A, *silty algal brachiopod biomicrudite;* one bed; sampled at top of unit; bed dips beneath the reef core at 35° to 40° NE; bed warped downward by overburden of the reef core; encrusting algae (30%) brachiopods (impunctate, 15%), bryozoans (5%), slightly helically coiled gastropods (1%), crinoidal material (3%), traces of ostracodes and *Epimastopora* sp.; limonite concentrated in algae; 15% terrigenous material; 55% skeletal material; 2% phosphate. 1.9

Coffeyville terrigenous facies:

Brown and gray clay. 0.2

Covered.

Total section measured 8.8

39. NE¼ SW¼ NE¼ sec. 28, T. 24 N., R. 13 E., Washington County, 50 yards east of stratigraphic section 20 directly behind a barn. (See columnar section, facing page 56.)

Feet

Hogshooter Formation.

Stratified reef facies (top eroded):

39-3, C, *crinoidal algal biosparrudite;* irregularly bedded unit; composed almost entirely of skeletal material; entire articulated crinoid cups common along bedding surfaces; large fronds of fenestrate bryozoans common; crinoid plates, cups, and columnals (70%), encrusting algae (10%), bryozoans (5%), traces of solitary horn corals, pseudopunctate brachiopods, and arthropod fragments; limonite concentrated in the encrusting algae; algae encrusting some skeletal material parallel to bedding; algae as a cement in some parts of rock; 9% terrigenous material; approximately 85% skeletal material. 1.1

Marl; abundant crinoidal material. 0.2

39-2, B, *phosphatic crinoidal bryozoan biosparrudite;* irregular unit with undulating bedding planes; crinoidal plates, columnals, and cups (65%), bryozoans (10%), encrusting algae (5%), brachiopod and pelecypod shells (1%), planispirally coiled gastropods, solitary horn corals rare; limonite concentrated in sparry calcite cement and in algae; skeletal material accumulated rapidly; no abrasion of skeletal material; 8% terrigenous material; approximately 80% skeletal material; 2% phosphate; trace of glauconite. 0.3

	Feet
Marl; composed almost entirely of crinoidal material.	0.6

Coffeyville Formation.

Lost City Member:

39-1, A, *silty algal biomicrudite;* one bed; encrusting algae (20%), pelecypods and helically coiled gastropods (2% each), pseudopunctate brachiopods, bryozoans, and crinoidal material (1% each); limonite scattered through rock, and often concentrated in algal structures; skeletal material unabraded; micrite matrix; 16% terrigenous material; approximately 30% skeletal material; trace of glauconite.	0.6

Coffeyville terrigenous facies:

Brown clay and siltstone.	1.0
Covered.	
Total section measured	3.8

40. NW¼ SE¼ NW¼ sec. 31, T. 26 N., R. 14 E., Washington County, in west bank of small stream 15 yards north of stratigraphic section 28 (small reef development). (See columnar section, page 101.)

Hogshooter Formation.

Upper Winterset unit (only first bed above lower Winterset was sampled); top eroded:

	Feet
Irregularly bedded brachiopod biomicrudites; beds 2 to 7 inches thick; not sampled; slumped and partially covered.	12.0
40-2, B, *algal biomicrudite;* one irregular bed; clear patches of coarse sparry calcite resembling algal mat structure described by Folk (1959a, p. 27) approximately 20 percent of rock; brachiopod shells (5%), bryozoan fragments (2%); definite parallelism of irregular sparry calcite areas; only unit in the upper Winterset illustrating an abundance of these clear sparry calcite developments, possibly the result of influence from the reef development 15 yards to the south; 5% terrigenous material; 25 to 30% skeletal material.	0.3
Brown and gray clay.	0.5

Lower Winterset unit:

40-1, A, *silty phosphatic glauconitic algal crinoidal biosparrudite;* one thin bed; encrusting algae as cement for much of rock; limonite concentrated in algal structures; 35% terrigenous material; 55% skeletal material; 5% phosphate; 1% glauconite.	0.2

Coffeyville Formation.

	Feet
Stark Member:	
Brown and gray clay.	0.2
Black fissile shale.	0.5
Brown and gray clay.	0.2
Canville Member (covered):	
Limestone present but covered in bottom of stream.	
Total section measured	13.9

42. NE¼ NW¼ NE¼ sec. 5, T. 25 N., R. 14 E., Washington County, in roadcut on south side of east-west section-line road. (See columnar section, page 101.)

	Feet
Hogshooter Formation.	
Upper Winterset unit (top eroded):	
Brachiopod biomicrudite, similar in lithology to 2-5; only one irregularly bedded unit; remainder of upper Winterset eroded.	0.3
Gray and brown clay.	0.1
Lower Winterset unit:	
42-3, B, *fine-sand phosphatic glauconitic algal crinoidal biosparrudite;* one bed approximately 2 inches thick; encrusting algae (30%), crinoidal material (15%), pelecypod fragments (5%), planispirally to slightly helically coiled gastropods (2%), bryozoans (1%), traces of conodonts, punctate brachiopods, and arthropod fragments; skeletal material fragmented and abraded; limonite concentrated in algal structures; algae as cement for much of skeletal and terrigenous material; 15% terrigenous material; 55% skeletal material; phosphate nodules, composed of many smaller particles of phosphate cemented with calcite, 8% of the rock; 2% glauconite.	0.2
Coffeyville Formation.	
Stark Member:	
Gray clay.	0.1
42-2, *fissile black shale* with thin elongated limestone concretions.	0.4
Gray clay.	0.1
Canville Member:	
42-1, A, *fine-sand algal bryozoan crinoidal biomicrosparrudite;* one bed; crinoidal material, encrusting algae, and bryozoans (15% each), pelecypod shells (5%), punctate brachiopod shells (2%), traces of ostracodes and arthropod fragments; skeletal material only slightly fragmented and abraded; pseudomorphs of limonite after pyrite in some	0.3

	Feet
bryozoans; bryozoan material contains limonite replacements probably after pyrite; cement is microspar and fine-crystalline sparry calcite; similar in lithology to 2-1 and 3-2; 16% terrigenous material; 55% skeletal material; slight trace of glauconite.	
Coffeyville terrigenous facies:	
Brown and gray clay.	0.3
Covered.	
Total section measured	1.8

INDEX

(**Boldface number** indicates main reference)