Upper Ordovician Formations In the Maysville Area Kentucky

GEOLOGICAL SURVEY BULLETIN 1244-B

Prepared in cooperation with the Kentucky Geological Survey

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By JOHN H. PECK

CONTRIBUTIONS TO STRATIGRAPHY

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UPPER ORDOVICIAN FORMATIONS IN THE MAYSVILLE AREA, KENTUCKY

By JOHN H. PECK

ABSTRACT

Upper Ordovician strata in the Maysville area, Kentucky, are divided into five formations. The basal Kope Formation is overlain by the Fairview Formation. Above the Fairview are two newly defined map units, the Grant Lake Limestone and the overlying Bull Fork Formation. The Preachersville Member of the Drakes Formation overlies the Bull Fork.

The Kope Formation consists of gray calcareous shale with thin layers of interbedded fossiliferous limestone. It is about 270 feet thick in the Maysville area. The Fairview Formation consists of closely interbedded fossiliferous limestone, shale, and minor limy siltstone. It is about 85 feet thick near Maysville. The Grant Lake Limestone is chiefly gray rubbly-weathering irregularly thin bedded fossiliferous and argillaceous limestone having irregular partings and seams of gray calcareous shale. The Grant Lake is 100–120 feet thick in the Maysville area.

The Bull Fork Formation consists of interbedded shale and limestone. Shale content increases from about 20 percent near the base to about 80 percent at the top. The shale is gray to greenish gray, calcareous, and locally fossiliferous. The limestone is chiefly gray, evenly thin to medium bedded, very fine to coarse grained, and very fossiliferous. The Bull Fork Formation is about 200 feet thick in the type area and thins southward.

The Preachersville Member of the Drakes Formation consists of grayish-green calcareous to dolomitic mudstone and minor dolomitic limestone and dolomite. It is about 25 feet thick near Maysville and thickens southward. It is the uppermost Ordovician unit on the east flank of the Cincinnati arch.

INTRODUCTION

Upper Ordovician rocks are exposed in the area of Maysville, Ky., on the east flank of the Cincinnati arch about 50 miles southeast of Cincinnati, Ohio (fig. 1). Geologic mapping at a scale of 1:24,000 as part of a cooperative mapping program undertaken by the Kentucky Geological Survey and the U.S. Geological Survey has necessitated reexamination of and subsequent changes in the stratigraphic nomen-

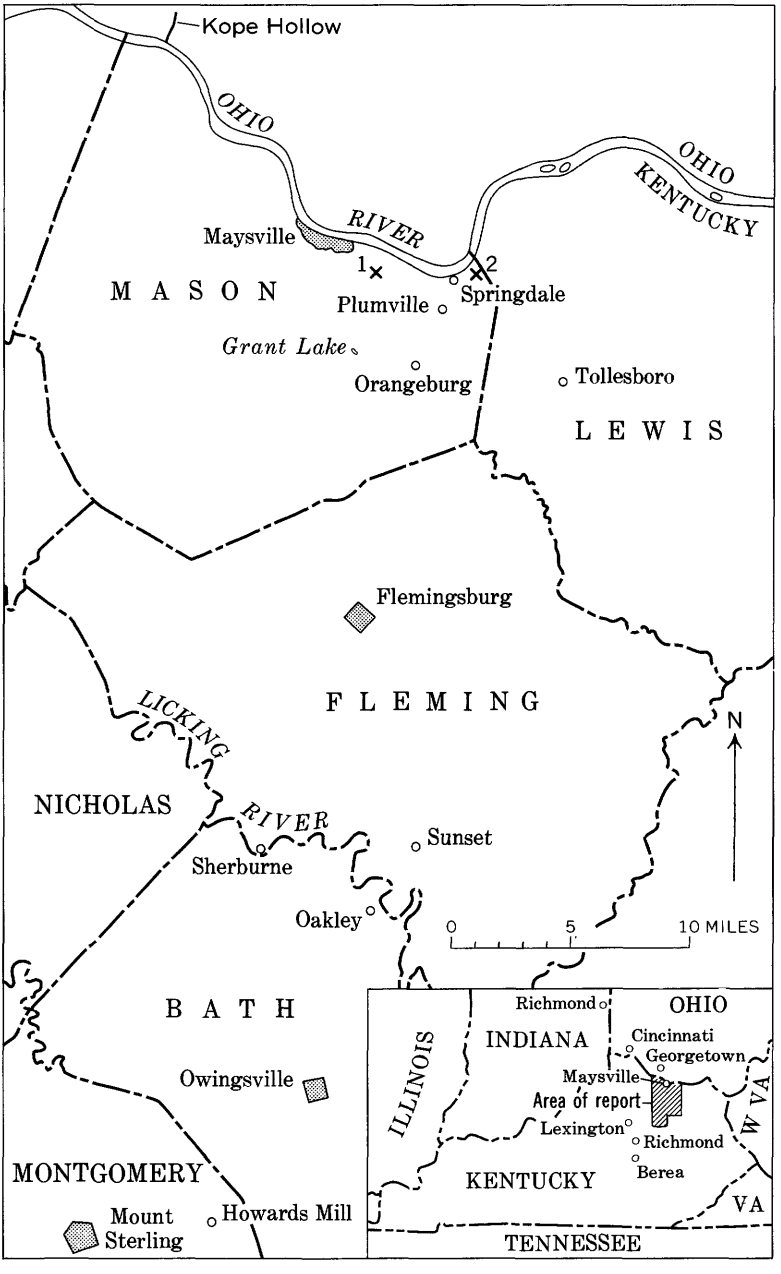

FIGURE 1.—Map of the Maysville area, Kentucky. Measured sections: 1, Sleepy Hollow; 2, County line.

clature of Upper Ordovician rocks in Kentucky. This report outlines the history of the nomenclature and describes the character of the formations being mapped in the Maysville area. Two of these formations are defined and named herein.

Since early in this century, Maysville and Richmond have been used as formation, group, or stage terms for the upper two-thirds of the Upper Ordovician strata surrounding the Cincinnati arch. The nomenclature of Upper Ordovician strata of the Cincinnati arch was mainly established in the region of Ohio, Indiana, and Kentucky surrounding Cincinnati. Stratigraphic units were defined and named in large part on the basis of their fossil content. Names of stratigraphic units defined in or near Cincinnati were later applied to rocks in the Maysville area largely by faunal correlations. Most of the earlier nomenclature in the Maysville area, therefore, cannot be used in the mapping of rock units on today's base maps.

The Upper Ordovician strata near Maysville are about 700 feet thick, consist largely of interbedded fossiliferous limestone and shale, and are divisible into five formations (fig. 2). The basal unit, the herein adopted Kope Formation, was recently named and defined (Weiss and Sweet, 1964) for rocks exposed at Maysville and nearby in Ohio. The Kope is about 270 feet thick near Maysville and consists of shale and a little interbedded limestone. The Fairview Formation, the one formation of the five whose type locality is in Cincinnati, consists of closely interbedded limestone and shale and is about 85 feet thick. The Grant Lake Limestone and Bull Fork Formation, defined herein, consist of 110 feet of irregularly bedded argillaceous limestone with minor shale and 200 feet of interbedded shale and limestone. The Preachersville Member of the Drakes Formation, which was recently named (Weir and others, 1965), consists of mudstone and minor interbedded dolomitic limestone and dolomite; it is about 25 feet thick near Maysville. The Preachersville Member is the uppermost unit of Ordovician strata in the Maysville area, as well as elsewhere along the east side of the Cincinnati arch.

F. A. Schilling, Jr., formerly with the U.S. Geological Survey, has gathered many of the data in this report. G. W. Weir and E. R. Cressman, of the U.S. Geological Survey, have made many suggestions, and data from their work on the Ordovician strata of the Cincinnati arch in Kentucky have helped to establish the units described herein.

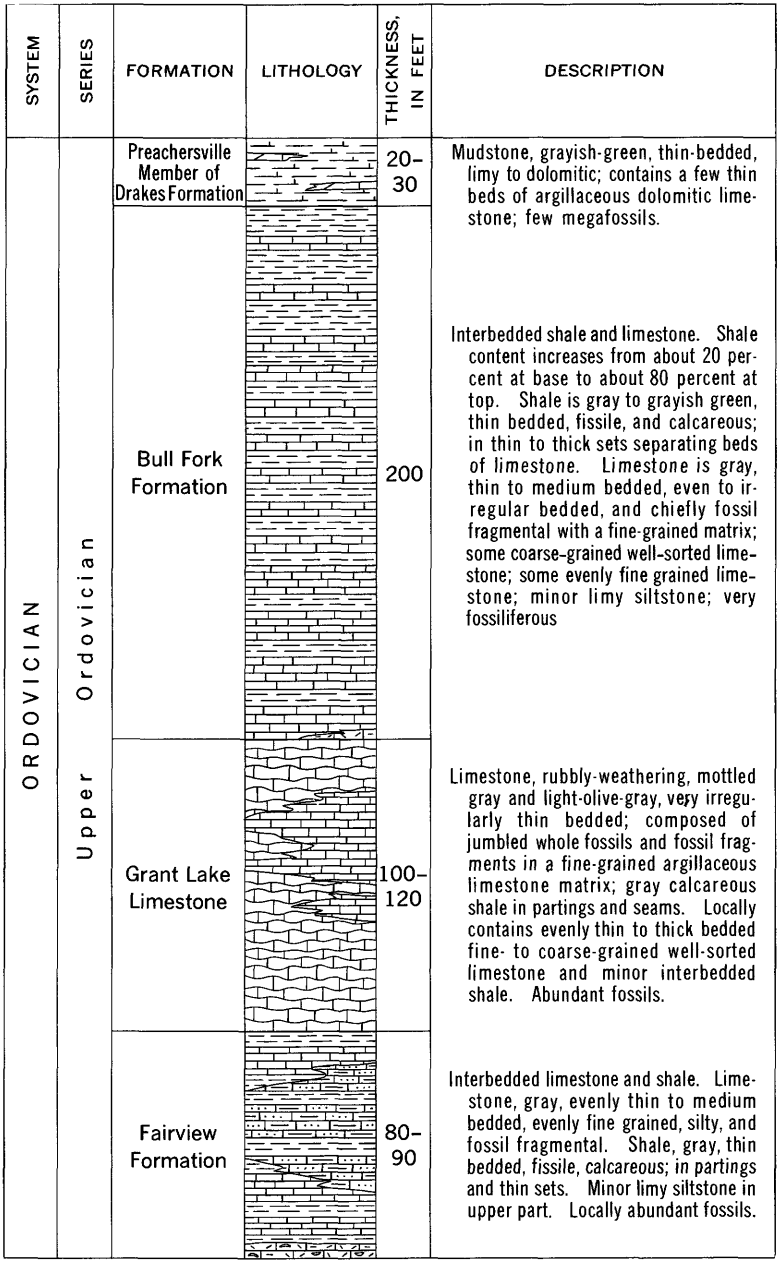

FIGURE 2.—Generalized stratigraphic section of Upper Ordovician rocks above the Kope Formation in the Maysville area, Kentucky.

PREVIOUS NOMENCLATURE

Stratigraphic nomenclature in the Cincinnati region has recently been reviewed by Gutstadt (1958, p. 518–521), Weiss and Norman (1960), and Fox (1962, p. 622–628). The following discussion includes only those stratigraphic names which have been used in the Maysville area. Previous nomenclature of Upper Ordovician rocks above the Kope Formation in the Maysville area is shown in figure 3.

FAIRVIEW, FAIRMOUNT, AND MOUNT HOPE

The Fairmount or *Dekayia aspera* beds were defined at Cincinnati by Nickles (1902, p. 78–82) as a subdivision of the Lorraine Group (Winchell and Ulrich, 1897, p. 102–103). The beds were characterized "by regular alternations of evenly-bedded, bluish limestones from 2 to 6 inches thick, rarely more, and bluish or sometimes yellowish or brownish shales" (Nickles, 1902, p. 78). Limestone makes up at least one-third of the unit. The base of the Fairmount was placed at the horizon of *Strophomena planoconvexa*, "which has a very limited vertical range" (Nickles, 1902, p. 77). The upper contact was placed at the base of the thin shelly limestone of the Bellevue or *Monticulipora molesta* beds.

The Fairmount and the underlying Mount Hope or *Amplexopora septosa* beds (Nickles, 1902, p. 76–78) were combined by Bassler (1906, p. 10) to form the Fairview Formation, named for Fairview Heights at Cincinnati. In defining the Fairview Formation, Bassler stated that the Mount Hope and Fairmount were so closely related faunally and distinguished with such difficulty that they could not be mapped separately. The base of the Mount Hope and, thus, the base of the Fairview Formation was placed at a thick limestone layer containing a mass of fossils identified by Nickles (1902, p. 76) as chiefly *Dalmanella multisecta*. The faunally defined lower boundary of the Fairview Formation at Cincinnati is within a few feet of a lithologic boundary, and the Fairview Formation recently has been redefined and mapped as a rock-stratigraphic unit in the Cincinnati area (Ford, 1965).

The following discussion of the Fairview Formation at Cincinnati is quoted from Ford's thesis (p. 16–29):

> * * * for the past 60 years the Fairview Formation has meant a rock sequence at Cincinnati with a faunally defined base, a loosely defined lithologic top and a poorly exposed and somewhat incomplete type section at Fairview Heights. * * * On the basis of the geologic mapping for this paper, the Fairview is here redefined as a rock-stratigraphic unit. It consists of an unbroken sequence of interbedded limestones and pelitic rocks in which no stratum is persistently thicker than 1.5 feet, and usually not more than 0.6 foot. * * * The base of the formation is at the base of the limestone overlying the last pelitic rock greater than 2 feet

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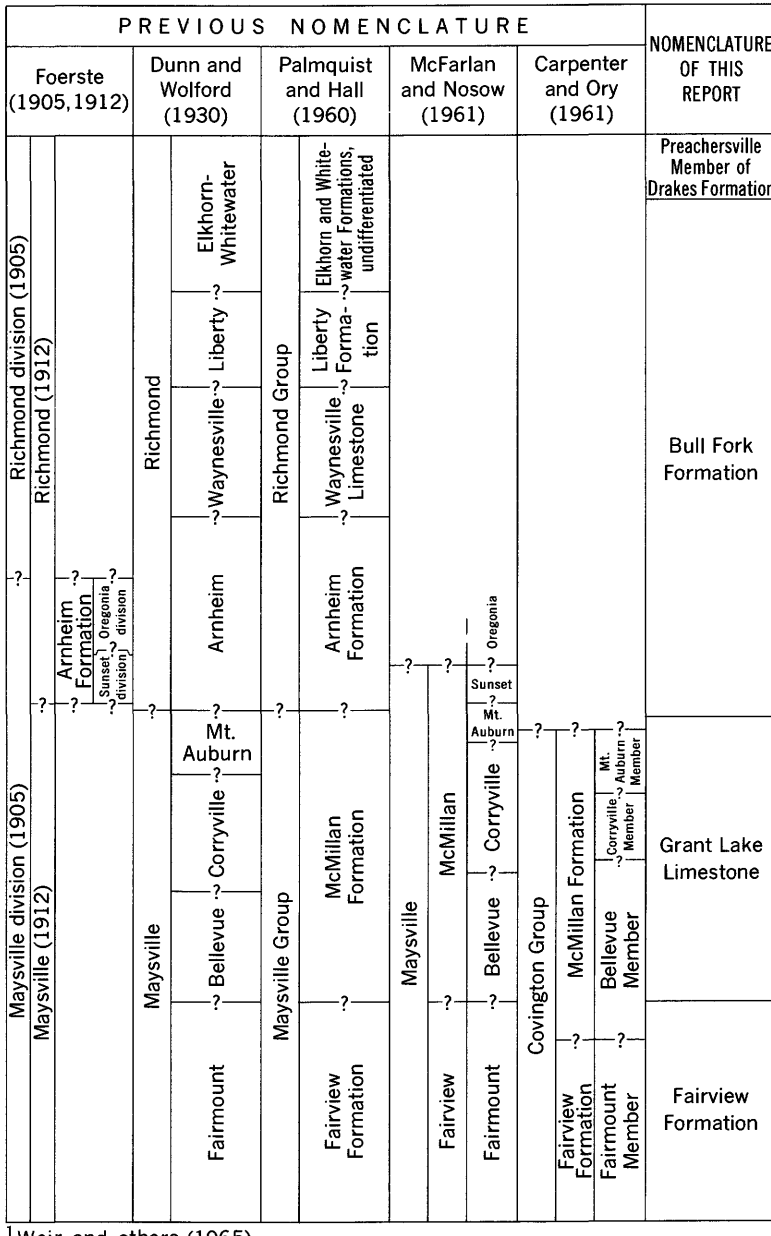

[1] Weir and others (1965)

FIGURE 3.—Nomenclature of Upper Ordovician rocks above the Kope Formation in the Maysville area, Kentucky.

in thickness. The uninterrupted close spacing of the limestone strata in the bulk of the formation is a significant intrinsic lithic property. The top of the formation is sharply defined at the top of a limestone underlying pelitic rocks which are more than 2 feet thick and which exhibit marked lithologic contrast. The Fairview Formation is exposed in its entirety along Clifton Avenue, Cincinnati, in the south- and west-facing cliff below Bellevue Park. This is the type section of the Fairview Formation as redefined. It is 108 feet thick. The base of the redefined formation lies some 8 to 10 feet below Nickles' Mount Hope * * * In Boone, Kenton and Campbell counties, Kentucky, just south of the Ohio River. the Miamitown Shale is not identifiable * * * There the Fairview rocks grade upward into overlying shelly limestones with no distinctive pelitic break between the two.

The names Fairview Formation, Mount Hope, and Fairmount have been applied to rocks in the Maysville area that are approximately time equivalent to all or part of the Fairview Formation at Cincinnati but that are only in part similar lithologically. The closely interbedded limestone and shale characteristic of the Fairview Formation at Cincinnati occur at Maysville only in the Fairmount of McFarlan and Nosow (1961, p. 278) and the Fairmount Member plus part of the Bellevue Member of the McMillan Formation, as used by Carpenter and Ory (1961, p. 374–376).

Rocks designated at Maysville as the Mount Hope Member of the Fairview Formation by Carpenter and Ory (1961, p. 374) and McFarlan and Nosow (1961, p. 278) are lithologically unlike the typical Fairview and have been included in the Kope Formation by Weiss and Sweet (1964, p. 1296). The name Fairview Formation is retained in the Maysville area for the rock unit characterized by lithology similar to that of the Fairview Formation mapped by Ford at Cincinnati. The names Mount Hope and Fairmount are not appropriate for rock units at Maysville.

COVINGTON, McMILLAN, BELLEVUE, CORRYVILLE, AND MOUNT AUBURN

Nickles (1902, p. 82–83) gave the name Bellevue or *Monticulipora molesta* beds to about 20 feet of rock immediately above the Fairmount beds at Clifton Avenue, Cincinnati. The Bellevue consists of about 15 feet of thin shelly limestone overlain by about 5 feet of interbedded limestone and shale "considerably different lithologically and somewhat faunally" (p. 82). Nickles included these upper 5 feet of beds in the Bellevue because they contained *Monticulipora molesta*, which was absent in the overlying division, the Corryville or *Chiloporella nicholsoni* beds. Thus, by definition, the Bellevue consists of rocks of two different lithologies, and its upper boundary was placed at the highest occurrence of *M. molesta*.

The Corryville or *Chiloporella nicholsoni* beds were named at Cincinnati and consist of about 60 feet of shale and interbedded limestone (Nickles, 1902, p. 83). Nickles' description follows: "In this division the limestones are thinner and less frequent than in the quarry beds [Fairmount] and the shales more yellowish. Blue shale also occurs."

The next higher division, the Mount Auburn or *Platystrophia lynx* (*P. ponderosa* Foerste) beds, consists of about 20 feet of "mainly blue shale, though sometimes yellowish in exposure, with some rather irregularly bedded limestone" (Nickles, 1902, p. 85–86). The boundary between the Corryville and Mount Auburn beds was presumably identified on faunal criteria. The upper boundary of the Mount Auburn beds was based on the highest occurrence of *Platystrophia ponderosa*, for Nickles (p. 86) stated that the "Mount Auburn beds pass with little distinction into the next series of beds."

Bassler (1906, p. 10) designated the Bellevue, Corryville, and Mount Auburn as members of a new unit, the McMillan Formation, named for McMillan Avenue, Cincinnati. No description of the McMillan Formation or its boundaries was given. At the same time, Bassler (p. 9) defined his Covington Group, named for Covington, Ky., which included all strata in the Cincinnati area between the top of the Trenton and the top of the McMillan.

The upper boundary of the McMillan Formation and Covington Group in the Cincinnati area occurs within a thick succession of shale having moderate amounts of interbedded limestone. Caster, Dalve, and Pope (1961, p. 18) stated that no significant change occurs "in the lithological character from Maysville deposits (Mount Auburn) to the Richmondian (Arnheim). However, the base of the Richmond is defined by the appearance of the remains of many new animals even though many characteristic Maysville fossils persist to the top of the Lower Arnheim * * *." In outcrops where the boundary is exposed, such as those along Westwood-Northern Boulevard in western Cincinnati, at Mount Airy in northwestern Cincinnati, at the crossing of Interstate Route 75 and the New York Central Railroad near Maud, Ohio (see also Shaver and others, 1961, p. 36–39), and along Stonelick Creek near Newtonsville, Ohio, no lithologic break is apparent between the McMillan Formation and overlying rocks. The name McMillan, therefore, seems inadequate as a rock-stratigraphic term because a lithologically definable upper boundary is not present in the type area. The same conclusion was also reached by J. P. Ford (written commun., 1965).

The names Covington Group, McMillan Formation, and Bellevue, Corryville, and Mount Auburn Members have previously been applied

to rocks in the Maysville area (see fig. 3), but workers have shown little agreement on the placement of formation and member boundaries in the same exposure at Maysville (McFarlan and Nosow, 1961, p. 278–279; Carpenter and Ory, 1961). The rocks previously called McMillan at Maysville are dominantly irregularly thin bedded argillaceous limestone having little shale. The greater part of the McMillan-type rocks at Cincinnati are shale and thin interbedded limestone, very similar to rocks overlying the so-called McMillan at Maysville. The recognition of the Covington Group and of the McMillan Formation and its members at Maysville was primarily based on the similarity of faunal characteristics between the rocks at Maysville and those at Cincinnati. Thus, the names Covington, McMillan, Bellevue, Corryville, and Mount Auburn have been used to show time or faunal equivalence to units largely defined on faunal characteristics at Cincinnati, and these names are inappropriate for lithologic divisions in the Maysville area.

ARNHEIM, SUNSET, AND OREGONIA

Nickles (1902, p. 86–87) defined the Warren or *Homotrypa bassleri* beds and stated, "Limestone is not very abundant in the beds under consideration, whose thickness is about 80 feet. The intercalated shales are of a dark bluish color, rather marly." The Warren beds were named for Warren County, Ohio, and overlie the Mount Auburn beds; little or no lithologic distinction is recognized between the two divisions. Foerste (1905, p. 150) proposed the name Arnheim as a substitute for Warren, which was preoccupied. The Arnheim bed was named for Arnheim, Brown County, Ohio, which is near Foerste's designated type section along Straight Creek. Foerste stated that "the top of the Arnheim bed consists of the nodular clay layer so characteristic of the exposures of this bed in Warren County, Ohio. The base of the Arnheim bed is a considerable distance down the stream, where it rests upon the top of the Mount Auburn bed, which contains an abundance of *Platystrophia lynx* at the top. The thickness of the Arnheim bed is estimated approximately at 63 feet."

Foerste (1910, p. 18–19) divided the Arnheim into two units, the lower Sunset division and upper Oregonia division. Later Foerste (1912) ranked the Arnheim as a formation; most later writers (Wolford, 1930, p. 303; Flower, 1946, p. 112) considered the Sunset and Oregonia to be of member rank. The Sunset division was named for Sunset, Fleming County, Ky. (see fig. 1). The type section was described by Foerste (1912, p. 432) as being 13 feet thick and consisting of "a rather uniform section of dense, argillaceous, dark blue limestone,

nearly unfossiliferous, but containing a few specimens of *Platystrophia ponderosa* about 3 feet below the top."

The Oregonia division was named for Oregonia, Warren County, Ohio. Foerste (1912, p. 441) described a measured section at Oregonia that contains about 38 feet of rubble clay rock capped by 5 feet of massive nodular argillaceous limestone that yielded one specimen of *Strophomena concordensis*. According to Foerste (p. 430) the separation and identification of his two members of the Arnheim Formation was "due largely to the fact that the Oregonia division includes a characteristic fauna; * * * *Dinorthis carleyi*, *Rhynchotrema dentata* var., *Leptæna richmondensis* var., and *Platystrophia ponderosa*." The top of the Arnheim Formation in Ohio was placed at the top of a nodular argillaceous limestone containing *Strophomena concordensis* (Foerste, 1912, p. 443–445).

The Sunset and Oregonia divisions of the Arnheim Formation were identified by Foerste (1912, p. 442–443) in a measured section 3 miles south of Maysville. These divisions had a similar lithology, interbedded limestone and shale, and were separated on the basis of fossils characteristic of the Oregonia division in the upper 28 feet of the 46-foot section. The top of the Arnheim was placed at the horizon of *Strophomena concordensis*, in limestone which is "difficult to distinguish lithologically from the overlying Waynesville section" (Foerste, 1912, p. 444).

McFarlan and Nosow (1961, p. 278–279) identified Foerste's Sunset at Maysville by faunal criteria but included the Sunset in the McMillan. The lithology characteristic of the Sunset division in its type locality is not present at Maysville and appears restricted to a small area in Fleming, Bath, and Montgomery Counties, Ky.

The Arnheim Formation as previously identified in the Maysville area by Foerste (1912, p. 442–443), Dunn and Wolford (1930), and Palmquist and Hall (1960) was primarily identified by its faunal characteristics. Lithologically, the interbedded limestone and shale of this Arnheim is indistinguishable from the overlying strata. The names Arnheim, Sunset, and Oregonia are, therefore, inappropriate for rock units in the Maysville area.

WAYNESVILLE, LIBERTY, WHITEWATER, AND ELKHORN

Nickles (1903, p. 205–207) proposed the name Waynesville or *Bythopora meeki* beds for about 50 feet of strata overlying his Warren beds (Arnheim). The Waynesville was named for Waynesville, Warren County, Ohio, and according to Nickles (p. 205) contained "some good limestone layers, 2 to 5 inches thick, * * * and a large amount of clay and clay shale." No explicit definition of the lower boundary was

given, but Nickles (p. 206) stated that in the "lowest layers *Dalmanella jugosa* (James), or a small variety of it, is very abundant."

The 35 feet of strata above the Waynesville beds was named the Liberty or *Strophomena planumbona* beds (Nickles, 1903, p. 207–208) for Liberty, Ind. The Liberty was described by Nickles (p. 207) as "even-bedded limestones averaging 3 inches in thickness, prevailingly blue in color, with clayey and shaley layers intervening, which are also usually blue in color." Nickles (p. 207) stated that the "first appearance of *Hebertella insculpta* (Hall) is considered to mark the beginning of this formation." Concerning the upper boundary, Nickles (p. 207) said that "these beds pass rather gradually into the next division on the west side of the [Cincinnati] uplift. On the east side a layer in which *Streptelasma rusticum* (Billings) is very abundant marks about this horizon and may be considered the upper boundary."

The Whitewater or *Homotrypa wortheni* beds were named by Nickles (1903, p. 208–209) for rocks above the Liberty beds; these rocks were exposed in the banks of the Whitewater River near Richmond, Ind. Nickles' description follows: "In this division the strata usually present a roughish, concretionary, nodular appearance, both the limestone and the shale. The color is usually brownish or yellowish, though at some localities bluish. The limestone layers, often more or less impure, are seldom over 2 inches thick and generally less. The thickness of this division is from 45 to 50 feet." *Homotrypa wortheni* was considered the characteristic fossil for the Whitewater although numerous other forms were listed (Nickles, 1903, p. 209).

Cumings (1908, p. 678) named the Elkhorn division or *Platystrophia lynx moritura* zone for about 50 feet of strata overlying the Whitewater beds and overlain by the Clinton (Brassfield). The type section is located along Elkhorn Creek southeast of Richmond, Ind. Cumings (1922, p. 438) gave this description of the type section: "at the top is a bed of soft clay-shale 4 feet thick, underlain by 6 feet of hard brownish limestone layers abounding in the brachiopods *Platystrophia moritura* and *Hebertella sinuata*. Below this come 25 feet of blocky, arenaceous limestone, underlain in turn by 15 feet of very soft blue, barren shale. Beneath this occur the lumpy Whitewater limestones abounding in *Rhynchotrema dentata*."

In the Maysville area, a thick sequence of interbedded shale and limestone overlain by a thin predominantly mudstone unit has previously been divided into units called Arnheim, Waynesville, Liberty, and Whitewater-Elkhorn by Dunn and Wolford (1930) and Palmquist and Hall (1960, sheet 3). (See fig. 3.) A recognizable and mappable lithologic break occurs about 25 feet below the base of the

Brassfield Formation within Dunn and Wolford's Whitewater-Elkhorn. The mudstone unit above this contact is lithologically unlike the typical Elkhorn lithology described previously. The rock below the contact is also unlike typical Elkhorn. McFarlan (1943, p. 33) did not recognize Elkhorn strata in Kentucky. The lumpy, nodular, or concretionary limestone characteristic of the Whitewater at the type locality is not present in the Maysville area. In this area, the boundaries separating the Arnheim and Waynesville, the Waynesville and Liberty, and the Liberty and Whitewater-Elkhorn have been placed at faunal breaks in the rock sequence. These faunal boundaries do not occur at recognizable lithologic breaks. The names Waynesville, Liberty, Whitewater, and Elkhorn, therefore, are inappropriate for rock-stratigraphic units in the Maysville area.

MAYSVILLE AND RICHMOND

Winchell and Ulrich (1897, p. 101–103) divided the rocks of the Cincinnati "period" into three groups, in ascending order, the Utica, the Lorraine, and the Richmond. The Utica and Lorraine Groups were considered equivalent to units of the same names in New York State. The Richmond Group was named for Richmond, Ind., and included the rocks previously called Lebanon beds (Orton, 1873, p. 371), the name Lebanon being preoccupied. Nickles (1902, p. 75) divided the Lorraine Group at Cincinnati into six series of beds. The base of the Lorraine was considered to be at the base of the Mount Hope or *Amplexopora septosa* beds, and the boundary between the Lorraine and Richmond Groups was considered to be at the top of the Warren or *Homotrypa bassleri* beds (Nickles, 1903, p. 75).

Foerste (1905, p. 150) proposed the name Maysville to replace Lorraine for strata at Cincinnati because the fauna of the Cincinnati rocks was different from that of the typical Lorraine in New York. The type section of the Maysville is a series of exposures along the Louisville and Nashville Railroad south of Maysville. Foerste (p. 150) stated that this "series of exposures gives a complete section of all the subdivisions of the Maysville division, from the Mount Hope bed to the top of the bed formerly known as Warren." At Maysville, the base of the Maysville division as defined by Foerste occurs within a thick unit of shale and some interbedded limestone. The lower boundary does not occur at a lithologic break but was placed at a faunal horizon considered equivalent to the base of the Mount Hope at Cincinnati. Subsequent workers in the Maysville area have shown little agreement on the placement of the lower boundary of the Maysville Group, as it is presently known. The boundary indicated by McFarlan and Nosow (1961, p. 278) and that indicated by Carpenter

and Ory (1961, p. 373–374) differed by more than 100 feet in the same section at Maysville. Both boundaries were placed on the basis of faunal criteria; McFarlan and Nosow used megafossils, whereas Carpenter and Ory used microfossils as well. Neither boundary coincides with a recognizable lithologic break.

The boundary between the Maysville division and the Richmond division was originally placed at the top of the Warren or Arnheim bed (Foerste, 1905, p. 150). Subsequently, Bassler (1906, p. 8) and Foerste (1909, p. 297) included the Arnheim in the Richmond Group. McFarlan and Nosow (1961, p. 279) considered the top of the Sunset as the upper boundary of the Maysville. Regardless of whether the boundary between the Maysville and Richmond Groups is placed at the base, within, or at the top of the Arnheim, its position depends on the recognition of fossils considered characteristic of each unit. Lithology has not been used as a criterion for separation.

The names Maysville and Richmond have been used (Twenhofel and others, 1954, chart 2) as time-stratigraphic terms (stages) as well as rock-stratigraphic terms (group). The terms were used as stage names (Sweet and others, 1959, p. 1030), and rocks were referred to the Richmondian and Maysvillian Stages (Hattin and others, 1961, p. 300). Whatever the suitability of the names Maysville and Richmond for time-stratigraphic units, they are inappropriate as rock-stratigraphic units in the Maysville area.

SUMMARY

The divisions of Upper Ordovician rocks above the Kope Formation in the Maysville area were primarily identified by early geologists on the basis of their faunal characteristics. These units are approximately time equivalent to divisions of Upper Ordovician rocks in the Cincinnati and Richmond areas. The previous nomenclature is inadequate for the lithologic divisions of the rock sequence in the Maysville area. The names Richmond, Maysville, Covington, Mount Hope, Fairmount, McMillan, Bellevue, Corryville, Mount Auburn, Arnheim, Sunset, Oregonia, Waynesville, Liberty, Whitewater and Elkhorn are inappropriate for rock-stratigraphic units at Maysville. The name Fairview Formation is retained for a rock unit similar in lithology to the Fairview Formation at Cincinnati.

PRESENT NOMENCLATURE

KOPE AND FAIRVIEW FORMATIONS

The Kope Formation was named by Weiss and Sweet (1964) and is used in the Maysville area as they defined it. It conformably overlies the Point Pleasant Formation, as used by Weiss and Sweet (p.

1301), which is considered of Middle Ordovician age by most workers. (See Weiss and Norman, 1960, pl. 1.)

The Kope consists of shale and a little interbedded limestone. Shale, which makes up 70–80 percent of the formation, is mainly gray, thin bedded, silty, and calcareous. Limestone is chiefly gray, very fine to coarse grained, poorly to well sorted, locally argillaceous to silty, and fossiliferous. It occurs in single thin to medium beds separated by variable thicknesses of shale. The Kope is about 270 feet thick in the Maysville area.

The Fairview Formation conformably overlies the Kope. It consists of closely interbedded limestone and shale and minor limy siltstone. Limestone, which makes up 50–60 percent of the formation, is mainly gray and chiefly of two types. Medium- to coarse-grained fossil fragmental limestone is dominant in the lower part. Fine-grained even-textured silty limestone containing few fossils is dominant in the upper part. Limestone is generally in even, thin to medium beds.

Shale makes up about 35–40 percent of the formation, is chiefly medium gray, calcareous, and silty, and occurs as partings and thin beds separating limestone beds. Limy siltstone makes up about 5–15 percent of the formation. The siltstone is mainly light olive gray and evenly thin to medium bedded, but bedding is contorted locally and forms "flow rolls." Siltstone is most abundant in the upper half of the formation.

The contact between the Kope and Fairview is placed at the base of the closely spaced limestone and shale. The contact is locally sharp, but regionally the lithology of the two formations is transitional.

The Fairview as used here follows Ford's usage at Cincinnati (Ford, 1965, p. 15–21). It is the Fairmount as used by McFarlan and Nosow (1961, p. 280) and the Fairmount plus a few feet of the McMillan Formation as used by Carpenter and Ory (1961, p. 374–376). (See fig. 3.)

GRANT LAKE LIMESTONE

The Grant Lake Limestone is here named for Grant Lake, which is about 2.8 miles west-northwest of Orangeburg, Mason County, Ky. The type section (measured section 1) was described from roadcuts along Kentucky Route 1449 about 4 miles north-northwest of Orangeburg (fig. 4).

The Grant Lake is chiefly irregularly bedded argillaceous limestone and minor interbedded shale. Limestone, which makes up 70–90 percent of the formation, is mainly medium to light gray and has

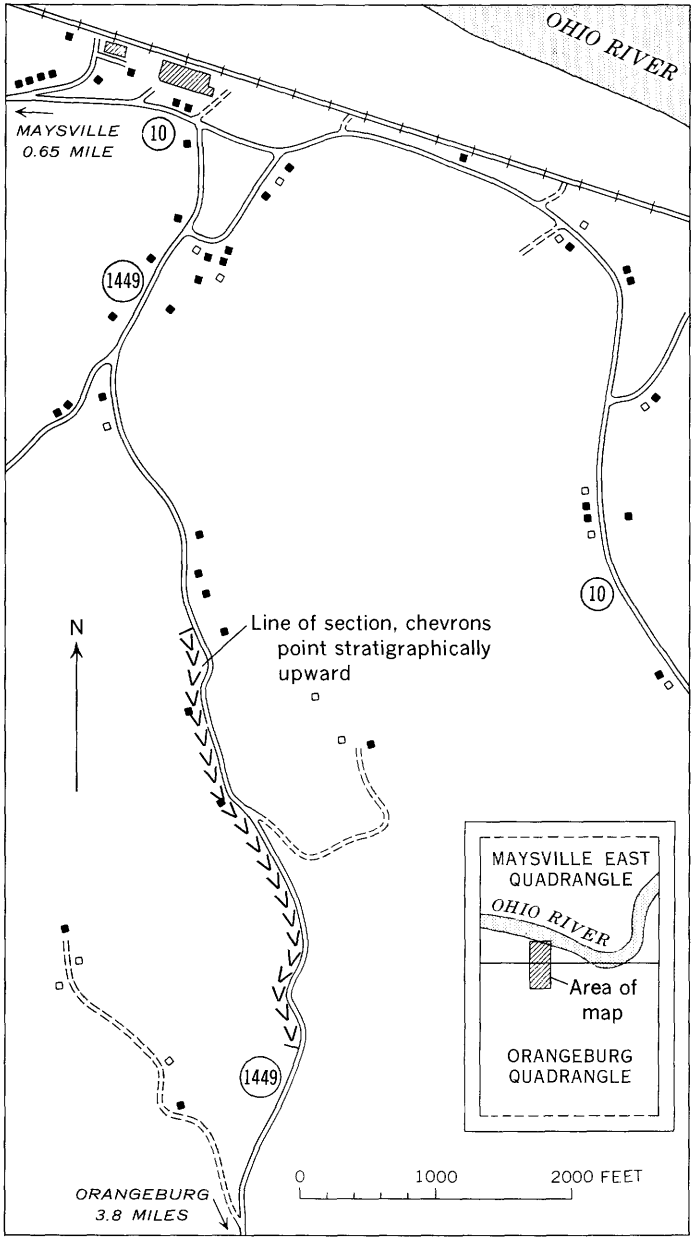

FIGURE 4.—Type section of the Grant Lake Limestone.

light-olive-gray mottling. The dominant type of limestone consists of a micrograined to medium-grained poorly sorted argillaceous limestone matrix surrounding jumbled large fossil fragments and whole fossils. The beds are thin, very irregular, and rubbly weathering. Thin- to thick-bedded fine- to coarse-grained well-sorted clastic limestone in even beds occurs locally. Gray calcareous shale occurs as irregular partings and thin beds separating limestone layers.

The Grant Lake is very fossiliferous throughout. Brachiopods and bryozoans are the most abundant and conspicuous faunal elements, but pelecypods, gastropods, cephalopods, trilobites, crinoids, and ostracodes occur locally.

The Grant Lake is relatively resistant to erosion and forms moderately steep slopes. Weathering of the limestone produces a distinctive rubble of rounded cobble-size fragments and a litter of fossil fragments. The Grant Lake Limestone is transitional into the underlying Fairview Formation (fig. 5). The contact is placed so as to separate alternating planar beds of limestone and shale of the Fairview Formation from irregularly bedded poorly sorted argillaceous limestone of the Grant Lake. The upper contact of the Grant Lake is sharp in some places (fig. 6), but the lithology is transitional in others. The contact is placed so as to separate rubbly argillaceous limestone of the Grant Lake from alternating limestone and shale of the Bull Fork Formation.

The Grant Lake has been mapped in Mason, Lewis, and Fleming Counties and has been recognized in exposures from Georgetown, Ohio, to Howards Mill, Ky. The formation is about 110 feet thick in its type locality. Between Sherburne and Mount Sterling, Ky., the lower part of the Grant Lake grades laterally to interbedded limestone and shale of the Calloway Creek Limestone and limy mudstone of the Tate Member of the Ashlock Formation (Weir and others, 1965). The upper part of the Grant Lake extends southwestward to near Richmond, Ky., where it grades laterally to limy mudstone of the Tate Member, micrograined limestone of the Gilbert Member, and nodular limy siltstone and silty limestone of the Stingy Creek Member of the Ashlock Formation (Weir and others, 1965). Previous workers have correlated the beds here included in the Grant Lake Limestone with the McMillan Formation of the Cincinnati area (Palmquist and Hall, 1960; McFarlan and Nosow, 1961; Carpenter and Ory, 1961).

BULL FORK FORMATION

The Bull Fork Formation is here named for Bull Fork Creek, a tributary of the Ohio River heading near Plumville, Mason County, Ky. The type section (measured section 2) was described from road-

FIGURE 5.—Contact of the Grant Lake Limestone (Ogl) and the Fairview Formation (Of). Evenly bedded limestone and interbedded shale characteristic of the Fairview is overlain by irregularly thin bedded argillaceous limestone characteristic of the Grant Lake. The lithology is somewhat transitional here. A 5-foot Jacob staff is shown for scale. Roadcut on Kentucky Route 10 about 1.5 miles northwest of Maysville.

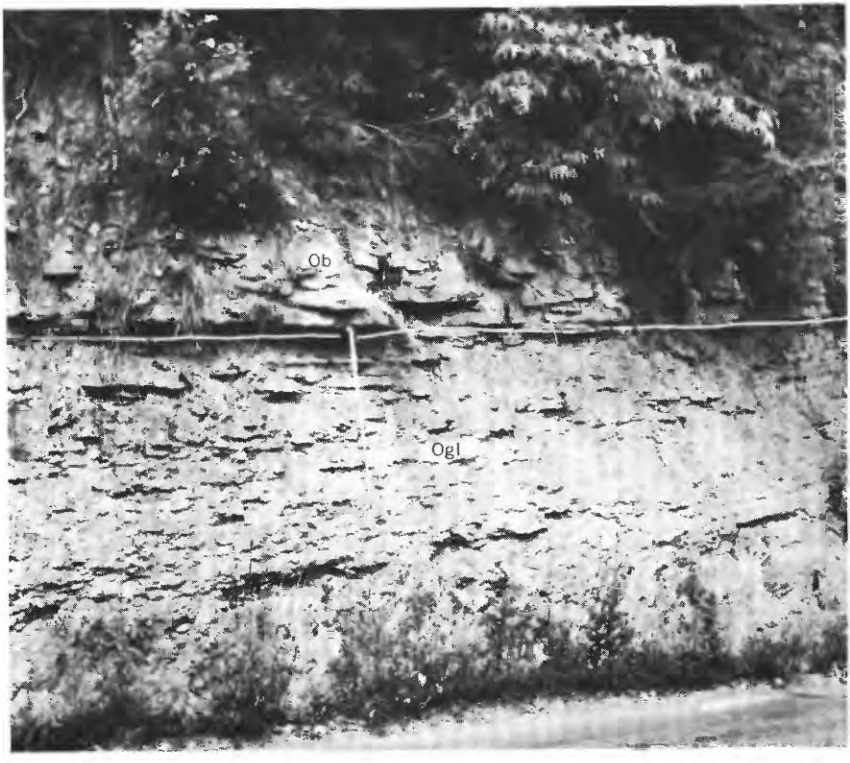

FIGURE 6.—Contact of the Grant Lake Limestone (Ogl) and the Bull Fork Formation (Ob). The very irregularly bedded argillaceous limestone is characteristic of the upper part of the Grant Lake. The basal Bull Fork has more evenly bedded limestone and thin interbeds of shale. Type section of the Grant Lake, roadcut on Kentucky Route 1449, 1.3 miles south of the junction with Kentucky Route 10. A 5-foot Jacob staff is shown for scale.

cuts along the east side of Kentucky Route 1443, about 1.9 miles east of Springdale, Ky. (fig. 7).

The Bull Fork Formation is composed of alternating shale and limestone, the shale content gradually increasing from about 20 percent of the formation near the base to about 80 percent near the top. The characteristic appearance of the formation in roadcuts is shown in figure 8. Shale is medium gray, grading to grayish green in the upper part, is calcareous, plastic when wet, thin bedded, fissile to poorly fissile, and obscurely laminated. Shale occurs as thin partings and seams, and as sets from 1 inch to 4 feet thick between limestone beds. Locally, shale grades laterally to obscurely bedded calcareous mudstone or to nodular argillaceous limestone.

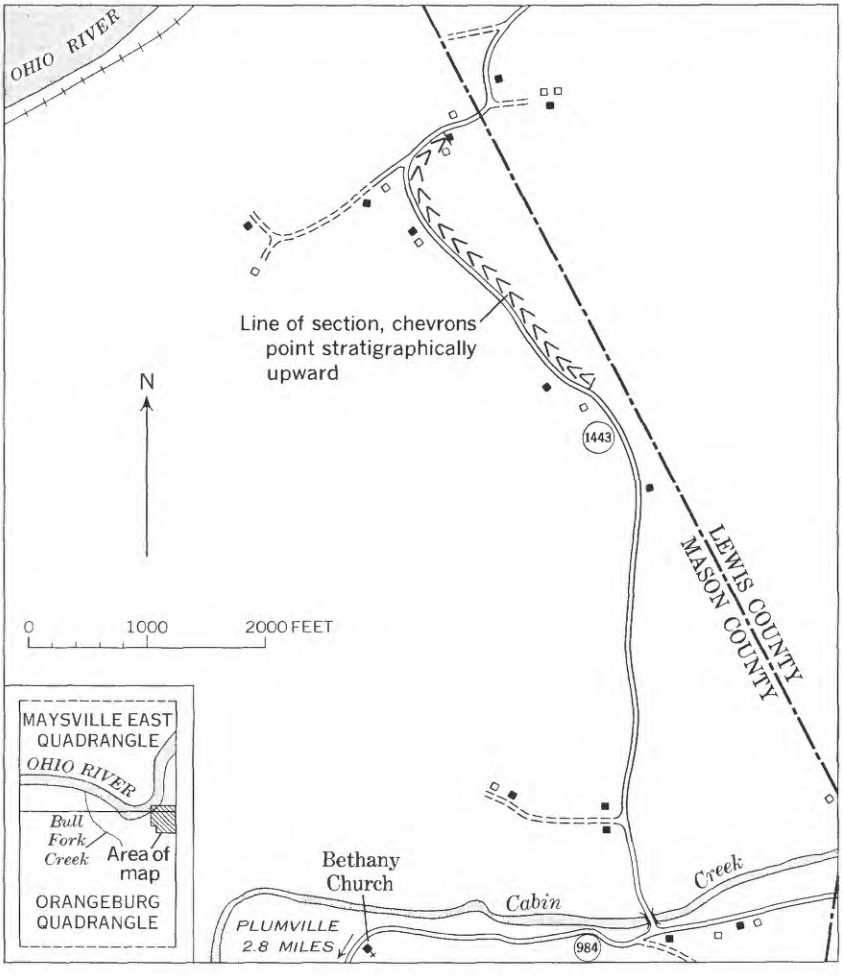

FIGURE 7.—Type section of the Bull Fork Formation.

Limestone of the Bull Fork Formation consists mainly of three types. The most common type, which makes up 50–70 percent of the limestone, is mainly gray, has some olive-gray to greenish-gray mottling, and has a fair- to well-sorted very fine to medium-grained matrix enclosing medium to very coarse fossil fragments that are oriented subparallel to the bedding. In many places this type of limestone contains pods and stringers of argillaceous material. Bedding is even to irregular, and beds range in thickness from 1 to 8 inches and average about 4 inches. Large ripple marks occur locally on the upper surfaces of beds.

FIGURE 8.—Characteristic interbedding of fossiliferous limestone and shale near middle of the Bull Fork Formation. Limestone beds are even to slightly irregular in thickness. Roadcut 0.6 mile southeast of Oakley on the road between Oakley and Wyoming, Ky.

The second type of limestone makes up 5–40 percent of the overall limestone content of the formation and increases in abundance southward from Flemingsburg toward the Mount Sterling area. This limestone is mainly olive gray, microgranular, and even textured and contains sparse fossil fragments. Locally ostracodes are common. In many places the limestone contains fine filaments and specks of carbonaceous material. The even bedding is smooth and undulatory. Beds range in thickness from 1 to 18 inches but are generally about 6 inches thick.

The third type makes up 5–30 percent of the limestone of the Bull Fork Formation and decreases in abundance southward from the Ohio River. Limestone of this type is medium to bluish gray, fine to coarse grained, well sorted, and may be slightly phosphatic. It is composed dominantly of closely packed grains of fossil debris cemented by crystalline calcite. The limestone is evenly bedded to crossbedded at low angles. Beds range from 2 to 18 inches in thickness; thin crossbeds occur in sets as much as 2 feet thick. This type of limestone is relatively resistant and commonly forms ledgy outcrops.

Lime mudstone, limy siltstone, and other diverse types of limestone are minor local constituents of the Bull Fork. The formation is very fossiliferous. Brachiopods and bryozoans are the most conspicuous faunal elements, but corals (both solitary and colonial), trilobites, pelecypods, gastropods, cephalopods, crinoids, and ostracodes are locally abundant. In the type area, a zone of abundant rugose corals is present near the middle of the formation. The top of the zone occurs about 100–115 feet above the base of the formation and locally is a useful horizon marker for mapping.

The Bull Fork Formation is generally nonresistant; it crops out poorly and forms moderate slopes on which lies an abundance of slabby limestone float. In the upper part, thick sets of shale weather to produce a poor, fluffy clay soil that supports little vegetation.

At the time of this writing (1965), the type section of the Bull Fork Formation has slumped badly, and some parts previously exposed are now covered. Discontinuous exposures, however, in the bed of the East Fork of Cabin Creek (Tollesboro quadrangle, Kentucky) and along the larger branches of Crooked Creek (Manchester Islands quadrangle, Kentucky) provide good examples of the lithology characteristic of the Bull Fork Formation in the type area.

The lithology of the Bull Fork Formation is transitional with the mudstone and minor interbedded dolomitic limestone and dolomite of the overlying Preachersville Member of the Drakes Formation (Weir and others, 1965). The upper contact is placed at the top of the highest persistent fossiliferous limestone.

The Bull Fork Formation has been mapped in parts of Mason, Lewis, and Fleming Counties and has been recognized in exposures south as far as Howards Mill. The Bull Fork is about 200 feet thick in the type area and thins to the south. Previous workers have correlated the beds here included in the Bull Fork Formation with the upper part of the McMillan Formation (McFarlan and Nosow, 1961, p. 278–

279), the Arnheim, Waynesville, and Liberty Formations, and all or part of the Whitewater Formation of Ohio and Indiana (Foerste, 1912; Dunn and Wolford, 1930; Palmquist and Hall, 1960).

PREACHERSVILLE MEMBER OF THE DRAKES FORMATION

The Drakes Formation and the Preachersville Member were named and defined by Weir, Greene, and Simmons (1965) in south-central Kentucky. Measured sections between the type locality and the Maysville area indicate that Preachersville as used here is a northern extension of the upper part of the Preachersville Member in its type area.

The Preachersville Member in the Maysville area consists of calcareous to dolomitic mudstone and minor interbedded dolomitic limestone and dolomite. Mudstone makes up about 90 percent of the formation, is chiefly grayish green but locally reddish purple near the top, thin bedded, fissile to blocky, and locally silty. Dolomitic limestone and dolomite are gray to brown, fine to medium grained, argillaceous to silty, and occur as thin lenses and irregular beds. Megafossils are sparse, and those present are fragmented and poorly preserved.

Near Maysville the Preachersville Member is 25–30 feet thick, and it increases in thickness southward. The Brassfield Formation of Early Silurian age overlies the Preachersville. In the Maysville area the contact between the Preachersville and Brassfield appears conformable, and locally the lithology is transitional between the two.

MEASURED SECTIONS

SECTION 1.—*Sleepy Hollow*

[Type section of Grant Lake Limestone and representative section of Fairview Formation in Maysville area. Section measured in roadcuts along Kentucky Route 1449, beginning about 0.7 mile south of the junction with Kentucky Route 10, Mason County, Ky. (Maysville East and Orangeburg quadrangles, see fig. 4). Base of section at E. 2,152,100; N. 410,450 (10,000-ft grid based on Kentucky coordinate system, north zone). Measured with Abney level and Jacob staff by F. A. Schilling, Jr., and J. H. Peck, June 1963; additional description by J. H. Peck, March 1965]

	Thickness (feet)
Bull Fork Formation (incomplete):	
13. Limestone (70 percent) interbedded with shale (29 percent) and limy siltstone (1 percent). Limestone of two types. Dominant type medium light gray (*N* 6) [1] to medium bluish gray (5*B* 5/1);	

[1] Color names and numbers based on rock color chart by Goddard and others (1948).

	Thickness (feet)
Bull Fork Formation—Continued	
weathers grayish orange (10*YR* 7/4); contains closely packed fossil fragments in a fine- to medium-grained limestone matrix; in even to slightly irregular thin to medium beds; abundant brachiopods and bryozoans. Minor limestone is medium light gray to light bluish gray (5*B* 7/1); weathers light olive gray (5*Y* 6/1) to grayish orange; fine to coarse grained; well sorted; in thin even beds. Shale medium dark gray (*N* 4); weathers dusky yellow (5*Y* 6/4); fissile; calcareous; in thin sets and partings. Limy siltstone light olive gray; weathers yellowish gray (5*Y* 7/2); in very thin lenses and beds, and as thin sheaths on limestone. Unit relatively nonresistant; not measured, about 10 ft exposed.	
Grant Lake Limestone:	
12. Limestone (95 percent) interbedded with shale (5 percent). Limestone rubbly weathering and mottled medium dark gray (*N* 4) and light olive gray (5*Y* 6/1); weathers light gray (*N* 7) to yellowish gray (5*Y* 6/1); composed of jumbled whole fossils and fossil fragments in a fine-grained argillaceous limestone matrix that makes up 50 percent or more of the rock; in very thin very irregular rough-surfaced beds and discontinuous lenses and nodules; called rubbly and argillaceous limestone in remainder of section; very abundant brachiopods and bryozoans; pelecypods locally. Minor fine-grained even-textured limestone in thin even beds. Shale medium dark gray; weathers light gray; fissile; calcareous; in irregular and discontinuous partings and seams. Unit resistant; well exposed	19
11. Limestone (85 percent) interbedded with shale (15 percent). Limestone of three types in about equal abundance. Type 1 rubbly and argillaceous limestone. Type 2 medium gray (*N* 5); weathers medium gray to yellowish gray (5*Y* 7/2); fine grained; well sorted; called fine-grained limestone in remainder of section; laminated to locally cross laminated; evenly thin to medium bedded; few megafossils. Type 3 medium gray; weathers yellowish gray to grayish orange (10*YR* 7/4); composed of closely packed coarse fossil fragments cemented with coarsely to medium-crystalline calcite; small amounts of fine-grained matrix; local argillaceous inclusions; evenly thin to medium bedded; abundant brachiopods and bryozoans. Shale, like that in unit 12, as partings and sets as much as 2 in. thick. Unit resistant; well exposed	3
10. Covered	13

	Thickness (feet)
Grant Lake Limestone—Continued	
9. Limestone (85 percent) interbedded with shale (15 percent). Limestone of three types. Type 1 (50 percent of limestone) medium light gray (*N* 6), some grayish green (5*GY* 6/1) mottling; weathers grayish orange (10*YR* 7/4); composed of closely packed whole fossils and fossil fragments in a fine- to medium-grained limestone matrix; locally argillaceous; abundant brachiopods and bryozoans. Type 2 (40 percent of limestone) medium light gray to medium bluish gray (5*B* 5/1), weathers same to grayish orange; coarse grained; fair to well sorted; cemented with sparry calcite; grains chiefly of worn fossil fragments; may be slightly phosphatic; called coarse-grained limestone in remainder of section; abundant brachiopods, bryozoans, and crinoid columnals. Type 3 (10 percent of limestone) medium bluish gray, silty, and fine grained. All limestones chiefly evenly thin to medium bedded; a few beds irregular. Shale medium gray (*N* 5); weathers yellowish gray (5*Y* 7/2); fissile; calcareous; as partings and sets as much as 3 in. thick. Unit relatively nonresistant; poorly exposed	15
8. Limestone (95 percent) interbedded with shale (5 percent). Limestone of three types in about equal abundance: Type 1 medium light gray and coarse grained; abundant brachiopod and bryozoan fragments. Type 2 rubbly and argillaceous; abundant brachiopods and bryozoans; local petroleum residue. Type 3 medium bluish gray and fine grained. All limestone chiefly in thin irregular beds, a few beds as much as 8 in. thick; a few beds even. Shale, like that in unit 9, as irregular partings and seams. Unit resistant; well exposed	6
7. Limestone (90 percent) interbedded with shale (10 percent). Limestone of two types about equal in abundance: Type 1 medium gray (*N* 5) to medium bluish gray (5*B* 5/1); fine grained. Type 2 similar to type 3 of unit 11 except that it has local greenish gray (5*GY* 6/1) mottling; abundant brachiopods and bryozoans; gastropods and pelecypods locally common. Both types chiefly in thin even beds, a few beds as much as 1 ft thick; a few beds irregular. Shale, like that in unit 9, as partings and thin seams. Unit relatively resistant; well exposed	12
6. Limestone (90 percent) interbedded with shale (10 percent). Limestone of two types. Type 1 (80 percent of limestone) rubbly and argillaceous; chiefly thin bedded, a few beds as much as 8 in. thick; abundant brachiopods and bryozoans; gastropods and pelecypods locally. Type 2 medium dark gray (*N* 4), weathers medium light gray (*N* 6) to grayish orange (10*YR* 7/4); fine to coarse grained; well sorted; chiefly in irregular thin to medium beds, a few even beds. Shale like that in unit 12. Unit resistant; well exposed	41
Total Grant Lake Limestone	109

	Thickness (feet)
Fairview Formation:	
5. Limestone (55 percent) interbedded with shale (35 percent) and limy siltstone (10 percent). Limestone of two types. Type 1 (60 percent of limestone) medium bluish gray (5*B* 5/1) to light olive gray (5*Y* 6/1); silty; fine grained; evenly thin to medium bedded, a few beds as much as 1½ ft thick; cut-and-fill structure locally; flow roll in bed at base. Type 2, medium light gray (*N* 6) to light bluish gray (5*B* 7/1); weathers same to grayish orange (10*YR* 7/4); closely packed medium to coarse fossil fragments having finely to coarsely crystalline calcite cement; moderate amounts of fine-grained limestone matrix; sparse argillaceous inclusions; whole fossils on bedding surfaces; called fossil fragmental limestone in remainder of section; evenly to irregularly thin to medium bedded; abundant brachiopods and bryozoans; locally abundant crinoid columnals. Type 2 more common in upper part of unit. Some composite limestone beds made up of alternations of types 1 and 2. Shale olive gray (5*Y* 3/2); weathers grayish olive (10*Y* 4/2); fissile; calcareous; silty; as partings and sets as much as 6 in. thick. Limy siltstone light olive gray (5*Y* 6/1), laminated, locally cross laminated; in thin to medium even to lenticular beds; local ripple marks; few fossils. Unit moderately resistant; well exposed	22
4. Limestone (50 percent) interbedded with shale (40 percent) and limy siltstone (10 percent). Limestone of two types. Type 1 (60 percent of limestone) silty, fine grained, and similar to limestone in unit 5; evenly thin to medium bedded; local ripple marks. Type 2 fossil fragmental limestone similar to that in unit 5; chiefly in thin even to slightly irregular beds, some as much as 8 in. thick; abundant fossils. Some composite beds as in unit 5. Shale like that in unit 5. Limy siltstone like that in unit 5; grades locally to silty limestone. Unit nonresistant; fair exposures	21
3. Limestone (70 percent) interbedded with shale (25 percent) and limy siltstone (5 percent). Limestone of two types. Type 1 (70 percent of limestone) fossil fragmental limestone having local pale-reddish-brown (10*R* 5/4) specks (phosphatic?); chiefly evenly thin bedded, a few beds as much as 8 in. thick; abundant fossils. Type 2 light olive gray (5*Y* 7/2), silty, fine grained; ripple marks locally; evenly thin to medium bedded; more abundant in upper 12 ft of unit. A few composite limestone beds as in unit 5. Shale like that in unit 5; in partings and sets as much as 3 in. thick. Limy siltstone like that in unit 5 except in very thin to thin beds and lenses; some as sheaths on limestone. Unit relatively nonresistant; well exposed	32

	Thickness (feet)
Fairview Formation—Continued	
2. Limestone (85 percent) interbedded with shale (15 percent). Limestone chiefly medium light gray (*N* 6) to medium bluish gray (5*B* 5/1); weathers light gray (*N* 7) to grayish orange (10*YR* 7/4); composed of jumbled large whole fossils and fossil fragments and coarsely to medium-crystalline calcite cement; irregular clay films; obscurely bedded in sets a few inches to as much as 2 ft thick; profuse strophomenid brachiopods and abundant bryozoans. Minor silty fine-grained limestone in thin even beds in lower 2 ft of unit. Shale, like that in unit 1, as partings and sets as much as 4 in. thick in lower 2 ft of unit. Unit forms prominent ledge; well exposed	6
Total Fairview Formation	81
Kope Formation (incomplete):	
1. Shale, medium-gray (*N* 5) to olive-gray (5*Y* 4/1); weathers light gray (*N* 7) to greenish-gray (5*GY* 6/1); thin bedded; calcareous; locally abundant bryozoans; a few thin lenses and beds of fine- to coarse-grained fossiliferous limestone; sparse limy siltstone lenses. Unit nonresistant; not measured, about 4 ft poorly exposed.	

SECTION 2.—*County line*

[Type section of Bull Fork Formation. Section measured in roadcuts along Kentucky Route 1443 beginning about 0.9 mile north of the junction with Kentucky Route 984, Mason County, Ky. (Orangeburg and Maysville East quadrangles, see fig. 7.) Base of section at E. 2,176,500; N. 408,850 (10,000-ft grid based on Kentucky coordinate system, north zone). Measured with Abney level and Jacob staff by F. A. Schilling, Jr., June 1963; additional description by J. H. Peck, March 1965]

	Thickness (feet)
Preachersville Member of Drakes Formation (incomplete):	
13. Mudstone, grayish-green (10*GY* 5/2); weathers grayish yellow green (5*GY* 7/2); thin bedded; somewhat fissile; limy to dolomitic; a few very thin irregular beds of argillaceous to silty dolomitic limestone containing sparse recrystallized fossil fragments. Unit nonresistant; poorly exposed	21
Bull Fork Formation:	
12. Shale (80 percent) interbedded with limestone (19 percent) and limy siltstone (1 percent). Shale grayish green (10*GY* 5/2); weathers grayish yellow green (5*GY* 7/2); thin bedded; fissile; limy to dolomitic; in sets a few inches to as much as 4 ft thick. Limestone of two types. Dominant type 1 medium light gray (*N* 6); weathers yellowish gray (5*Y* 7/2); composed of closely packed medium to coarse fossil fragments in a very fine to fine-grained limestone matrix; sparse silty to argillaceous inclusions; abundant brachiopods and bryozoans. Minor type 2 medium light gray to medium bluish gray (5*B* 5/1); weathers yellowish gray; evenly fine grained; well sorted; few fossils. Both types in thin even beds. Limy siltstone light olive gray; in very thin rippled beds intercalated with shale. Unit nonresistant; poorly exposed. Upper contact placed at top of highest bed of fossiliferous limestone	19

	Thickness (feet)
Bull Fork Formation—Continued	
11. Shale (70 percent) interbedded with limestone (29 percent) and limy siltstone (1 percent). Shale, like that in unit 12 except not dolomitic, in sets as much as 3 ft thick. Limestone of three types: two about equal in abundance, the third minor (1–2 percent). Type 1 fossil fragmental limestone similar to type 1 of unit 12; some sparry calcite cement. Type 2 fine grained and similar to type 2 of unit 12. Type 3 (minor) light gray (N 7); weathers grayish orange (10YR 7/4); coarse grained; well sorted; made up of worn fossil fragments cemented with coarsely to medium-crystalline calcite. All limestone in thin even beds. Limy siltstone similar to that in unit 12; mostly in upper part. Unit nonresistant; fair exposures	28
10. Covered	9
9. Shale (65 percent) interbedded with limestone (33 percent) and limy siltstone (2 percent). Shale similar to that in unit 11 except some is medium light gray (N 6); weathers dusky yellow (5Y 6/4); in sets a few inches to as much as 2 ft thick. Limestone of three types. The most abundant (about two-thirds) is fossil fragmental limestone similar to type 1 of unit 12 except for some light-olive-gray (5Y 6/1) mottling and common argillaceous inclusions; abundant fossils. Type 2 (about one-third) fine grained and similar to type 2 of unit 12; some thinly laminated beds; some pyrite. A few beds of coarse-grained limestone similar to type 3 of unit 11. All types in even thin to medium beds. Limy siltstone similar to that in unit 12. Unit relatively resistant; moderately well exposed	26
8. Shale (60 percent) interbedded with limestone (40 percent). Shale medium gray (N 5); weathers dusky yellow (5Y 6/4); thin bedded; fissile; limy; in sets a few inches to as much as 2 ft thick. Limestone of two types. More abundant type fossil fragmental limestone similar to that in unit 9; abundant brachiopods and bryozoans. Less abundant type fine grained, similar to type 2 of unit 12; some beds thinly laminated. Both types chiefly in even thin beds, a few beds as much as 8 in. thick. Unit nonresistant; fair discontinuous exposures	16
7. Shale (60 percent) interbedded with limestone (40 percent). Shale, like that in unit 8, as partings and thin sets. Limestone of three types. Dominant type fossil fragmental limestone like that in unit 9 except that the matrix is locally argillaceous; in thin even to irregular beds having rough surfaces; abundant brachiopods and bryozoans. Limestone second in abundance coarse grained like type 3 of unit 11; in thin even beds. Minor fine-grained limestone, like type 2 of unit 12, in thin even beds. At top of unit 2 in. of coquina composed chiefly of whole shells of *Catazyga headi*. Horn corals common in shale and limestone of this unit. Unit relatively resistant; fair to good exposures	24

	Thickness (feet)
Bull Fork Formation—Continued	
6. Mostly covered. Shale and interbedded limestone of about equal abundance. Described from float and small scattered exposures. Shale, like that in unit 8, as thin sets and partings. Limestone of three types. Dominant type fossil fragmental limestone like that in unit 7; chiefly evenly thin bedded, some irregular rough-surfaced beds. Less common types fine-grained limestone like type 2 of unit 12 and coarse-grained limestone like type 3 of unit 11; both in thin even beds. Abundant fossils. Unit nonresistant	26
5. Limestone (70 percent) interbedded with shale (30 percent). Limestone of two types. Dominant type fossil fragmental limestone like type 1 of unit 12 except that some beds have a large amount of matrix and sparse fossil fragments. Less common type coarse-grained limestone like type 3 of unit 11; may be slightly phosphatic. Both limestones in very thin to thin even beds having rough surfaces. Shale, like that in unit 8, in thin beds and partings. Abundant fossils. Unit resistant; well exposed	5
4. Mostly covered. Shale interbedded with limestone in roughly equal proportions. Described chiefly from float. Limestone of three types. Dominant type fossil fragmental limestone similar to that in unit 9; in thin even to irregular beds. Less abundant type coarse-grained limestone similar to type 3 of unit 11 except that it may be slightly phosphatic; in thin even beds. A few thin even beds of fine-grained limestone like type 2 of unit 12. Shale weathered; yellowish gray (5*Y* 7/2) to dusky yellow (5*Y* 6/4); limy; as thin sets and partings. Shale and limestone very fossiliferous. Unit nonresistant	11
3. Limestone (50 percent) interbedded with shale (50 percent). Limestone of three types. Most abundant type (60 percent) fossil fragmental limestone like that in unit 9; in thin even to irregular beds. Type 2 (25 percent) coarse-grained limestone similar to type 3 of unit 11 except that it contains some large whole fossils and large fossil fragments; may be slightly phosphatic; in thin even beds; mostly in upper part. Type 3 (15 percent) fine-grained limestone similar to that in unit 7; in thin even beds; mostly in middle part of unit. Shale, like that in unit 8, as partings and thin sets. Abundant fossils. Unit relatively resistant; well exposed	18
2. Limestone (70 percent) interbedded with shale (30 percent). Limestone of two types in about equal amounts. Type 1 fossil fragmental limestone similar to that in unit 9; in thin rough-surfaced even to irregular beds; chiefly in upper part of unit. Type 2 coarse-grained limestone similar to type 3 of unit 11 except that it is slightly phosphatic and contains grayish-red (5*R* 4/2) specks; chiefly evenly thin bedded; a few beds as much as 8 in. thick; mostly in lower part of unit. Shale, like that in unit 8, as partings and sets a few inches to as much as 1 ft thick. Abundant fossils. Unit moderately resistant; well exposed	20

	Thickness (feet)
Bull Fork Formation—Continued	
1. Limestone, medium-light-gray (*N* 6); dark-yellowish-orange (10*YR* 6/6) specks; coarse grained; well sorted; slightly phosphatic; sparry calcite cement; thin to medium bedded; obscurely cross-bedded in part; shale partings; sparse whole fossils. Forms prominent ledge. Lower contact sharp	3
Total Bull Fork Formation	204

Grant Lake Limestone (incomplete):

Limestone, medium-light-gray (*N* 6) and light-olive-gray (5*Y* 6/1); large fossils and coarse fossil fragments in a micrograined to fine-grained argillaceous limestone matrix; very thin irregular rubbly beds; irregular shale partings. Unit not measured; about 3 ft exposed.

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