THE STRATIGRAPHY OF THE CEDAR CITY FORMATION (MIDDLE DEVONIAN) OF MISSOURI

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ABSTRACT. — The Middle Devonian strata of central and northeastern Missouri, formerly assigned to the Callaway Formation which embraced the Cooper Limestone Facies and the Callaway Limestone Facies, are assigned to the Cedar City Formation (new name) in this report. The names Cooper and Callaway are retained to designate the lithofacies of the Cedar City Formation. The Cooper Lithofacies is divided into seven physiofacies: the Lamine River Conglomerate, the Shiel Clay, the Ralls Oolitic Limestone Conglomerate, the Little Shaver Creek Laminated Limestone, the Little Splice Creek Brecciated Limestone, the Smithton Limestone and the Clifton City Sparritic Limestone. The Callaway Lithofacies is divided into four physiofacies: the Lupus Sandstone, the Mineola Crinoidal or Arenaceous Limestone, the Sandy Hook Dolomitic Limestone or Dolomite and the Calwood Limestone. The various physiofacies of the Cooper and Callaway Lithofacies interfinger with one another. Each facies is defined and described.

In 1852 (Unklesbay, A. G., 1952) Owen reported tracing a Devonian limestone from Callaway County, Missouri, northward toward Iowa. This was the first record of Devonian rocks in Missouri. Swallow (1855 and 1860) also wrote of the occurrence of Devonian rocks in Callaway County. In 1873 Broadhead recognized Devonian strata in Warren County, Missouri.

Keyes (1894) was the first to use the name Callaway. Unfortunately the name was applied to two distinct limestones, one in central Missouri and the other in southeastern Missouri. Keyes again used the name Callaway in reports of 1895 and 1896. It was Greger (1909) who recognized that Keyes had confused what was later to be called Saint Laurent Limestone in southeastern Missouri with the Callaway Limestone in central Missouri and suggested restriction of the term Callaway to the central Missouri unit. Subsequently Wilson (1922), Branson (1923 and 1944) and other workers essentially followed Greger's usage of the term Callaway. There were, however, differences of interpretation concerning the age relationships of the Callaway Limestone.

Swallow (1855) introduced the name Cooper Limestone ("Cooper marble") when he described the Devonian limestones from exposures in Cooper County, Missouri, where, according to Swallow, they are best developed along Clear Creek and on the Lamine River between the mouths of Clear Creek and Otter Creek.

E. B. Branson (1920) named the Mineola Formation "from outcrops about a half-mile south of Mineola . . ." in Montgomery County. Exposures of this formation had been referred to as the Crinoidal limestone

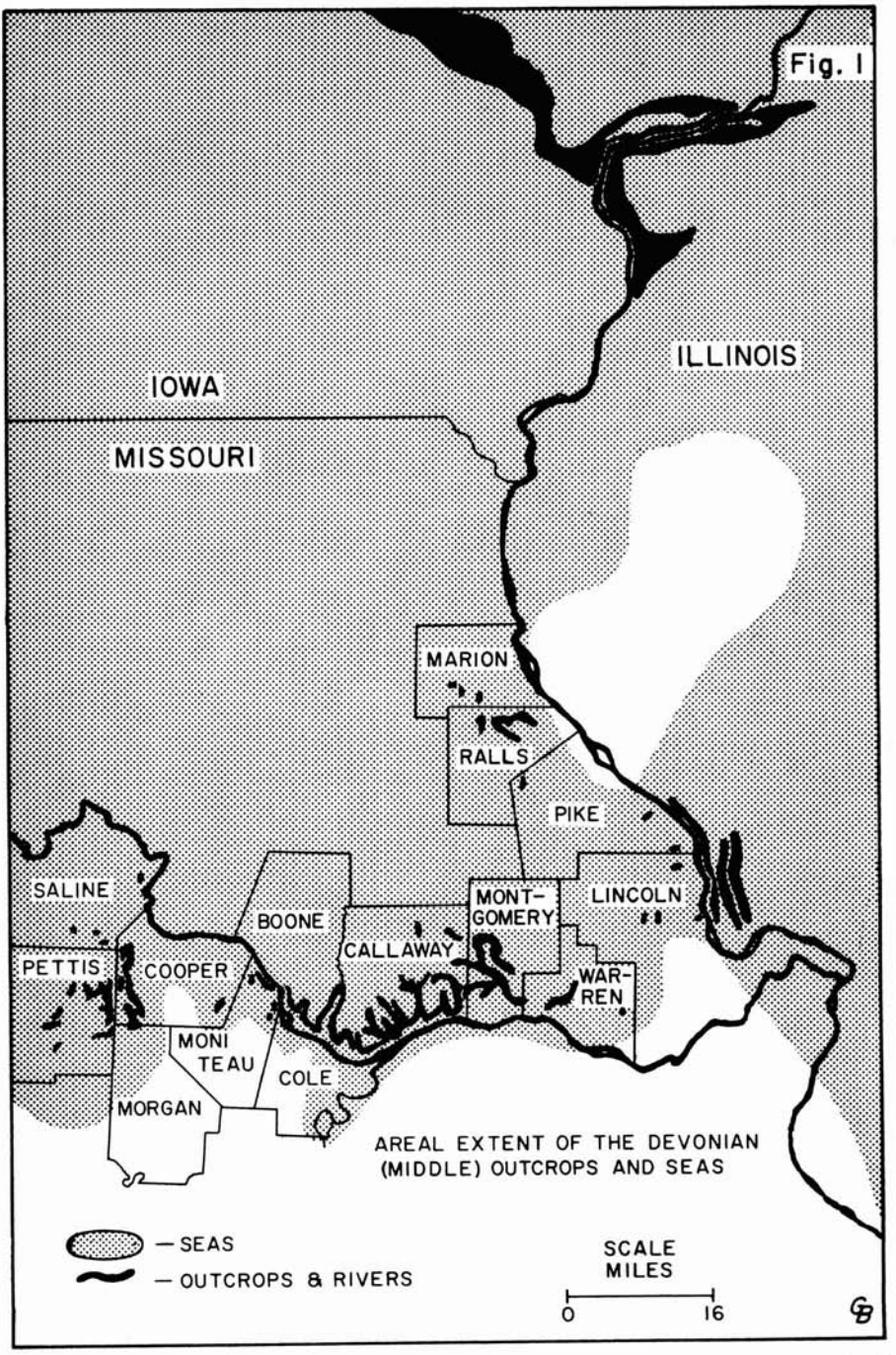


FIGURE 1.—Areal extent of the Devonian (Middle) outcrops and seas in central-northeastern Missouri and western Illinois (drafted by Mississippi Valley Investigations, Southern Illinois University).

by Broadhead (1873) (Branson, E. B., 1944). The Ashland Formation was named and described in 1941 by E. B. Branson from a locality seven miles southeast of Ashland, Boone County, and nine miles northwest of Jefferson City, Cole County (Section 1). Cooper, G. A. (1942) refers to the Ashland as the *Rensselandia* (*Newberria*) zone of central and northeastern Missouri and as the *Rensselandia* Beds of central Missouri (1944).

In 1952 Unklesbay revised the usage of the terminology applied to Middle Devonian of central Missouri. In describing the Middle Devonian of Boone County, he employed the term Callaway as a formational designation embracing the Callaway, Cooper and Ashland Limestone facies. The latter three limestones had previously been recognized as formations. The Mineola was not recognized in Boone County at that time. It should be noted, however, that V. R. Sinclair (1956), while working in the type area of the Mineola Limestone in Montgomery County employed the Mineola as a facies of the Callaway Formation.

As field work on the Middle Devonian of central and northeastern Missouri progressed, it became increasingly evident that the Cooper, Callaway, Mineola and Ashland Formations were actually facies of a single formation as had been suggested by Unklesbay.

In order to avoid the confusion resulting from the usage of the name Callaway as both a formation name and as the name for a facies of the same formation, I propose a new formational name, the Cedar City, which embraces all of the Middle Devonian of central and northeastern Missouri. This name was derived from the town of Cedar City, which is 0.5 mile directly north of the Missouri River Bridge at Jefferson City and about 3.75 miles southwest of the type area (Section 2). The town of Cedar City is the only sizable geographic feature in the area of the type section, the name of which has not been previously used as a formational designation. The type area of the Cedar City Formation is located along the northwest and southeast sides of U.S. Highway 54 in the N ½ SW Sec. 36, T. 45 N., R. 11 W., Callaway County, Missouri. This area was selected as the type because the several outcrops present exhibit many of the physiofacies of both the Cooper and Callaway Lithofacies of the Cedar City Formation and well display the stratigraphic relationships among the various facies. Many of the biofacies of the Cedar City are also well developed here. (Figs. 2-5)

The decision to replace the name Callaway as a formational designation rather than as a facies designation was prompted by the fact that the Middle Devonian of central and northeastern Missouri can be readily divided, grossly, into two distinct limestone facies, the Cooper and the Callaway, which interfinger with one another.

The Cooper is a nearly dense limestone, lacking clastic deposits in most places, except basally, and containing few megafossils. It is best developed in Saline, Pettis, Morgan and Cooper Counties in west central Missouri. The Callaway, on the other hand, is a fine to coarse-grained limestone containing many clastic deposits and many megafossils. It is best

developed in Callaway and Montgomery Counties in central Missouri. There is also the consideration that the names Callaway and Cooper have been applied as names of equal rank for so long a time, that it seems less confusing to reduce the name Callaway to a facies name just as the Cooper has been. Specifically, these names are employed here as lithofacies terms following the usage of R. C. Moore (in Longwell, C. R., 1949). The lithofacies designations are useful in the grouping of the several physiofacies and biofacies which characterize the Cedar City Formation. The Ashland and Mineola Formations of E. B. Branson are here regarded as a biofacies (*Rensselandia* Beds—Fraunfelter, G. H., 1951) and a physiofacies, respectively, of the Callaway Lithofacies. It is the study of these units, the physiofacies and biofacies, and their relationships to one another which reveals the geologic history of the Middle Devonian of central and northeastern Missouri.

Lithofacies and Physiofacies Descriptions

The major difficulty in understanding the stratigraphy of the Cedar City Formation is the great variability in lithologies present in the formation, coupled with the fact that even closely-spaced sections are likely to differ greatly in thickness and lithologic details. A reference to the accompanying diagram of the land-sea relationships (Fig. 1) will call attention to the fact that the

Figure 2.—Second outcrop of the Cedar City Formation north of Jefferson City, Missouri, along west side of U.S. Highway 54 (Section 2).

Figure 3.—South end of third outcrop of the Cedar City Formation north of Jefferson City, Missouri, along west side of U.S. Highway 54 (Section 2).

Figure 4.—North end of third outcrop of the Cedar City Formation north of Jefferson City, Missouri, along the west side of U.S. Highway 54 (Section 2).

Figure 5.—First outcrop of the Cedar City Formation north of Jefferson City, Missouri, along the east side of U.S. Highway 54 (Section 3).

Cedar City is a remarkable record of comparatively near shore deposition with a great variety of environments over short distances and successive times; each of which is reflected in distinctive deposits. (Measured Sections 1 to 11 are included in Table 1).

TABLE 1.—Measured Sections of the Cedar City Formation.

Section 1

Center N ½ SE SW SW Sec. 1, T. 45 N., R. 12 W., in a southwest-trending tributary to a southeast-flowing tributary to Cedar Creek, about one mile southwest of Zumalt Bridge and about five miles southeast of Ashland, Boone County, Missouri (Jefferson City Quadrangle). Type section of the Ashland Formation.

	Thickness	
	Feet	*Inches*
Covered		
Devonian System		
Erian Series		
Cedar City Formation		
Calwood Physiofacies		
9. Limestone, light to medium tannish-gray, fine-grained, clastic, medium to thick-bedded	2	4
Little Shaver Creek Physiofacies		
8. Limestone, light to medium tannish-gray, fine-grained, clastic, finely laminated, medium to thick-bedded	1	8
Calwood Physiofacies		
7. Similar to 9 above	13	2
Sandy Hook Physiofacies		
6. Limestone, light to medium yellowish-brown, fine-grained, dolomitic, thin-bedded	7	0
Mineola Physiofacies		
5. Limestone, light gray to white, coarse-grained, crinoidal, medially arenaceous, medium to thick-bedded, pyritic, limonitic, weathering to a yellowish-brown or pink color	5	9
Sandy Hook Physiofacies		
4. Limestone, yellowish-brown, fine-grained, dolomitic, thin to medium-bedded	6	5
Little Splice Creek Physiofacies		
3. Limestone, light to medium grayish-tan, fine-grained, brecciated, thick-bedded to massive	5	6
Little Shaver Creek Physiofacies		
2. Limestone, light to medium grayish-tan, fine-grained, finely laminated, thick-bedded to massive	1	9
Little Splice Creek Physiofacies		
1. Limestone, light to medium grayish-tan, fine-grained, brecciated, thick-bedded to massive	1	2
Total Thickness	44	9
——— Unconformity ———		
Ordovician System		
Canadian Series		
Jefferson City Formation		

Section 2

NE SW Sec. 36, T. 45 N., R. 11 W., second and third Devonian exposures along the west side of U.S. Highway 54 north of Jefferson City, Cole County, Missouri (Jefferson City Quadrangle). Type area of the Cedar City Formation.
Pennsylvanian sandstones

——————— Unconformity ———————

Devonian System
Erian Series
Cedar City Formation

Calwood Physiofacies		
8. Limestone, light to medium tannish-gray, dense to fine-grained, massive with orange-colored calcite-filled veins and vugs	5	0
Clifton City Physiofacies		
7. Limestone, light tannish-gray, dense, thick-bedded, pyritic	2	8
Calwood Physiofacies		
6. Similar to 8 above	6	4
Clifton City Physiofacies		
5. Limestone, medium grayish-tan, dense to fine-grained, thick-bedded	2	0
Mineola Physiofacies		
4. Limestone, light greenish to tannish-gray, dense, thick-bedded, arenaceous	1	5
Clifton City Physiofacies		
3. Limestone, light to medium grayish-tan, dense to fine-grained, thick-bedded, chalcopyritic, limonitic with calcite veins and vugs near base	9	1
Clifton City Physiofacies		
2. Limestone, light to medium tannish-gray, dense to fine-grained, thick-bedded to massive, in part banded and brecciated	1	8
Sandy Hook Physiofacies		
1. Limestone, light tannish-gray, fine grained, massive, chalcopyritic	7	6
Total Thickness	35	8

Covered

Section 3

NW SE SE NW SW Sec. 36, T. 45 N., R. 11 W., first Devonian exposure north of Jefferson City, Cole County, Missouri, along the east side of U.S. Highway 54 (Jefferson City Quadrangle). Type area of the Cedar City Formation.

Covered

Devonian System
Erian Series
Cedar City Formation

Calwood Physiofacies		
6. Limestone, light grayish-tan, dense, massive in upper half. Limestone, medium tannish to greenish-gray, argillaceous, largely thick-bedded	5	7
Mineola Physiofacies		
5. Limestone, medium tannish-gray, dense, crinoidal, medium to thick-bedded	3	11
Little Shaver Creek Physiofacies		
4. Limestone, medium tannish-gray, dense, finely laminated, stromatoporoidal, massive	7	6
Clifton City Physiofacies		
3. Limestone, light to medium tannish-gray, dense to fine-grained, stromatoporoidal, massive with sparry calcite	2	0
Little Splice Creek Physiofacies		
2. Limestone, light to medium tannish-gray, fine-grained, brecciated, massive	2	0

Little Shaver Creek — Lupus Physiofacies

1. Limestone, light to medium tannish-gray, fine-grained, finely laminated, massive. Sandstone, white to light gray, fine-grained, calcareous, thin-bedded, zero to eight inches in thickness	3	0
Total Thickness	24	0

——— Unconformity ———

Ordovician System
Canadian Series
Jefferson City Formation

Section 4

SE NE SW Sec. 36, T. 45 N., R. 11 W., along the east side of an old railroad cut, about 100 feet east of the previous locality. Type area of the Cedar City Formation.

Covered

Devonian System
Erian Series
Cedar City Formation

Calwood Physiofacies		
6. Limestone, light to medium tannish-gray, dense, thick-bedded	1	4
Sandy Hook Physiofacies		
5. Limestone, light grayish-tan, dense to fine-grained, dolomitic, thin-bedded	1	7
Calwood Physiofacies		
4. Limestone, medium purplish-gray to tan, fine-grained, thick-bedded. Limestone, greenish to tannish-gray, fine-grained, argillaceous, medium-bedded at the base	4	0
Clifton City Physiofacies		
3. Limestone, very light gray, dense, massive with sparry calcite	6	7
Lupus Physiofacies		
2. Sandstone, yellowish-brown, fine-grained, calcareous, massive	0	4
Little Splice Creek Physiofacies		
1. Limestone, light tannish-gray, dense, arenaceous, brecciated, massive	1	5
Total Thickness	15	3

——— Unconformity ———

Ordovician System
Canadian Series
Jefferson City Formation

Section 5

SE NW SW SW Sec. 5, T. 45 N., R. 19 W., about two miles west and south of Otterville, Cooper County, Missouri, along northwest side of U.S. Highway 50, about fifteen-hundredths of a mile west of junction with Missouri Highway 135 (Otterville West Quadrangle). Type section of the Cooper Lithofacies.

Covered

Devonian System
Erian Series
Cedar City Formation
Clifton City Physiofacies

5. Limestone, light to medium grayish tan or tannish-gray, dense to fine-grained, stylolitic, vermicular, medium-bedded to massive with sparry calcite, sandy green clay partings and vug fillings medially, coarse-grained "patches" and limonite staining	12	6

Smithton Physiofacies		
4. Limestone, light grayish-tan, slightly vermicular, massive	2	1
Little Splice Creek Physiofacies		
3. Limestone, light to medium grayish-tan, dense, finely to coarsely-brecciated, stylolitic, vermicular, pyritic, massive with large calcite veins and crystals, greenish-blue clay partings, limonite staining, and mottling	13	7
Smithton Physiofacies		
2. Limestone, light to medium tannish-gray or grayish-tan, dense, finely-brecciated, slightly arenaceous, vermicular, stylolitic, massive with red to purple clay partings medially	6	2
Lamine River Physiofacies		
1. Chert conglomerate, medium tannish-gray or grayish-green with well-cemented or friable fine to medium-grained, calcareous sandstone matrix. Weathers to a yellowish-brown color and contains some green clay	8	0
Total Thickness	42	4

Covered

Section 6

SW NE NE Sec. 17, T. 56 N., R. 6 W., in the east wall af the Central Stone Company quarry, about one half mile east and south of Huntington, Ralls County, Missouri (Rensselaer Quadrangle). Type section of the Shiel Physiofacies.

Devonian System		
Grassy Creek Formation		
No Assigned Series		
Devonian System		
Erian Series		
Cedar City Formation		
Little Splice Creek Physiofacies		
4. Limestone, light to medium grayish-tan, dense, coarsely-brecciated with some pebbles of reworked Noix oolite	2	6
Little Shaver Creek Physiofacies		
3. Limestone, light to medium grayish-tan, dense, thick-bedded, stromatolitic	6	1
Little Splice Creek Physiofacies		
2. Limestone, light grayish-tan, dense, brecciated, pyritic, partly banded wiih calcite and chalcedony-filled veins and vugs and irregular shale partings and sandstone lenses	5	6
Shiel Physiofacies		
1. Clay, bluish to yellowish-green, arenaceous with sand lenses near the top and limestone lenses near the base	5	2
Total Thickness	19	3

——————— Unconformity ———————

Ordovician System		
Champlanian Series		
Kimmswick Formation		

Section 7

NW SE SE SE Sec. 9, T. 47 N., R. 14 W., the first outcrop southeast of Lupus, Moniteau County, Missouri, along the Missouri River bluffs and the Missouri Pacific Railroad about seven-tenths of a mile southeast of Lupus (Columbia Quadrangle). Type section of the Little Splice Creek Physiofacies.

Mississippian System		
Kinderhookian Series		
Chouteau Formation (Siphonodella Beds)		

———— Unconformity ————

Devonian System
Erian Series
Cedar City Formation
Little Shaver Creek Physiofacies
11. Limestone, light tan, fine-grained, arenaceous, finely laminated, thin-bedded 1 2
Sandy Hook Physiofacies
10. Dolomite, light tan to light grayish-tan, fine-grained, arenaceous; in part cross-laminated, finely laminated and brecciated; thin-bedded with small cut and fill of crinoidal Mineola 13 10
Little Splice Creek Physiofacies
9. Limestone, light to dark tannish-gray, dense, brecciated, massive with limestone and chert fragments 3 0
Little Shaver Creek Physiofacies
8. Limestone, dark tannish-gray, dense, stromatolitic, vermicular, thick-bedded 1 0
Mineola Physiofacies
7. Limestone, medium gray, fine to medium-grained, arenaceous, massive 2 0
Little Shaver Creek Physiofacies
6. Limestone, light to medium tannish-gray, dense, stromatolitic, thick-bedded 0 8
Mineola Physiofacies
5. Limestone, light to medium grayish-tan, fine to medium-grained, conglomeratic, arenaceous, massive 2 0
Lupus Physiofacies
4. Sandstone, medium grayish-tan, fine-grained, calcareous, massive 1 6
Lamine River Physiofacies
3. Limestone Conglomerate, light gray to light grayish-tan with white, fine-grained, friable sandstone matrix.. 0 4
Little Shaver Creek Physiofacies
2. Limestone, light grayish-tan, dense, stromatolitic, massive with calcite-filled veins and vugs 2 8
Lamine River Physiofacies
1. Clay, green, dark brown or gray, arenaceous, massive with dark gray limestone, light gray sandstone and calcareous sandstone pebbles and cobbles 10 0

Total Thickness 38 2

———— Unconformity ————

Ordovician System
Champlanian Series
Saint Peter Formation

Section 8

W ½ NE SW SW SE Sec. 1, T. 46 N., R. 9 W., about two and three-tenths miles northeast of Hams Prairie, Callaway County, Missouri, along west side of dirt road about one-tenth mile southeast of Stinson Creek bridge (Fulton Quadrangle). Type section of the Callaway Lithofacies.

Devonian System
Senecan Series
Snyder Creek Formation
Devonian System
Erian Series
Cedar City Formation
Calwood Physiofacies
7. Limestone, light gray, dense, massive 10 6
Limestone, medium gray to dark brownish-gray, fine-grained, medium to thick-bedded 12 6

Calwood and Sandy Hook Physiofacies		
6. Limestone, purplish-gray, fine to medium-grained, in part dolomitic, thin-bedded, hackly	6	4
Sandy Hook Physiofacies		
5. Dolomite, light to dark gray or yellowish-brown, fine to medium-grained, arenaceous, thin-bedded	4	5
Mineola Physiofacies		
4. Limestone, light to dark gray, fine to medium-grained, medium to thick-bedded with a thin, yellowish-brown, fine to medium-grained sandstone in the middle	7	1
Limestone, yellowish-brown, fine to medium-grained, arenaceous, highly weathered	1	8
Sandy Hook Physiofacies		
3. Limestone, light to dark gray or reddish-brown, fine to medium-grained, dolomitic, thin-bedded to massive	5	5
Limestone, light brown or yellowish-brown, fine to medium-grained, dolomitic, argillaceous, arenaceous	2	10
Smithton Physiofacies		
2. Limestone, light gray, dense, massive	2	7
Lupus Physiofacies		
1. Sandstone, light gray, calcareous, massive, intermittent	0	6
Total Thickness	53	10

——— Unconformity ———

Ordovician System
Canadian Series
Jefferson City Formation

Section 9

SW SW SE Sec. 4, T. 47 N., R. 14 W., about two-tenths of a mile northwest of Lupus, Moniteau County, Missouri, along the Missouri River bluffs and the Missouri Pacific Railroad, just northwest of Big Splice Creek (Columbia Quadrangle). Type section of the Lupus Physiofacies.

Covered		
Devonian System		
Erian Series		
Cedar City Formation		
Lupus Physiofacies		
1. Sandstone, white with yellowish-brown or reddish-brown streaks, fine to medium-grained, cross-laminated, friable except for top eight inches which are well-cemented, massive with nodules of sandstone at base	17	6
Mineola Physiofacies		
2. Limestone, light to medium tannish-brown, grayish-tan, yellowish-brown or pinkish-brown, medium to coarse-grained, arenaceous, crinoidal, thick-bedded with chert	10	0
Total Thickness	27	6

——— Unconformity ———

Ordovician System
Canadian Series
Jefferson City Formation

Section 10

SW SE SE NW Sec. 13, T. 46 N., R. 14 W., in an abandoned quarry about three-fourths of a mile southeast of Sandy Hook, Moniteau County, Missouri, along the Missouri River bluffs and Missouri Pacific Railroad (Centertown Quadrangle). Type section of the Sandy Hook Physiofacies.

Mississippian System
Kinderhookian Series
Chouteau Formation (Siphonodella Beds)

———— Unconformity ————

Devonian System
Erian Series
Cedar City Formation
Sandy Hook Physiofacies
6. Limestone, light greenish-gray to grayish-tan, dense, dolomitic, mottled, pyritic, arenaceous medially 12 9
Lamine River Physiofacies
5. Chert Conglomerate, light to medium grayish-white, fine-grained, calcareous sandstone matrix, massive 0 6
Calwood—Mineola Physiofacies
4. Limestone, light grayish-tan, fine to medium-grained, arenaceous, argillaceous, cherty, glauconitic, thick-bedded 2 0
Mineola—Smithton Physiofacies
3. Limestone, medium grayish-tan, coarse-grained, crinoidal, thick-bedded 0 9
Lamine River Physiofacies
1. Chert Conglomerate, light grayish-tan, yellowish-brown-weathering, arenaceous, calcareous, medium to coarse-grained sandstone matrix with small chert fragments and pebbles of oolite-glauconite 2 0

Total Thickness 18 0

Covered

Section 11

NW SE SE Sec. 8, T. 48 N., R. 8 W., at the junction of Auxvasse Creek and a west-flowing tributary to Auxvasse Creek about one-half mile north of U.S. Highway 70, east and south of Old Auxvasse Church (Fulton Quadrangle). Type area of the Calwood Physiofacies.

Top of the hill.
Devonian System
Erian Series
Cedar City Formation
Calwood Physiofacies
8. Limestone, light to dark grayish-tan, weathers yellowish to reddish-brown, fine to medium-grained, in part dolomitic (Sandy Hook) medially, thick-bedded with dark brown shale partings 24 6
Sandy Hook Physiofacies
7. Dolomite, medium yellowish-brown, fine-grained, massive 1 7
Calwood Physiofacies
6. Limestone, medium to dark grayish-tan, fine to medium-grained, thick-bedded, with nodules at the base 6 5
Covered 4 0
Mineola Physiofacies
5. Limestone, medium grayish-tan, weathering, yellowish-brown, fine to coarse-grained, crinoidal, arenaceous, vuggy, in part dolomitic in upper half, thick-bedded .. 12 0
Lupus Physiofacies
4. Sandstone, light to medium grayish-tan in upper half to light or medium gray in lower half, fine to coarse-grained, slightly crinoidal, limonitic, calcareous, massive 12 1
Clifton City Physiofacies
3. Limestone, medium pinkish or grayish-tan, dense to fine-grained, medium-bedded with sparry calcite 0 6
Lupus Physiofacies
2. Sandstone, white to light or medium gray, fine-grained, limonitic, calcareous, massive 3 0

Little Shaver Creek Physiofacies		
1. Limestone, medium to dark grayish-tan, dense to fine-grained, finely laminated, calcitic, thin-bedded	6	6
Total Thickness	70	7

Stream level

The Cooper Lithofacies. — The Cooper Lithofacies consists mainly of dense to sublithographic, very finely clastic limestones, which are light to medium grayish-tan or tannish-gray, pinkish-gray or bluish-gray and, for the most part, thick bedded or massive. Calcite-filled veins, vugs and vermicules are common. The basal portion of the Cooper Lithofacies is made up of a chert and limestone conglomerate, a green clay or an oolitic limestone conglomerate.

The Cooper Lithofacies crops out in Saline, Pettis, Morgan, Cooper, Moniteau, Cole, Boone, Callaway, Montgomery, Pike, Ralls and Marion Counties.

The maximum thickness of the Cooper Lithofacies, about 43 feet, was measured in an abandoned quarry about 2 miles southwest of Otterville along the north side of U.S. Highway 50 (Section 5). This section is here designated the type section of the Cooper Lithofacies. (FIG. 6)

The Cooper Lithofacies is overlain by the *Siphonodella* Beds of the Bachelor Formation (Mehl, 1960) over most of its outcrop area. Where the Bachelor is absent, it is overlain by the Chouteau Formation. In other areas it is overlain by the Holts Summit Formation (Mehl, 1960), Turpin Sandstone (Mehl, 1960), the Grassy Creek Formation or the Callaway Lithofacies. The Cooper Lithofacies over most of its outcrop area overlies the Cotter-Jefferson City Formations. In places it overlies the Saint Peter, Joachim, Kimmswick and Maquoketa Formations.

With the exception of *Rensselandia* and a few favositids at the Hall and Riley quarry (NW SW SW Sec. 23, T. 49 N., R. 21 W., Saline County) and some stromatoporoids northwest of Otterville (S½ SE NW SE Sec. 29, T. 46 N., R. 19 W., Cooper County), the Cooper Lithofacies is barren of megafossils to the west in Saline, Pettis, Morgan, Cooper, Moniteau and Cole Counties. None of the fossils listed from the Cooper by Greger (1920, p. 21) were found during this study. However, there is an abundance of ostracodes and charophytes present (NW SE SE NW Sec. 5, T. 46 N., R. 19 W., Cooper County). The Cooper Lithofacies does contain megafossils in Boone County and elsewhere, where it interfingers with the Callaway Lithofacies. (See Table 2.—*Megafauna of the Cooper Lithofacies*).

Since the Cooper Lithofacies interfingers with and, therefore, is equivalent to the Callaway Lithofacies, and since both lithofacies contain Middle Devonian fossils, a Middle Devonian age is assigned to the Cooper.

FIGURE 6.—Type section of the Cooper Lithofacies (Section 5).

The Physiofacies of the Cooper Lithofacies

The Lamine River Conglomerate Physiofacies.—The initial deposit of the Cooper Lithofacies, a chert, phosphate and limestone conglomerate, is hereby designated the Lamine River Physiofacies. It is best developed in Pettis and Cooper Counties along the Lamine River, for which it is named, and its tributaries. This facies also crops out along the Missouri River 0.75 mile northeast of Saline City in Saline County, between the towns of Lupus and Marion in Moniteau and Cole counties and about 0.75 miles west of Lupus. Similar deposits are to be found in Boone County about 1.5 miles northwest of Easley and about 0.6 mile southeast of Wilton, along the Missouri River. In Callaway County it occurs about 2.5 miles east of New Bloomfield on Hiller's Creek, in Lincoln County on Bob's Creek about 0.25 mile west of Brussels and in Ralls County about 4.5 miles northwest of New London.

The thickness of the Lamine River Facies varies from zero to 29 feet. The maximum thickness was measured about 4 miles north of Smithton (NC NW NE NW Sec. 26, T. 46 N., R. 20 W., Pettis County).

This conglomerate contains angular fragments of chert ranging in size from sand to boulders and fragments of limestone ranging from pebbles to cobbles. The chert is largely dark gray, bluish-gray, brownish-gray or white; plain, banded or oolitic; resembling that found in the Jefferson City Formation. The limestone pebbles and cobbles are dark brownish-gray and fine-grained. At Easley (SW SE SE Sec. 28, T. 47 N., R. 13 W., Boone County) fragments of Cooper limestone (Clifton City), occur sparsely in the basal conglomerate. The limestone cobbles are

Table 2.—Megafauna of the Cooper Lithofacies.

Coelenterata
- *Alveolities subramosus?* Rominger
- *Aulopora?* sp. no. 1
- *Aulopora?* sp. no. 2
- *Blothrophyllum cooperensis* (Branson)
- *Blothrophyllum* sp.
- *Cylindrophyllum* sp.
- *Cystiphylloides americanus* (Edwards and Haime)
- *Cystiphylloides conifolis* (Hall)
- *Favosites alpenensis alpenensis* Winchell and varieties
- *Favosites romingeri romingeri* Swann and varieties
- *Hexagonaria lativentra* (Stainbrook)
- *Hexagonaria profunda* (Hall)
- *Hexagonaria quadrigeminum arctica* (Meek)
- *Tabulophyllum* sp.

Stromatopora
- *Ansotylostroma laxum* Galloway and St. Jean
- *Clathrocoilona abeona* Yavorsky
- *Stachyodes caespitosa* Lecompte

Bryozoa
- *Sulcoretepora mineolanensis* (Branson)

Brachiopoda
- *Athyris nuculoidea* Cooper
- *Atrypa devoniana bentonensis* Stainbrook
- *Cranaena linckleani* (Hall)
- *Cranaena* sp.
- *Eosyringothyris* sp. no. 1
- *Eosyringothyris* sp. no. 2
- *Rensselandia johanni* (Hall)
- *Rensselandia missouriensis* (Swallow)

Pelecypoda
- *Conocardium ohioense* Meak
- *Conocardium* sp.

Gastropoda
- *Turbonopsis providencis* (Broadhead)
- Small high-spired gastropods

Cephalopoda
- *Acleistoceras?* sp. no. 1
- *Acleistoceras?* sp. no. 2

well-developed in the NW SW NE NE Sec. 24, T. 46 N., R. 14 W. in Cole County. No fossils were found in these limestone pebbles and cobbles.

The matrix of the Lamine River consists of fine to medium-grained quartz sand which weathers to a yellowish-brown or red and contains pyrite, pseudomorphs of limonite after pyrite and hematite in small quantities. The quartz grains are, for the most part, rounded like those found in the Saint Peter Formation and some are frosted. In places the matrix has a green color due to the presence of green clay or the interfingering of the Shiel Physiofacies. At one locality the matrix is gray because of the presence of organic material (Section 5). The matrix is friable to well-cemented, especially toward the top, the cement being largely calcium carbonate with minor amounts of limonite and hematite.

The Lamine River Conglomerate Facies:

1. interfingers with, underlies and overlies the Shiel Clay Facies.
2. is overlain by the Lupus Sandstone Facies and is apparently stratigraphically equivalent to that facies (see also the Lupus Facies).
3. overlies and underlies the Little Shaver Creek Laminated Limestone Facies.
4. overlies, underlies and interfingers with the Smithton Limestone Facies.
5. overlies and underlies the Little Splice Creek Brecciated Limestone Facies.
6. underlies the Clifton City Intraclastic Limestone Facies (to the northwest of Lupus, along the Missouri River, the Clifton City grades into the Little Shaver Creek which grades into the Mineola).
7. grades laterally into the Smithton and Little Splice Creek Facies.
8. overlies, underlies and interfingers with the Mineola Facies.
9. underlies and interfingers with the Sandy Hook Facies.
10. is overlain by the *Siphonodella* Beds of the Bachelor Formation and by the Chouteau and Burlington Formations of Mississippian age.
11. is underlain by the Cotter-Jefferson City, Saint Peter and Kimmswick Formations of Ordovician age.

On the north side of Moniteau Creek about three miles southwest of Sandy Hook (SW SE NE Sec. 27, T. 46 N., R. 14 W., Moniteau County), the Lamine River contains *Ptyctodus calceolus* (Newberry and Worthen); therefore, the Lamine River is no older than Devonian in age. The age of the Lamine River is Middle Devonian, since it is closely related stratigraphically with all of the physiofacies of the Cooper Lithofacies which is considered to be Middle Devonian in age.

The Shiel Clay Physiofacies.—The Shiel Clay Facies is also a basal unit of the Cooper Lithofacies. It is best exposed in the vicinity of the town of Shiel, hence the name, in Ralls County, especially in the quarry of the Central Stone Company at Huntington, about 1.5 miles northeast of Shiel (Section 6). The Shiel crops

out in Pettis, Cooper, Moniteau, Cole, Callaway and Ralls Counties.

The maximum thickness measured was 15.5 feet (NW NE NW Sec. 32, T. 46 N., R. 13 W.) about a mile northeast of the town of Marion in Cole County. Ten feet was measured at Section 7, about 0.5 mile southeast of Lupus in Moniteau County. Both of these localities are along the Missouri River bluffs. A nine foot thickness of this facies was measured along a tributary to Turkey Creek (SE SE NE S ½ Sec. 2, T. 56 N., R. 5 W.) about 2 miles southwest of New London in Ralls County.

The Shiel Facies consists of green clay-shale, which, southeast of Lupus (Section 7), is very arenaceous and contains piles and lenses of dark, brownish-gray limestone pebbles and cobbles. Lithologically these limestone pebbles and cobbles resemble the dark upper limestone beds of the Kimmswick Formation in the Huntington quarry. Also in the Huntington Quarry (Section 6) the Shiel contains stringers of light to medium gray, fine-grained limestone. Northwest of Marion (NW NE NW Section 32, T. 46 N., R. 13 W., Cole County) the Shiel is very cherty. The sand found in the Shiel is similar to that found in the Saint Peter Formation and the chert like that found in the Jefferson City Formation.

Southeast of Lupus the Shiel can be traced directly into the Lamine River Facies (Section 7). In the NW SE Section 24, T. 56 N., R. 5 W., about 3.25 miles north and slightly west of New London, the Shiel Facies underlies the Lamine River Conglomerate Facies (Williams, 1952). In the west half of the same section this Shiel underlies the Ralls Conglomerate Facies (Williams, 1952).

The Shiel Clay Facies:

1. overlies, underlies and interfingers with the Lamine River Facies.
2. is overlain by and interfingers with the Little Shaver Creek Facies.
3. is overlain and underlain by the Smithton Facies.
4. underlies the Little Splice Creek Facies.
5. overlies and underlies the Ralls Conglomerate Facies.
6. overlies the Saint Peter, Cotter-Jefferson City and Kimmswick Formations of Ordovician age.
7. underlies the Grassy Creek Shale of Upper Devonian age.

In Ralls County the Shiel Clay has yielded freshwater-type ostracodes, charophytes, chitinozoa, holothurian sclerites and scolecodonts. The charophytes belong to the genus *Trochiliscus*, which does not occur in rocks older than Devonian. In Cole County (M W½ SW SW Section 29, T. 46 N., R. 13 W.), *Ptyctodus calceolus* (Newsberry and Worthen) is present in the Shiel at the base of the section.

Thus we see that the Shiel Facies contains fossils no older than Devonian in age and is closely related stratigraphically to other facies of the Cooper Lithofacies; and therefore, is assigned a Middle Devonian age.

The Ralls Oolitic Limestone Conglomerate Physiofacies. — The Ralls Conglomerate Physiofacies is a basal

unit of the Cooper Lithofacies in parts of Ralls County. It crops out at three localities and occurs as a constituent of another facies at a fourth locality. The first locality is in the SE SE NE S ½ Section 2, T. 56 N., R. 5 W., about 2 miles southwest of New London, where the maximum observed thickness of the facies, seven and one half feet, is exposed. Six inches of the facies is exposed at the second locality in the NE SW NE SW Section 24, T. 56 N., R. 5 W., about 3.5 miles north and slightly west of New London. At the third locality, in the NW NW NW Section 19, T. 56 N., R. 4 W. (Williams, 1952) about 4 miles north of New London, 22 inches of Ralls Conglomerate is present. Scattered pebbles and cobbles of this facies occur within the upper Little Splice Creek Facies in Huntington Quarry (Section 6) about 1.5 miles northeast of Shiel.

The bulk of the Ralls Conglomerate Physiofacies consists of light whitish-gray, oolitic limestone containing rounded granules to boulders of oolitic limestone. This facies may also be made up of light gray to reddish-brown oolitic limestone with chert granules and pebbles present toward the top of the exposure at the first locality. Also included are granules to cobbles of light to medium gray, fine-grained to sublithographic limestone. The basal six inches of the section at the first locality consists of medium greenish to tannish-gray, fine-grained to dense, clastic, laminated limestone of the Little Shaver Creek Facies. Here the matrix is oolitic limestone, of essentially the same color as the granules, pebbles, cobbles and boulders, which grades northward into an arenaceous, oolitic limestone with granules and pebbles aligned roughly parallel to the bedding planes. This facies grades laterally in the same direction into a medium to dark, tannish-gray limestone containing oolitic limestone pebbles and finally into a laminated, medium tannish-gray, fine-grained, calcitic limestone, the Little Shaver Creek Facies.

The unit as a whole is medium to thick-bedded or massive.

At localities two and three the matrix tends to be a sublithographic limestone.

The oolitic limestone matrix and the granules to boulders are similar, lithologically, to the Noix Oolite of the Cyrene Member of the Edgewood Formation, Lower Silurian.

The Ralls Facies:

1. is overlain and underlain by the Shiel Facies.
2. is underlain and grades into the Little Shaver Creek Facies.
3. is overlain and underlain by the Smithton.
4. interfingers with the Little Splice Creek Facies.

Consequently, the Ralls Facies is stratigraphically equivalent, at least in part, to the Shiel, Little Shaver Creek, Smithton and Little Splice Creek Facies.

No fossils have been found in the Ralls Conglomerate Facies.

The Little Shaver Creek Laminated Limestone Physiofacies.—The Little Shaver Creek Laminated Limestone Physiofacies is best developed along Little Shaver Creek in eastern Pettis County. This facies crops out in Pettis, Cooper, Mor-

gan, Saline, Moniteau, Cole, Boone, Callaway, and Ralls Counties. It is named for the Little Shaver Creek.

The maximum observed thickness of this facies is in the SE SW Sec. 15, T. 56 N., R. 5 W., about 4.5 miles northwest of New London, Ralls County, where about nine and a half feet are exposed. A little more than six feet are exposed in the Huntington Quarry, about 1.5 miles northeast of Shiel (Section 6). In Pettis and Cooper Counties the maximum observed thickness was three and a half feet (CN ½ S ½ NW Sec. 35, T. 46 N., R. 20 W., Pettis County), about 2.75 miles north of Smithton. However, the facies is geographically more extensive in this area. (FIG. 7)

This facies consists of light to dark, tannish-gray or grayish-tan to pinkish-gray or tan, fine-grained, dense or sublithographic, thin-bedded to largely unevenly thick-bedded or massive, laminated, clastic limestone. About 4.5 miles northwest of New London in Ralls County (SE SW Sec. 15, T. 56 N., R. 5 W.), it contains in the base of the upper unit broken fragments of stromatolites and limestone pebbles. Northeast of Hartsburg (NW NE NW NW Sec. 33, T. 46 N., R. 12 W., Boone County) and at Sections 1 and 3, the Little Shaver Creek is very light grayish-tan and relatively coarsely clastic.

Along the Missouri River bluff about 1 mile northwest of Lupus (NE SW SW NW Sec. 4, T. 47 N., R. 14 W., Moniteau County), there is a reddish-brown shale between the top of the upper Little Shaver Creek and the *Siphonodella* Beds, which is lithologically similar to the Upper Devonian shale found along the Missouri River bluffs between Providence and Easley in Boone County. This latter unit was formerly assigned to the Grassy Creek, but is now assigned to the Holts Summit Formation by M. G. Mehl (personal communication).

In the Lupus area the Little Shaver Creek becomes more coarsely grained, as does the Clifton City, where it occurs towards the base of the Cedar City sequence. Laterally, with the introduction of quartz sand, it grades into the Mineola.

The Little Shaver Creek Facies:

1. overlies, underlies, and interfingers with the Smithton Facies.
2. overlies, underlies, and interfingers with the Clifton City Facies.
3. overlies, underlies, and interfingers with the Little Splice Creek.
4. overlies, underlies, and interfingers with the Sandy Hook Facies.
5. overlies, underlies, and grades into the Mineola Facies.

FIGURE 7.—A ledge of typical Little Shaver Creek Physiofacies in its type area (center N½ S½ NW Sec. 35, T.46 N., R.20 W.), Pettis County, Missouri, in draw just east of county road.

6. overlies and underlies the Calwood Facies.
7. overlies and underlies the Lupus Facies.
8. overlies and underlies the Lamine River Facies.
9. overlies, underlies, and interfingers with the Shiel Facies.
10. overlies the Cotter-Jefferson Formations (Lower Ordovician).
11. underlies the *Siphonodella* Beds of the Bachelor Formation (basal Mississippian).

Since the Little Shaver Creek is stratigraphically equivalent to the Mineola, Sandy Hook and Calwood Facies which contain Middle Devonian fossils, the Little Shaver Creek is here regarded as Middle Devonian in age. At some places the laminations in Little Shaver Creek are probably organic in origin (NE SW SW N ½ Sec. 2, T. 55 N., R. 5 W., Ralls County), but, for the most part, the laminations seem to be sedimentary in origin.

Little Splice Creek Brecciated Limestone Physiofacies.—The Little Splice Creek Brecciated Limestone Facies is named for Little Splice Creek in Moniteau County. This creek empties into the Missouri River less than 0.25 mile northwest of a measured section (Section 7) which well displays the facies. The Little Splice Creek Facies is best developed in Moniteau and Ralls Counties. It also occurs in Pettis, Cooper, Cole, Boone and Callaway Counties. The thickest, well-developed section is in the quarry of the Central Stone Company at Huntington, Ralls County (Section 6). Here about eight feet is present. Therefore, the thickness of the facies ranges from zero to eight feet.

The Little Splice Creek Facies is light to medium grayish-tan or tannish-gray, light gray to white, pinkish-tan or light to dark bluish-tan, and, in some places, dark tannish-gray in color. It is a dense to sublithographic, brecciated limestone, somewhat arenaceous especially towards the base, with chert and chalcedony-filled vugs; calcite-filled vugs, veins and vermicules; clay partings and sand lenses. In part it is laminated and intraclastic. The limestone breccia fragments range in color from grayish-tan, tannish-gray or light gray to red and brown. In size they range from fine grains to pebbles and cobbles, but are largely in the granule to cobble range. The Little Splice Creek Facies is, for the most part, thick-bedded to massive.

The Little Splice Creek Facies:

1. underlies the *Siphonodella* Beds of the Bachelor Formation (basal Mississippian).
2. underlies, overlies and interfingers with the Little Shaver Creek Facies.
3. underlies, overlies and interfingers with the Smithton Facies.
4. overlies and interfingers with the Lamine River Facies.
5. underlies and grades into the Sandy Hook Facies.
6. underlies and interfingers with the Mineola Facies.
7. overlies the Lupus Facies.
8. overlies the Shiel Facies.
9. overlies the Jefferson City Formation (Lower Ordovician).

At two localities the breccia contains fossils. The one (Section 7) about 1 mile southeast of Lupus, Moniteau County, along the Missouri River, contains horn corals, *Favosites romingeri* var., *Blothrophyllum cooperensis, Eosyringothyris* sp., *Favosites alpenensis* var., and *Stropheodonta* sp. Here the breccia also contains reworked pebbles and cobbles of the Little Shaver Creek. At another locality (SC SE SW SE Sec. 5, T. 47 N., R. 14 W.) about 1 mile northwest of Lupus, Moniteau County, the breccia contains two species of *Blothrophyllum* and *Favosites alpenensis* var.

Thus the Little Splice Creek, is for the most part, stratigraphically younger than the Lamine River and Shiel Facies, is stratigraphically equivalent to the Smithton, Little Shaver Creek, Sandy Hook and Mineola Facies and contains fossils which are also present in the Callaway Lithofacies. Therefore, the Little Splice Creek is considered to be Middle Devonian in age.

The Smithton Dense Limestone Physiofacies.—The Smithton Facies is named from outcrops in Pettis and Cooper Counties within an area 3.5 miles north and 2.5 miles east of the town of Smithton, for which it is named, Pettis County. This facies is especially well exposed in an abandoned quarry (Section 5) along the north side of U.S. Highway 50 about 3 miles northeast of Smithton. Here over 25 feet of this facies is exposed, the maximum observed. The Smithton Facies crops out in Saline, Pettis, Cooper, Morgan, Moniteau, Cole, Boone, Callaway, Montgomery, Pike, Ralls and Marion counties.

The Smithton Facies consists of limestone, light to dark grayish-tan or tannish-gray, medium reddish-gray or medium bluish-gray or pinkish-tan, very finely clastic, dense or sublithographic, medium to thick-bedded or massive, in part vermicular with vermicules vertical, oblique or horizontal to the bedding planes. This limestone is also in part calcitic, with calcite-filled veins, vugs and vermicules (sparry calcite); in part pyritic, with pyrite-filled veins and vugs; the darker color present is often due to pyrite concentrations. At one locality the Smithton contains joints and vugs filled with barite (Section 5). It also contains green clay-filled vugs, vermicules and partings, limonite staining and pellets, limonite-filled vugs and vermicules, hematite staining and pellets, and hematite-filled vugs and vermicules. In places the Smithton is partially crinoidal, where it is adjacent to the Mineola Facies. At some localities the Smithton is in part glauconitic towards the base. The contained sparry calcite may be aligned parallel to the bedding planes and may also be silicified. In places the Smithton is mottled. The mottling, more often than not, is due to concentrations of pyrite, the darker color mentioned above. In part the Smithton is stylolitic and contains scattered angular, but usually rounded and in part frosted, quartz grains at various horizons. At one locality (Section 5) the facies contains secondary ("leak") clay-shale partings of red to purple color, probably Pennsylvanian material. In places the Smithton contains Jefferson City-type chert near the base. In other

places, also at various horizons, it contains white to medium blue or bluish-gray chert in elongate nodules, one quarter inch by two to three inches, or in layers as thick as ten inches to one foot. The latter, where observed, were at or near the base of the facies. The thick-bedded chert is often vermicular. The Smithton is also in part clastic, becoming more clastic towards the east in Moniteau, Cole, Boone, Callaway and Montgomery Counties. Ripple marks are present in the middle of the Smithton section (NW NW SW SW Sec. 34, T. 47 N., R. 19 W., Cooper County) and at the top of the Smithton section (across U.S. Highway 54 from Section 2). Where sparritic, the Smithton is similar to the Clifton City in lithology. The Smithton Physiofacies represents the "typical" Cooper of previous authors.

The Smithton:

1. overlies and underlies the Lamine River Facies.
2. overlies, underlies and interfingers with the Little Shaver Creek Facies.
3. overlies, underlies and interfingers with the Little Splice Creek Facies.
4. overlies, underlies and interfingers with the Clifton City Facies.
5. overlies, underlies and interfingers with the Mineola Facies.
6. overlies, underlies and probably interfingers with the Sandy Hook Facies.
7. overlies and underlies and interfingers with the Calwood Facies.
8. overlies, underlies and interfingers with the Lupus Facies.
9. overlies the Joachim Formation (Middle Ordovician).
10. overlies the Cotter-Jefferson City (Lower Ordovician).
11. overlies the Saint Peter Formation (Middle Ordovician).
12. underlies the *Siphonodella* Beds of the Bachelor (basal Mississippian).
13. underlies the Chouteau Formation (Kinderhook).

The Smithton contains abundant charophytes and ostracodes in places. Charophytes are especially abundant throughout the Smithton Facies (NW SE SE NW Sec. 5, T. 47 N., R. 19 W., Cooper County), about 1.75 miles northeast of Clifton City along the northwest side of State Highway 135. Ostracodes are also abundant at or near the base of this facies, especially in an abandoned quarry, about 2.25 miles west of Otterville along the north side of U.S. Highway 50 (Section 5).

In Boone County (E ½ SW NE NE Sec. 4, T. 45 N., R. 12 W.), the Smithton contains *Turbinopsis providencis*. What Marbut (1907) referred to as an abundant "loose growing compound coral" in Morgan County apparently is actually vermicules filled with calcite which stand out in relief due to weathering. The Smithton contains *Rensselandia* in the Hall and Riley Quarry (NW SW SW Sec. 23, T. 49 N., R. 21 W., Saline County).

Since the Smithton contains *Rensselandia*, it must be considered Middle Devonian in age. It should be

noted that the Smithton interfingers or is closely associated stratigraphically with facies which do contain Middle Devonian fossils in central and northeastern Missouri. It should also be noted that the trochiliscid-type of charophyte found in the Smithton in west central Missouri is not known from rocks older than Devonian.

The Clifton City Intraclastic Limestone Physiofacies. — The Clifton City Facies was named from an outcrop in a road ditch along the east side of a county road about 0.5 mile south of the town of Clifton City, for which it is named, in Cooper County (CL between Sections 17 and 18, T. 46 N., R. 19 W.). Here about eleven feet, the maximum observed, is exposed. The facies is also well exposed about 1.75 miles northeast of Clifton City along the northwest side of State Highway 135 (NW SE SE NW Sec. 5, T. 47 N., R. 19 W.), Cooper County. The Clifton City Facies, about nine feet, is well-exposed in an abandoned quarry along the north side of U.S. Highway 50, about 2.25 miles west of Otterville (Section 5) in Cooper County. This facies is also exposed in Saline, Pettis, Morgan, Moniteau, Cole, Boone, and Callaway Counties.

The distinguishing lithologic characteristic of the Clifton City Facies is the placement of the sparry calcite which tends to enclose groups of clastic particles, giving the rock a roughly reticulate appearance. The Clifton City Facies consists of intraclastic limestone, very light to dark tannish-gray or light to medium grayish-tan, light to medium pinkish-gray or pinkish-tan in color. In some places it is abundantly pyritic. This facies varies from medium to thick-bedded or massive and not uncommonly contains scattered, rounded, and, in places, frosted grains of fine quartz. Rarely it is vermicular. It contains many veins and vugs filled with sparry calcite and green clay, the latter especially toward the top of outcrops. In places it is limonitic and hematitic and occasionally contains thin quartz sand lenses. In one outcrop, pseudomorphs of limonite after pyrite occur. Only the presence of laminations make the Little Shaver Creek distinguishable from it in the lower part of Cedar City sections in Moniteau and Boone Counties. In places the Clifton City is stylolitic.

The Clifton City Facies:

1. overlies, underlies and interfingers with the Smithton Facies. It should be noted here that the Clifton City becomes more coarsely clastic in Moniteau, Cole, Boone and Callaway Counties as compared to its nature in Saline, Pettis, Cooper and Morgan Counties. Also, in the first mentioned group of counties the Clifton City is largely contained within the Smithton Facies, which also becomes more clastic coming east into central Missouri. As the Clifton City and the Smithton become more clastic and finally develop a "grainy appearance," they form the Calwood Facies. When they become sandy and crinoidal, as well as coarsely clastic, they form the Mineola Facies. If they are dolomitized, which seems

to occur only in areas where they have become relatively coarsely clastic, they form the Sandy Hook Facies. As long as the limestones in question have the appearance of being a dense limestone in the field, even though they may be quite clastic, but finely so, they are assigned to the Smithton and Clifton City Facies.

2. overlies, underlies and interfingers with the Little Splice Creek Facies.
3. overlies, underlies and interfingers, as well as grades upward into, Little Shaver Creek Facies.
4. overlies, underlies and interfingers or is adjacent to the Mineola Facies. The latter situation exists where there is an erosional contact between the two.
5. overlies, underlies and interfingers with the Sandy Hook Facies.
6. overlies, underlies and interfingers with the Calwood Facies.
7. overlies and underlies and in places interfingers with the Lupus.
8. overlies Lamine River Facies.
9. overlies the Jefferson City Formation (Lower Ordovician).
10. overlies the Saint Peter Formation (Middle Ordovician).
11. underlies the *Siphonodella* Beds of the Bachelor Formation (basal Mississippian).

Where the Clifton City is contained within the Smithton the former sometimes contains ostracodes. West of Holts Summit where the Clifton City grades into the Mineola ostracodes are present. Megafossils are found in this physiofacies only in the Boone-Callaway County area.

Since the Clifton City Facies contains Middle Devonian fossils, interfingers with and is otherwise closely allied to the Calwood, Mineola and Sandy Hook Facies which contain Middle Devonian fossils, the Clifton City Facies must be considered stratigraphically equivalent to those facies and of Middle Devonian age.

The Callaway Limestone Lithofacies. — The Callaway Limestone Lithofacies is best developed in Callaway County. The most representative outcrop is located about 2.25 miles northeast of Hams Prairie (Section 8). This section displays well the Mineola, Sandy Hook and Calwood Physiofacies and at the base a thin bed of Lupus Sandstone. The former three physiofacies are overlain by the Calwood ("grainy" Smithton) Physiofacies and are underlain by the Smithton of the Cooper Lithofacies. The Smithton interfingers with the Little Shaver Creek Facies and the Little Splice Creek Facies in descending order, all physiofacies of the Cooper Lithofacies. This section also displays well the *Hexagonaria profunda, Hexagonaria lativentra, Atrypa missouriensis, Stropheodonta, Tabulophyllum* and *Stachyodes* biofacies.

Greger (1936) mentioned Bellama Springs, Callaway County, as the type section of the Callaway Formation; no further information was

found. This outcrop is located about 0.75 mile north and slightly east of the Hams Prairie locality, referred to above. The name Bellama Springs is no longer in general use and could not be found on any of the available maps. According to M. G. Mehl, however, (personal communication) the section referred to as Bellama Springs by Greger is the same section which is herein referred to as the Crow's Fork section (SW NW NW NE Sec. 1, T. 46 N., R. 9 W., Callaway County). The section does not show the Mineola Physiofacies or the *Stropheodonta* and *Tabulophyllum* Biofacies as well as the Hams Prairie section does. Nor does the Crow's Fork section include any Lupus Sandstone (FIGS. 8-11)

The thickest section of the Callaway Lithofacies observed and measured is about 63.5 feet in thickness and occurs at the junction of a west-flowing tributary to Auxvasse Creek and Auxvasse Creek (NW SE SE Sec. 8, T. 48 N., R. 8 W., Callaway County), overlying the Little Shaver Creek Facies of the Cooper (called Plattin by Branson) and covered above.

FIGURE 8.—Greger's type section of the Callaway Formation at Bellama Springs (SW NW NW NE Sec. 1, T.46 N., R.9 W.), Callaway County, Missouri, along northwest side of county road.

FIGURE 9.—Upper part of the type section of the Callaway Lithofacies (Section 8).

FIGURE 10.—Middle part of the type section of the Callaway Lithofacies (Section 8).

FIGURE 11.—Lower part of the type section of the Callaway Lithofacies (Section 8).

Lithologically the Callaway Lithofacies consists of limestone, very light to dark tannish-gray or grayish-tan, fine-grained, thin-bedded to massive, in part dolomitic, argillaceous, coarsely crinoidal and arenaceous.

The Callaway Lithofacies crops out in Saline, Pettis, Cooper, Moniteau, Cole, Boone, Callaway, Montgomery, Warren, Saint Charles, Lincoln, Pike, Ralls, and Marion Counties. It is overlain, underlain, and interfingers with the various physiofacies of the Cooper Lithofacies. Where not directly associated with the Cooper, in Saline County, north of Saline City, it is underlain by the Kimmswick Formation. It is underlain by the Jefferson City and Saint Peter Formations in Moniteau, Cole, Boone and most of Callaway County. Along Clarks Branch north of Williamsburg, the Callaway is underlain by the Plattin and southeast of Readsville along Big Tavern and Tavern Creeks it is underlain by the Joachim. In Montgomery County the Callaway is underlain by the Plattin and Joachim. In Warren County it is underlain in the western part by the Plattin, and south of Warrenton by the Kimmswick. It is also underlain by the Kimmswick, where exposed, in Saint Charles County. In Lincoln County it is underlain by the Maquoketa. In Pike County the Callaway is underlain by the Bowling Green or the Maquoketa. In Ralls County the Callaway overlies Kimmswick or the Maquoketa. In Marion County it apparently also overlies Kimmswick, but the underlying strata and the base of the Callaway were not seen there.

Where it is not associated with the Cooper or is not covered the Callaway is overlain in Saline, Pettis, Cooper, Moniteau and Cole Counties by the *Siphonodella* Beds of the Bachelor Formation. In Moniteau County (NE SW SW NW Section 4, T. 47 N., R. 14 W.) the Callaway Lithofacies is overlain by shale lithologically similar to a small patch of shale overlying the Cedar City in Boone County about one mile southeast of Providence along the Missouri River bluffs (near the center of Section 28, T. 47 N., R. 13 W.). This shale was formerly referred to the Grassy Creek Formation, but is now regarded as Holts Summit by M. G. Mehl (personal communication) (see Rush, T. D., 1950). In Boone County it is also overlain by the *Siphonodella* Beds or where they are absent, by the Chouteau. In Callaway County it is overlain by the *Siphonodella* Beds, Pennsylvanian sands and shales or by the Upper Devonian Snyder Creek or Holts Summit Formations. In Montgomery County it is overlain by the Snyder Creek Shale. In Warren County, where observed, it is overlain by the Bachelor or the Chouteau Formation. In Saint Charles County the Callaway is covered above. In Lincoln County it is overlain by the Chouteau and Grassy Creek Formations. In Pike County it is overlain by the Grassy Creek and Turpin Sandstone. In Ralls County it is overlain by Grassy Creek, covered or overlain by part of the Cooper Lithofacies. In Marion County it is overlain by the Grassy Creek Shale. (See Table 3.—Megafauna of the Callaway Lithofacies).

The Callaway Lithofacies underlies the Snyder Creek, Turpin, Grassy Creek, Holts Summit, Massie Creek, *Siphonodella* Beds of the Bachelor Formation or Bachelor, Chouteau Formations and Pennsylvanian sandstones. It overlies the Jefferson City, Saint Peter, Joachim,

TABLE 3. — Megafauna of the Callaway Lithofacies.

Coelenterata
- *Alveolites* sp. no. 1
- *Alveolites* sp. no. 2
- *Alveolites* sp. no. 3
- *Alveolites suborbicularis* Lamarck
- *Aulacophyllum?* sp.
- *Aulopora* sp. no. 1
- *Aulopora* sp. no. 2
- *Aulopora?* sp. no. 3
- *Bethanyphyllum?* sp.
- *Bethanyphyllum* sp.
- *Billingsastraea billingsi* (Calvin)
- *Blothrophyllum cooperensis* (Branson)
- *Blothrophyllum* sp.
- *Chaetetes* sp.
- *Cladopora dichotoma* Hall
- *Cladopora roemeri* (Billings)
- *Cladopora* sp.
- *Cylindrophyllum panicum* (Winchell)
- *Cystiphylloides americanus* (Edwards and Haime)
- *Cystiphylloides conifolis* (Hall)
- *Drymopora grabaui* (Branson)
- *Eridophyllum* sp. no. 1
- *Eridophyllum* sp. no. 2
- *Eridophyllum* sp. cf. *E. seriale* Edwards and Haime
- *Favosites alpenensis alpenensis* Winchell and varieties
- *Favosites romingeri romingeri* Swann and varieties
- *Favosites* sp.
- *Hallia?* sp.
- *Heliophyllum halli* Edwards and Haime
- *Heliophyllum halli degener* Hall
- *Heterophrentis prolifica?* (Billings)
- *Heterophrentis?* sp.
- *Hexagonaria brandonensis* (Stainbrook)
- *Hexagonaria cedarensis* (Stainbrook)
- *Hexagonaria lativentrum* (Stainbrook)
- *Hexagonaria profunda* (Hall)
- *Moravophyllum* sp. no. 1
- *Moravophyllum* sp. no. 2
- *Moravophyllum?* sp.
- *Tabulophyllum callawayensis* (Branson)
- *Tabulophyllum callawayensis?* (Branson)
- *Thamnopora limitaris* Rominger
- *Thamnopora limitaris?* Rominger
- *Wedekindophyllum* sp.

Stromatopora
- *Anostylostroma laxum* Galloway and St. Jean
- *Clathrocoilona abeona* Yavorsky
- *Stachyodes caespitosa* Lecompte
- *Stromatopora divergens* Galloway and St. Jean
- *Stromatopora divergens?* Galloway and St. Jean
- *Stromatopora pachytexta* Lecompte
- *Stromatopora obscura* Galloway and St. Jean
- *Stromatopora submixta* Galloway and St. Jean

Annelida
- *Spirorbis omphaloides* Goldfuss

Blastoidea
- *Codaster gracilis* (Wachsmuth)
- *Pentremitidea* sp.
- *Placoblastus* sp., cf. *P. obovatus* (Barris)

Crinoidea
- *Megistocrinus missouriensis* Branson and Wilson

Echinoidea
- Echinoid spines

Bryozoa
- *Acrogenia prolifera?* Hall
- *Anastomopora* sp. cf. *A. cinctuta* (Hall)
- *Coscinotrypa missouriensis* (Branson)
- *Fenestella missouriensis* Branson
- *Fistulipora communis* (Ulrich)
- *Fistulipora magna-monticulata* (Branson)
- *Fistulipora* sp.
- *Hederella* sp., cf. *H. calvini* Bassler
- *Hederella conferta* (Hall)
- *Hederella filiformis* (Billings)
- *Hemitrypa mineolaensis* Branson
- *Hemitrypa* sp.
- *Leioclema occidens* (Hall and Whitfield)
- *Polypora finitima?* Deiss
- *Polypora* sp., cf. *P. magnifica* Deiss
- *Polypora* sp. no. 1
- *Polypora* sp. no. 2
- *Reptaria stolonifera* Rolle
- *Stictopora subcarinata* Hall
- *Sulcoretepora mineolaensis* (Branson)
- *Taeniopora exigue* Nicholson
- *Trematopora* (*Orthopora*) *reticulata?* Hall
- *Trematopora?* sp.

Brachiopoda

Anathyris quadrilobata Cooper
Ambothyris halli (Branson)
Athyris fultonensis Branson
Athyris nuculoidea Cooper
Athyris sp., cf. *A. nuculoidea* Cooper
Athyris vittata (Hall)
Athyris vittata (Hall) var.
Athyris? sp.
Atrypa bellula Stainbrook
Atrypa sp. no. 1
Atrypa devoniana bentonensis Stainbrook
Atrypa devoniana var.
Atrypa sp., cf. *A. spinosa* Hall
Centronella sp.
Cranaena elia (Hall)
Cranaena iowensis (Calvin)
Cranaena jacunda Hall
Cranaena jacunda? Hall
Cranaena late Stainbrook
Cranaena lincklaeni (Hall)
Cranaena lincklaeni? (Hall)
Cranaena littletonensis Stainbrook
Cranaena romingeri (Hall)
Cranaena romingeri? (Hall)
Cranaena sp., af. *C. romingeri* (Hall)
Cranaena sp.
Cranaena subglobosa Stainbrook
Cranaena sublingulata Stainbrook
Cranaena sublingulata? Stainbrook
Cranaena subobata Savage
Cranaena sp., aff. *C. thomasi* Stainbrook
Crania crenustriata Hall
Cyrtina hamiltonensis (Hall)
Cyrtina missouriensis (Swallow)
Cyrtina missouriensis? (Swallow)
Cyrtina sp.
Cyrtina triquetra (Hall)
Cyrtina triquetra? (Hall)
Douvillina bellistriata Cooper and Cloud
Douvillina sp.
Elytha subundifera (Meek and Worthen)
Eosyringothyris aspera (Hall)
Eosyringothyris aspera? (Hall)
Eosyringothyris calvini Stainbrook
Eosyringothyris sp.
Eosyringothyris occidentalis (Swallow)
Eosyringothyris sp.
Eosyringothyris? sp.
Eosyringothyris thomasi Stainbrook
Leptaena sp.
Leptostrophia fragilis Hall
Leptostrophia occidentalis Stainbrook
Leptostrophia sp., cf. *L. occidentalis* Stainbrook
Leptostrophia perplana (Conrad)
Leptostrophia perplana? (Conrad)
Lingula sp.
Meristella carinata? Stewart
Meristella sp., cf. *M. parva* Cooper and Cloud
Meristella sp.
Mutationella? sp.
Nucleospira ventricosa (Hall)
Nucleospira ventricosa? (Hall)
Orbiculoidea? sp.
Pentamerella laeviscula (Hall)
Pentamerella liorhyncha liorhynchoidea Cooper and Cloud
Pentamerella sp.
Pentamerella magna Stainbrook
Pentamerella sp., cf. *P. multicostata* Cleland
Pentamerella obsolescens (Hall)
Pentamerella sp.
Pentamerella? sp.
Petrocrania sp.
Petrocrania sp. no. 3
Petrocrania sp. no. 4
Pholidostrophia iowensis (Owen)
Productella sp. no. 1
Productella sp., cf. *P. belanskii* Stainbrook
Productella callawayensis (Swallow)
Productella sp. no. 2
Productella? sp.
Rensselandia johanni (Hall)
Rensselandia missouriensis (Swallow)
Rhipidothyris lepida Hall
Schizophoria iowensis Hall
Schizophoria lata Stainbrook
Schizophoria lata? Stainbrook
Schizophoria laudoni Stainbrook
Schizophoria laudoni? Stainbrook
Schizophoria propinqua (Hall)
Schizophoria sp.
Schuchertella arctostriata (Hall)
Schuchertella sp., cf. *S. arctostriata* (Hall)
Schuchertella sp., cf. *S. chemungensis* (Conrad)
Schuchertella sp., cf. *S. iowensis* Stainbrook
Schuchertella sp., cf. *S. perversa* (Hall)
Schuchertella? sp.
Spirifer (*Spinocyrtia*) *euruteines* Owen
Spirifer (*Spinocyrtia*) *iowensis* Owen
Spirifer (*Spinocyrtia*) sp.
Stenoscisma gregeri (Branson)
Stenoscisma gregeri? (Branson)
Stenoscisma sp. no. 1
Stenoscisma sp. no. 2
Stropheodonta sp.

Stropheodonta cedarensis Stainbrook
Stropheodonta dorsata Stainbrook
Stropheodonta halli Cleland
Stropheodonta halli? Cleland
Stropheodonta sp., cf. *S. iowensis* Owen
Stropheodonta littletonensis Stainbrook
Stropheodonta mineolaensis? Branson
Stropheodonta sp., cf. *S. parva* Owen
Stropheodonta plicata Hall
Stropheodonta plicata? Hall
Stropheodonta quadratella Stainbrook
Stropheodonta umbonata Stainbrook
Tylothyris annae (Swallow)
Tylothyris sp. no. 1
Tylothyris sp. no. 2
Tylothyris subvaricosa (Hall and Whitfield)
Tylothyris varicosa (Hall)
Tylothyris varicosa? (Hall)

Pelecypoda

Actinopteria sp.
Aviculopecten sp.
Aviculopecten? sp.
Conocardium ohioense Meek
Conocardium ornatus Cleland
Conocardium ornatus? Cleland
Conocardium sp. no. 1
Conocardium sp. no. 2
Leiopteria sp., cf. *L. bigsbyi* Hall
Leptodesma minutum Cooper and Cloud
Leptodesma sp., cf. *L. rogersi* Hall
Leptodesma sp.
Modiomorpha? sp.
Mytilarca sp.
Mytilarca? sp.
Nucula sp., cf. *N. corbuliformis* Hall
Nucula? sp.
Paracyclas rowleyi (Branson)
Paracyclas rowleyi? (Branson)
Paracyclas lirata? (Conrad)
Paracyclas tenuis Hall
Schizodus sp., cf. *S. appressus* Conrad

Gastropoda

Bellerophon pelops Hall
Bellerophan sp., cf. *B. thalia* Hall
Bellerophon sp.
Euryzone sp.
Loxonema sp., cf. *L. hamiltonae* Hall
Loxonema sp., cf. *L. terebra* Hall
Loxonema sp.
Mourlonia lucina? (Hall)
Platyceras sp., cf. *P. carinatum* Hall
Platyceras sp., cf. *P. erectum* Hall
Platyceras sp., cf. *P. nodosum* Conrad
Platyceras sp.
Small, high-spired gastropods

Cephalopoda

Anastomoceras sp. no. 1
Acleistoceras? sp. no. 1
Acleistoceras? sp. no. 2
Brevicoceras? sp. no. 1
Brevicoceras? sp. no. 2
Brevicoceras? sp. no. 3
Brevicoceras? sp. no. 4
Brevicoceras? sp.
Micronoceras sp.
Michelinoceras? sp. no. 1
Michelinoceras? sp. no. 2
Pseudorthoceras? sp. no. 1
Stereotoceras sp. no. 1
Stereotoceras sp. no. 2
Stereotoceras sp. no. 3
Stereotoceras sp. no. 4
Stereotoceras sp. no. 5

Mollusca—Incertae Sedis

Tentaculites bellulus Hall
Tentaculites attenuatus Hall

Trilobita

Cordania pulchra Cooper and Cloud
Cornuproetus calhounensis Cooper and Cloud
Cornuproetus sp.
Cornuproetus? sp.
Dechenella elevata Cooper and Cloud
"*Proetus*" sp., cf. "*P.*" *nortoni* Walter
"*Proetus*" sp.
Scutellum tullium depressum Cooper and Cloud
Scutellum sp.

Pisces

Ptyctodus calceolus (Newberry and Worthern)

Plattin, Kimmswick, Maquoketa and Bowling Green Formations.

The Callaway interfingers with the Cooper, underlies Upper Devonian, in part, and overlies Upper Ordovician, in part. The Callaway contains Middle Devonian fossils and is therefore, Middle Devonian in age.

The Lupus Sandstone Physiofacies.—The Lupus Sandstone Facies was named from the town of Lupus in Moniteau County. The thickest section of Lupus was observed and measured about 0.4 mile northwest of Lupus along the Missouri River

bluffs (Section 9) where 17.5 feet of calcareous, cross-laminated sandstone are exposed. The Lupus Facies is best developed in Moniteau, Cole, Boone, Callaway, and Ralls Counties. It also crops out in Saline, Montgomery, Lincoln, Pike and Marion Counties.

Lithologically, the Lupus is a quartz sandstone, white, light gray, weathering to medium grayish-tan, yellowish-white, light to medium brown, yellowish-brown, reddish-brown or green; fine to medium-grained, calcareous, in part dolomitic, friable to fairly well-cemented, with most of the quartz sand being well-rounded and in part frosted, similar to that found in the Saint Peter Formation. In Cole County, just northwest of Marion, the sand grains are angular and unfrosted and are different from those usually found in the Saint Peter Formation. This facies is not infrequently cross-laminated, pyritic, and sometimes contains calcite-filled veins and vugs and dark chert and phosphate pebbles. The Lupus Facies is lenticular and occurs at various horizons in the Cedar City Formation. It is not commonly associated with the Calwood Physiofacies.

The Lupus facies:

1. overlies, underlies and interfingers with the Lamine River Facies.
2. overlies the Shiel Facies.
3. overlies and underlies the Little Shaver Creek Facies.
4. overlies, underlies and interfingers with the Sandy Hook Facies.
5. overlies, underlies and interfingers with the Clifton City Facies.
6. overlies, underlies and interfingers with the Little Splice Creek.
7. overlies, underlies and interfingers with the Smithton Facies.
8. overlies, underlies and interfingers with the Mineola Facies.
9. overlies and underlies the Calwood Facies. At some places the Calwood is quite arenaceous (in the SE Section 22, T. 47 N., R. 8 W., Callaway County, for example) indicating that it interfingers with the Lupus.
10. overlies the Jefferson City Formation (Lower Ordovician).
11. overlies the Saint Peter Formation (Middle Ordovician).
12. overlies the Kimmswick Formation (Middle Ordovician).
13. overlies the Maquoketa (Upper Ordovician).

Along Stinson Creek (SW SE Section 27, T. 47 N., R. 9 W., Callaway County) about 2.75 miles southeast of Fulton, the Lupus also contains *Ptyctodus calceolus*. Here the Lupus occurs about 14 feet above the base of the Callaway section, lying between the Mineola above and the Calwood below. The Lupus is in part equivalent to the Auxvasse Creek Sandstone of Counselman (1934).

The presence of *Ptyctodus calceolus* (Newberry and Worthern) indicates that the Lupus Facies is not older than Devonian in age. The interfingering of Lupus with other Callaway Facies which contain Middle

Devonian fossils and the presence of Middle Devonian fossils in the Lupus indicates that the Lupus is Middle Devonian in age.

The Lupus is probably equivalent to the "Hoing" of Illinois, but the exact stratigraphic relations are not known.

The Sandy Hook Dolomite and Dolomitic Limestone Facies. — The Sandy Hook Facies was named from an abandoned quarry about 0.75 mile southeast of Sandy Hook, Moniteau County (Section 10), along the Missouri River bluffs. Here the Sandy Hook is 13 feet in thickness. The greatest thickness of Sandy Hook observed and measured was in the Fessenden Quarry about 2.5 miles east of Ely, Marion County (NW SE Section 29, T. 57 N., R. 6 W., Marion County). Here about 24.5 feet are exposed, the upper two and one-half feet interfingering with the Mineola and underlying the Lupus Facies. The Sandy Hook Facies crops out in Moniteau, Cole, Boone, Callaway, Montgomery, Warren, Lincoln, Pike, Ralls and Marion Counties.

Lithologically, the Sandy Hook Facies consists of dolomitic limestone, silty to arenaceous dolomite or dolomitic sandstone. Actually there are four lithologic phases which interfinger with one another. The first phase, where the various physiofacies of the Cooper interfinger with the Sandy Hook Physiofacies, consists of dolomitic limestone.

This phase is best developed along the Missouri River bluffs northwest of Lupus and northwest of Marion in Moniteau and Cole Counties (SE NE SE SW Section 4, T. 47 N., R. 14 W., Moniteau County and NW NE SW NE SE Section 30, T. 46 N., R. 13 W., Cole County, for examples). It is light to medium tannish-gray or grayish-tan, argillaceous, dense to fine-grained, thin to thick-bedded or massive, in places arenaceous, mottled, calcite-veined and vugged, finely-laminated and slightly cherty. The chert is reworked, resembling that found in the Jefferson City Formation. The second phase which has the greatest geographic distribution, is best developed in Moniteau, Cole, Callaway, Ralls and Marion Counties (E ½ SW SE NW Section 15, T. 47 N., R. 14 W., Moniteau County and W ½ SE SE SW NW Section 28, T. 56 N., R. 6 W., Ralls County, are fine examples). This second phase consists mainly of silty, laminated, arenaceous dolomite, dolomite or dolomitic sandstone. It is light to medium yellowish-brown, light to medium grayish-tan or light tannish-gray, reddish-brown, greenish-gray or white in color; dense to medium-grained, mostly fine-grained; thin-bedded, slabby, to massive, friable to well-cemented, the cement being dolomite, calcite and minor amounts of limonite and hematite; earthy; in places with chert, white, gray, dark blue or black; laminated, silty, arenaceous, argillaceous, mottled, brecciated, pyritic and glauconitic, with rewarked chert similar to that found in the Jefferson City Formation near the base. In a few places there are calcite and green clay-filled veins and vugs. This is the phase which is exposed in the quarry southeast of Sandy Hook in Moniteau County (Section 10). The third phase, which consists mainly of argillaceous dolomite and dolomitic limestone, is best developed in eastern Callaway,

Montgomery, Warren, Lincoln and Pike Counties. The interfingering of this phase with phase two is best seen in Callaway and Pike Counties. Fine exposures of this phase are found in the NE SE SE Section 34, T. 50 N., R. 1 E. in Lincoln County and in the MS ½ SE SE NW Section 30, T. 52 N., R. 2 E. in Pike County. This phase is light to medium yellowish-brown, reddish-brown, light to medium grayish-tan or tannish-gray, bluish-gray, light brown or medium tan; dense to medium-grained, mostly dense; thin-bedded to thick-bedded or massive; earthy; in places pyritic, chalcopyritic, arenaceous, laminated and mottled. This phase tends to be more crinoidal than the other phases of the Sandy Hook. The fourth phase is largely a silty to arenaceous dolomite. It is best developed in the Fessenden Quarry (NW SE Sec. 29, T. 57 N., R. 6 W.) in Marion County and in the draw just to the north of the abandoned Kennisson Quarry (NE SW NW Sec. 31, T. 45 N., R. 10 W.) in Callaway County. This phase is light gray, light brown, but largely medium to dark tannish-gray; fine-grained; thick-bedded to massive, for the most part; with white chert and sand lenses and in part laminated.

The first phase is distinguished from the other phases by its large calcium carbonate content and its limestone characteristics in general. The second phase is distinguished from the third phase by the fact that the second phase is more clastic, tends to be more laminated, brecciated and mottled. The third phase, on the other hand, seems to be more dolomitized, in general, more crinoidal, less clastic and more fossiliferous. Most of all the third phase tends to be more argillaceous and more of a reddish-brown in color. The differences here are more than likely a matter of position from shoreline, the third phase being a deeper water phase. The fourth phase is distinguished from the others by its very high dolomite content and by its darker color. This latter phase is clastic like phase two.

The Sandy Hook Facies:

1. overlies, underlies and interfingers with the Little Shaver Creek Facies.
2. overlies, underlies and interfingers with the Little Splice Creek.
3. overlies, underlies and interfingers with the Smithton Facies.
4. overlies and underlies the Clifton City Facies and interfingers with "Smithton-bearing" Clifton City.
5. overlies, underlies and interfingers with the Lupus Facies.
6. overlies, underlies and interfingers with the Mineola Facies.
7. overlies, underlies and interfingers with the Calwood Facies.
8. overlies the Lamine River Facies.
9. overlies the Cotter-Jefferson City Formations (Lower Ordovician).
10. overlies the Saint Peter Formation (Middle Ordovician).
11. overlies Joachim (Middle Ordovician).
12. overlies Plattin (Middle Ordovician).

13. overlies Maquoketa (Upper Ordovician).
14. overlies Bowling Green Member of the Edgewood Formation (Lower Silurian).
15. underlies Turpin (Upper Devonian).
16. underlies Grassy Creek Formation (Upper Devonian).
17. underlies the *Siphonodella* Beds of the Bachelor Formation (basal Mississippian).

The Sandy Hook Facies interfingers with most of the physiofacies of the Cooper Lithofacies and therefore is stratigraphically equivalent to the Cooper, in part. It also interfingers with all of the physiofacies of the Callaway Lithofacies. The Sandy Hook Facies contains Middle Devonian fossils. For these reasons the Sandy Hook Facies is considered to be Middle Devonian in age. From its relationships with non-Devonian formations, it cannot be older than lower Silurian or younger than upper Devonian. In Cole County along the Missouri River bluffs north of Marion (NW NE SW NE SE Section 30, T. 46 N., R. 13 W., Cole County), the Sandy Hook lies with distinct unconformity on the Smithton Physiofacies of the Cooper Lithofacies.

The Mineola Crinoidal, Arenaceous, Coarse-grained Limestone Facies.—The Mineola Formation was named by Branson (1920) "from outcrops about a half-mile south of Mineola, about 80 miles west of St. Louis on Highway 40. This section is now poorly exposed. The formation was spoken of as Crinoidal limestone by Broadhead (1873) from exposures in Warren and Montgomery Counties," (Branson, E. B., 1944, p. 128). As previously mentioned, the Mineola is considered here to be a physiofacies of the Callaway Limestone Lithofacies. The Mineola Facies is best developed in Callaway and Montgomery Counties. The thickest section measured and observed crops out along Auxvasse Creek at the junction with a west-flowing tributary (NW SE SE Section 8, T. 48 N., R. 8 W., Callaway County), about 0.5 mile north of U.S. Highway 40. Here almost eighteen feet of Mineola was measured with interfingering Lupus sandstone not included in the total. The Mineola also crops out in Saline, Cooper, Moniteau, Boone, Lincoln, Pike and Ralls Counties.

"The Mineola limestone is rather heterogeneous in composition and irregular in distribution. One of its typical phases is highly crystalline, crinoidal limestone, almost white in color, which weathers readily to a crumbly condition. This phase might easily be mistaken for ordinary Burlington limestone, though it weathers much more rapidly than Burlington. It contains large numbers of crinoid stems and in many places numerous crinoid heads from which the outer parts of the plates have been exfoliated." "Another phase, about as common as the crinoidal, is made up of a yellowish to pinkish-gray limestone, which contains large numbers of small irregular cavities produced by the solution of fossils. In most places the limestone is sandy." These are, in general, the two phases which are considered to make up the Mineola Facies in this report. "A brown limestone flecked with specks of white occurs rarely. It contains few im-

purities and the white specks are of calcite. The rock is abundantly fossiliferous." This latter phase of E. B. Branson is dolomitized Mineola and is here regarded as the third phase of the Sandy Hook Facies. The white specks referred to by E. B. Branson are largely undolomitized crinoid stem fragments. This phase is not uncommon in Montgomery and Warren Counties. "In some places the lowest member is a very sandy, pinkish to yellowish limestone, that grades into sandstone, and is abundantly fossiliferous. It ordinarily occurs in shallow erosion depressions in the older rocks." I see no reason to separate this latter phase from Branson's second phase. The sandstone with which it interfingers or grades is the Lupus facies. "The various phases are never present in one section and they seem to be contemporaneous deposits, the lithologic differences being due to variations in sedimentation" (Branson, E. B., 1944, p. 128-129). It is not uncommon to find more than one of E. B. Branson's first two phases occurring in one section. Along Auxvasse Creek (last locality cited) E. B. Branson's first two phases occur and can be seen to interfinger with one another. Along U.S. Highway 40, about 1.5 miles west and north of Mineola, along the north and south sides of the highway, E. B. Branson's phases one, two and three can be seen in one section.

As previously indicated the Mineola can be, in general, divided into two phases which interfinger with one another. The first phase consists of limestone; white, very light to medium gray, light to dark tannish-gray or light to medium grayish-tan, light brown, light to medium brownish-gray, medium pinkish-brown, light pinkish-gray; light to medium yellowish-brown, reddish-brown, pink or purple-weathering; dense to coarse-grained; thin-bedded to massive; crinoidal; clastic; in places arenaceous with quartz sand rounded and somewhat frosted like that found in the Saint Peter Formation or clear and angular or doubly terminated; glauconitic, slightly dolomitic, laminate, calcite-veined and vugged, stylolitic, cherty with chert similar to that found in the Jefferson City Formation or with pebbles of black chert, and with thin shale partings, cross-laminations and limonite-hematite grains and staining.

The second phase consists of limestone; very light to dark gray, light to dark tannish-gray or light to medium grayish-tan; light tan, light brown, light to medium brownish-gray weathering; dense to medium-grained; thin bedded to massive and sometimes irregularly-bedded; in places arenaceous with quartz sand as in phase one, conglomeratic or brecciated with medium gray limestone pebbles and sandy Smithton Limestone pebbles at the base (NW NW SW Section 15, T. 46 N., R. 8 W., Callaway County) and angular fragments of shale, limestone and chert, the latter like that found in the Jefferson City Formation, for the most part; pyritic, cross-laminated, calcite-veined and vugged, slightly crinoidal, speckled, poorly laminated, stylolitic and slightly dolomitic.

The Mineola Facies:

1. overlies, underlies and is stratigraphically equivalent to (erosional contact) the Smithton Facies.

2. overlies, underlies and grades into the Clifton City Facies.
3. overlies, underlies and interfingers with the Little Splice Creek Facies.
4. overlies and underlies the Little Shaver Creek Facies.
5. overlies, underlies and interfingers with the Lupus Facies.
6. overlies, underlies and interfingers with the Sandy Hook Facies.
7. overlies, underlies and interfingers with the Calwood Facies.
8. overlies and interfingers with the Lamine River.
9. overlies the Shiel Facies.
10. overlies the Jefferson City Formation (Upper Ordovician).
11. overlies the Saint Peter Formation (Middle Ordovician).
12. overlies the Joachim Formation (Middle Ordovician).
13. overlies the Plattin Formation (Middle Ordovician).
14. underlies the *Siphonodella* Beds of the Bachelor Formation (basal Mississippian).

The Mineola Facies contains Middle Devonian fossils and therefore, is Middle Devonian in age. The Mineola interfingers with the other facies of the Callaway Lithofacies. It interfingers with the Lamine River and Little Splice Creek Facies of the Cooper Lithofacies. There is an erosional contact between the Smithton-Clifton City and the Mineola where observed in the field. This contact is fairly sharp; however, fragments of Mineola are found in the two facies of the Cooper near the contact. Thus the indication, as previously mentioned, is that the Mineola was washed into channels in the Smithton and Clifton City while those two facies were still unconsolidated. Consequently, the time represented by the erosional break is apparently small. The youngest formation underlying the Mineola, is the Plattin Formation of the Middle Ordovician. The oldest formation overlying the Mineola is the *Siphonodella* Beds (basal Mississippian).

The Calwood Limestone Physiofacies.—The Calwood Physiofacies was named from the town of Calwood, Callaway County. Fine exposures of Calwood occur along Auxvasse Creek and its tributaries to the north and east of the town of Calwood. One of the best exposures occurs along the east bank of Auxvasse Creek from 2 to 2.5 miles northeast of the town of Calwood (Section 11). The Calwood Facies is best developed in Callaway and Montgomery Counties. It also crops out in Pettis, Moniteau, Boone, Warren, Lincoln, Pike and Marion Counties. The thickest section of well-developed Calwood measured and observed was in the SW NW SW SE Section 13, T. 47 N., R. 9 W., Callaway County, about 2.75 miles east of the western city limits of Fulton along the west bank of Crows Fork Creek, 0.25 mile southwest of the bridge on county road UU. Here the Calwood with some interfingering Sandy Hook Facies near the top of the exposed section is about thirty-seven feet in thickness. To the northeast, toward the aforementioned county road bridge along the east bank of the creek, much of the lower Calwood is replaced by the sandy phase

of the Mineola Facies. Sections of Calwood in excess of thirty feet are also to be seen near Crows Fork Creek along the north side of a county road in the SW NW NW NE Section 1, T. 46 N., R. 9 W., Callaway County, about 2.75 miles northeast of Hams Prairie. Here the Calwood Facies is quite arenaceous. About 2.75 to 3 miles southeast of Fulton along Stinson Creek (SW SE Section 27, T. 47 N., R. 9 W., Callaway County), the Calwood also exceeds thirty feet in thickness and interfingers with Mineola toward its base. About 2.5 miles north of Williamsburg, along the south and southwest bank of Whetstone Creek the Calwood exceeds thirty feet in thickness. To the southeast along the east side of the county road, also about 2.5 miles north of Williamsburg (C NW Section 10, T. 48 N., R. 7 W., Callaway), the lower half of the Calwood Facies is largely replaced by Sandy Hook Facies. On the Tapp farm (C N ½ SW NE Section 13, T. 46 N., R. 7 W. Callaway County) the Calwood would exceed thirty feet if it were not largely dolomitized forming Sandy Hook Facies. About 2.25 to 2.5 miles north and east of the town of Calwood, the Calwood Facies along the west bank of Auxvasse Creek in the SE SE NW Section 8, T. 48 N., R. 8 W., Callaway County, exceeds thirty feet in thickness and is in part dolomitized forming Sandy Hook Facies. Other examples could be cited, but these give the general picture that the Calwood Facies is best developed and thickest in the eastern Callaway County and thins to the east, west and south.

Lithologically the Calwood Facies is a limestone; light to dark gray, light to dark tannish-gray or light to dark grayish-tan, light to medium brownish-gray, pinkish-tan or pinkish-gray, and dark bluish-gray; sublithographic, dense or fine to coarse-grained; thin-bedded, slabby, medium to thick-bedded or massive; in places gnarly or nodular with light gray limestone nodules or white, gray or brown, elongate chert nodules; mottled, glauconitic and with granules and pebbles of rounded Jefferson City-like chert at the base; argillaceous with clay partings; arenaceous with floating quartz grains, lenses or pockets of quartz sand; crinoidal, clastic, pyritic, limonitic with limonite-filled vugs and pseudomorphs of limonite after pyrite; slightly hematitic with hematite staining; calcitic with large masses, crystals and calcite-filled veins and vugs; stylolitic, hackly and highly fractured. At some localities the Mineola takes on the color of the Calwood (Section 10 and in the SW SW SW SE Section 4, T. 47 N., R. 14 W., Moniteau County, for example). Actually, there are two phases of the Calwood, a dark grayish-tan, "purplish", argillaceous, organic phase which leaves a black "oil" sludge when acidized and a light grayish-tan calcareous phase which looks like Smithton, but is "grainy".

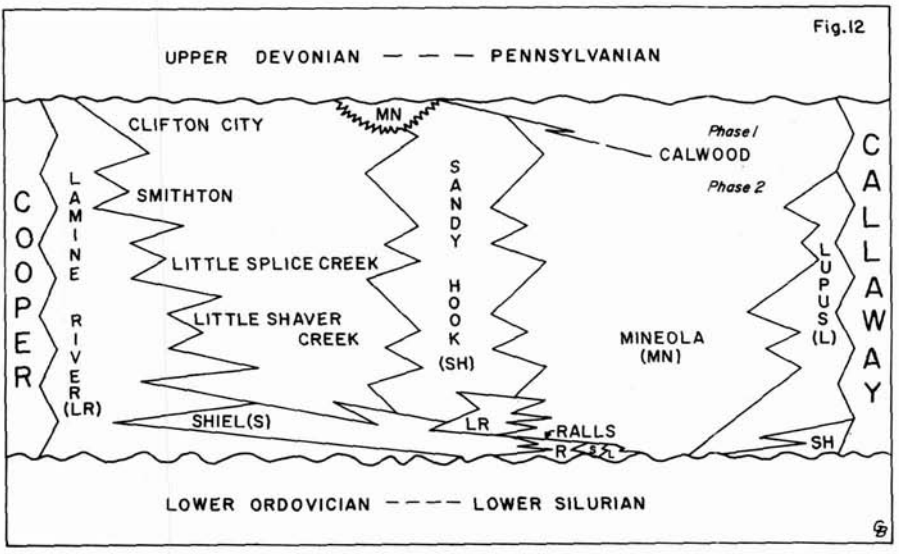
The Calwood Facies:

1. overlies, underlies and interfingers with the Smithton Facies.
2. overlies, underlies and interfingers with the Sandy Hook Facies.
3. overlies, underlies and interfingers with the Mineola Facies.

4. overlies, underlies and interfingers with the Lupus Facies.
5. overlies and underlies the Lamine River Facies.
6. overlies, underlies and interfingers with the Clifton City Facies.
7. underlies the Little Shaver Creek Facies.
8. interfingers with the Little Splice Creek Facies.
9. overlies the Jefferson City Formation (Lower Ordovician).
10. overlies the Joachim Formation (Middle Ordovician).
11. overlies the Plattin Formation (Middle Ordovician).
12. underlies the Snyder Creek Formation (Upper Devonian).
13. underlies the *Siphonodella* Beds of the Bachelor Formation (basal Mississippian).
14. underlies Pennsylvanian sandstone.

The Calwood Facies contains Middle Devonian fossils and therefore, must be considered Middle Devonian in age. The oldest beds overlying this facies is Snyder Creek Formation of the Upper Devonian and the youngest formation underlying the Calwood is the Plattin of the lower Middle Ordovician. The Calwood Facies as noted above interfingers with all of the other facies of the Callaway Lithofacies and with several of the facies of the Cooper Lithofacies.

The general physiofacies relationships of the Cedar City Formation are illustrated in Figure 12.



GENERAL RELATIONSHIPS OF THE PHYSIOFACIES AND LITHOFACIES OF THE CEDAR CITY FORMATION

FIGURE 12.—General relationships of the physiofacies and lithofacies of the Cedar City Formation (drafted by Mississippi Valley Investigations, Southern Illinois University).

The Cedar City Formation can also be subdivided into the *Turbonopsis, Hexagonaria profunda, Hexagonaria lativentra, Atrypa bellula, Atrypa missouriensis, Stropheodonta, Tabulophyllum* and *Stacyhodes* Biofacies.

Literature Cited

Branson, E. B. 1920. A geological section from 40 miles west of St. Louis County to Jackson County, Missouri. Am. Jour. Sci., 4th, 49: p. 271-272.

———. 1923. The Devonian of Missouri. Missouri Geol. Sur. 17: p. 24-25.

———. 1944. The geology of Missouri. Univ. of Missouri Studies 19: p. 128-129.

Broadhead, G. C. 1873. Warren County: Reports on the geological survey of the state of Missouri, 1855-1871. Missouri Bureau of Geol. and Mines. Jefferson City. p. 47-48.

Cooper, G. A., et al. 1942. Correlation of the Devonian sedimentary formations of North America. Geol. Soc. Amer. Bull. 53: p. 1745 and 1777.

———. 1944. Symposium on Devonian stratigraphy—remarks on correlation of Devonian formations in Illinois and adjacent states. 111. Geol. Sur. Bull. 68: p. 219.

Counselman, F. B. 1934. Geology and stratigraphic petrography of the Auxvasse Creek Quadrangle, Callaway County, Missouri. Ph.D. Thesis, Univ. of Missouri: p. 21-40.

Fraunfelter, G. H. 1951. The Rensselandia Beds (Middle Devonian) of central Missouri. Master's Thesis, Univ. of Missouri: 28 pp.

Greger, D. K. 1909. The Devonian of central Missouri. Amer. Jour. Sci., 4th, 27: pp. 374-375.

———. 1920. The Devonian of central Missouri (111). The Cooper Limestone. Amer. Jour. Sci., 4th, 50: p. 21.

———. 1936. *Atrypae* of the central Missouri Devonian. St. Louis Acad. Sci. Trans. 29, No. 2: p. 44.

Keyes, C. R. 1894. Paleontology of Missouri. Missouri Geol. Sur., 4, Part 1: pp. 30 and 43.

———. 1895. Characteristics of the Ozark Mountains. Missouri Geol. Sur. 8: p. 340.

———. 1896. The geological occurrence of Clays. Missouri Geol. Sur. 11, Chap. 2: p. 42.

Marbut, C. F. 1908. The Geology of Morgan County. Missouri Geol. Sur., 7: p. 49.

Mehl, M. G. 1960. The relationships of the base of the Mississippian system in Missouri. Jour. Sci. Lab., Denison Univ. 45, Art. 5: p. 73, 78, 84, 94, and 96.

Moore, R. C. in Longwell, C. R. 1949. Sedimentary facies in geologic history—Meaning of facies. Geol. Soc. Amer. Memoir 39: p. 16-17.

Rush, T. D. 1950. The Geology of southwestern Boone County, Missouri. Master's Thesis, Univ. of Missouri: p. 33.

Sinclair, V. R. 1956. Stratigraphy and structure of the Mineola-Danville area, Missouri. Master's Thesis, Univ. of Missouri: p. 58-65.

Swallow, G. C. 1855. Geology of Missouri—The first and second annual reports of the Geological Survey of Missouri. Missouri Geol. Sur.: p. 107.

———. 1855. Geology of Cooper County, Missouri—The first and second annual report of the Geological Survey of Missouri. Missouri Geol. Sur.: p. 196.

———. 1860. Description of new fossils from the Carboniferous and Devonian rocks of Missouri. St. Louis Acad. Sci. Trans. 1: p. 635-660.

Unklesbay, A. G. 1952. Geology of Boone County, Missouri. Missouri Geol. Sur. 33: p. 29-39.

Williams, J. H. 1952. The Geology of the New London area, Ralls County, Missouri. Master's Thesis, Univ. of Missouri: p. 39, 40, and 42.

Wilson, M. E. 1922. The occurrence of oil and gas in Missouri. Missouri Geol. Sur. 16: p. 52.

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