Borden Formation (Mississippian) in South- and Southeast-Central Kentucky

By G. W. WEIR, J. L. GUALTIERI, *and* S. O. SCHLANGER

CONTRIBUTIONS TO STRATIGRAPHY

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By G. W. Weir, J. L. Gualtieri, and S. O. Schlanger

ABSTRACT

The Borden Formation is a major stratigraphic unit in south- and southeast-central Kentucky. It includes strata divided by P. B. Stockdale in 1939 into the New Providence, Brodhead, Floyds Knob, and Muldraugh Formations of the Borden Group and locally also strata previously assigned to the Salem and Warsaw Limestones and to the St. Louis Limestone. The older nomenclature is unsuitable because the named stratigraphic units are not mappable.

The Borden Formation in south- and southeast-central Kentucky is composed of clayey and silty shale, limy and shaly siltstone and siltstone, and cherty, dolomitic, and argillaceous limestone and limestone. These rock types differ in proportion from place to place, but characterize mappable units that in this report are newly named or redefined as members of the Borden Formation. Members of the Borden recognized in this report are the Nancy Member (shale and shaly siltstone), the Cowbell and Halls Gap Members (resistant siltstone), the Nada and Wildie Members (shale and siltstone), the Renfro Member (argillaceous limestone and dolomite), and the Muldraugh Member (cherty and dolomitic limestone, limestone, and limy and dolomitic siltstone).

The Borden Formation conformably overlies black shale—the New Albany Shale of Devonian age in south-central and part of southeast-central Kentucky, the generally equivalent Chattanooga Shale in part of southeast-central Kentucky, and the Sunbury Shale of Early Mississippian age in northeast Kentucky. The Borden is conformably overlain by the Salem and Warsaw Limestones of Late Mississippian age in south-central Kentucky and by the Newman Limestone of Late Mississippian age in southeast-central Kentucky.

The Borden ranges from about 220 to 450 feet in thickness in south- and southeast-central Kentucky. The Borden Formation is chiefly of Early Mississippian age, but it locally includes some beds of Late Mississippian age.

INTRODUCTION AND ACKNOWLEDGMENTS

Current geologic mapping of 7½-minute quadrangles in southeast-central Kentucky shows that the Borden Formation is divisible into mappable members, which do not coincide with previously named divisions of the Borden. This paper describes seven members of the

Borden Formation in south- and southeast-central Kentucky (fig. 1). These are, in ascending order, the Nancy, Cowbell, Nada, Halls Gap, Wildie, Renfro, and Muldraugh Members (fig. 2).

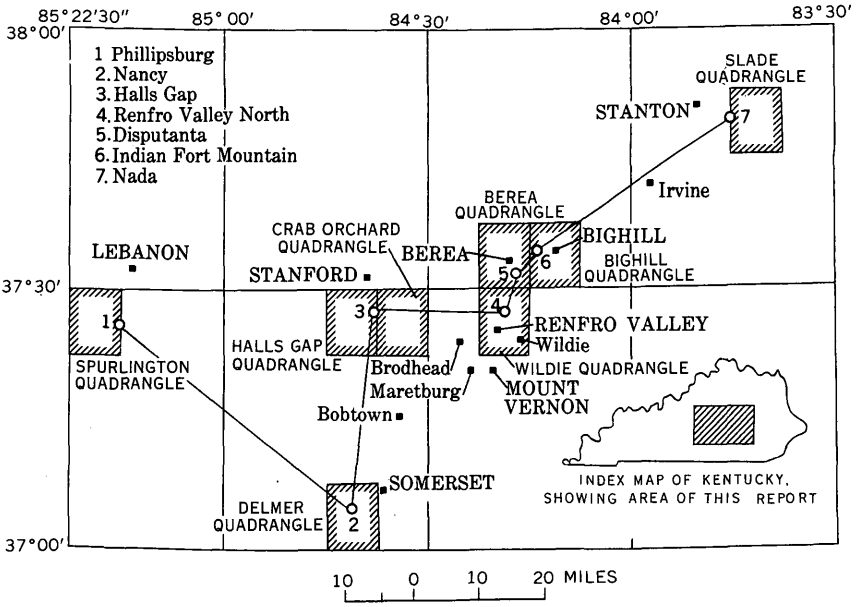

FIGURE 1.—Index map of south- and southeast-central Kentucky showing locations of principal measured sections, towns, and 7½-minute quadrangles mentioned in text.

This report is based in large part on the geological mapping of Kentucky being conducted by the U.S. Geological Survey in cooperation with the Kentucky Geological Survey. Areas not currently being mapped were studied chiefly in the spring and summer of 1962 by the writers, who reviewed exposed sections described by Stockdale (1939) and Butts (1922) and measured supplementary sections. Of special help was the information and criticism contributed by N. L. Hatch, R. C. Kepferle, R. Q. Lewis, Sr., E. G. Sable, and W. L. Peterson of the U.S. Geological Survey and by T. J. Crawford of the Kentucky Geological Survey.

PREVIOUS NOMENCLATURE

BORDEN GROUP

The name Borden Group, given to rocks of Early Mississippian age in Indiana by Cumings (1922), was extended by Stockdale (1931, 1939) to an equivalent sequence of shale, siltstone, and limestone in

Kentucky. Stockdale (1939) divided the Borden Group[1] of Kentucky into, in ascending order, the New Providence, Brodhead, Floyds Knob, and Muldraugh Formations. These formations, subdivided into named members and facies, were considered to extend generally throughout the outcrop of Lower Mississippian rocks of central Kentucky.

NEW PROVIDENCE FORMATION

The New Providence Formation (Borden 1874; Stockdale, 1931) was named for exposures near the village of Borden, formerly New Providence, Ind. The New Providence Formation as described by Stockdale (1939, p. 85, 106) has a vaguely defined top in its type area and throughout most of Kentucky. Stockdale (1939, p. 114, 117, 119, 153) noted that in many places the top of the New Providence is conjectural because there is no contrasting lithology. Restudy of many of Stockdale's sections in south- and southeast-central Kentucky shows that a major break in lithology—a mappable contact—commonly lies 50 to more than 100 feet above the top of the New Providence as described by Stockdale (1939). The meaning of the term New Providence in Kentucky is further confused by misunderstanding of relations between "New Providence" and the overlying Brodhead Formation as used by Stockdale (1939). In short, the mappable basal unit of the Borden differs so greatly from the interval commonly designated as New Providence that the name "New Providence" is not useful in south- and southeast-central Kentucky.

BRODHEAD FORMATION

Stockdale (1939, p. 125–136) gave the name Brodhead Formation to a generalized unit in Kentucky that overlies his New Providence Formation and underlies his Floyds Knob Formation. The type section of the formation is near the town of Brodhead in southeast-central Kentucky. There Stockdale assigned 117 feet of beds to the Brodhead, including at the base 65 feet of slightly silty shale, which closely resembles the underlying shale that he assigned to the New Providence. The mappable part of Stockdale's type Brodhead consists of about 50 feet of fairly resistant siltstone with minor shaly siltstone (in this report the Halls Gap Member of the Borden Formation).

A simple two-layer relation of the Brodhead and New Providence as inferred by Stockdale (fig. 3, upper section) does not exist. He

[1] Recently the Borden in southeast-central Kentucky has been called a formation rather than a group (Hatch, 1964).

thought, for example, that the lower siltstone bed near Brodhead (fig. 3, upper section) was the same as the lower siltstone bed near Conway (fig. 3, lower section) and, as shown in the upper section of figure 3, called both the Gum Sulphur Siltstone Member of the New Provi-

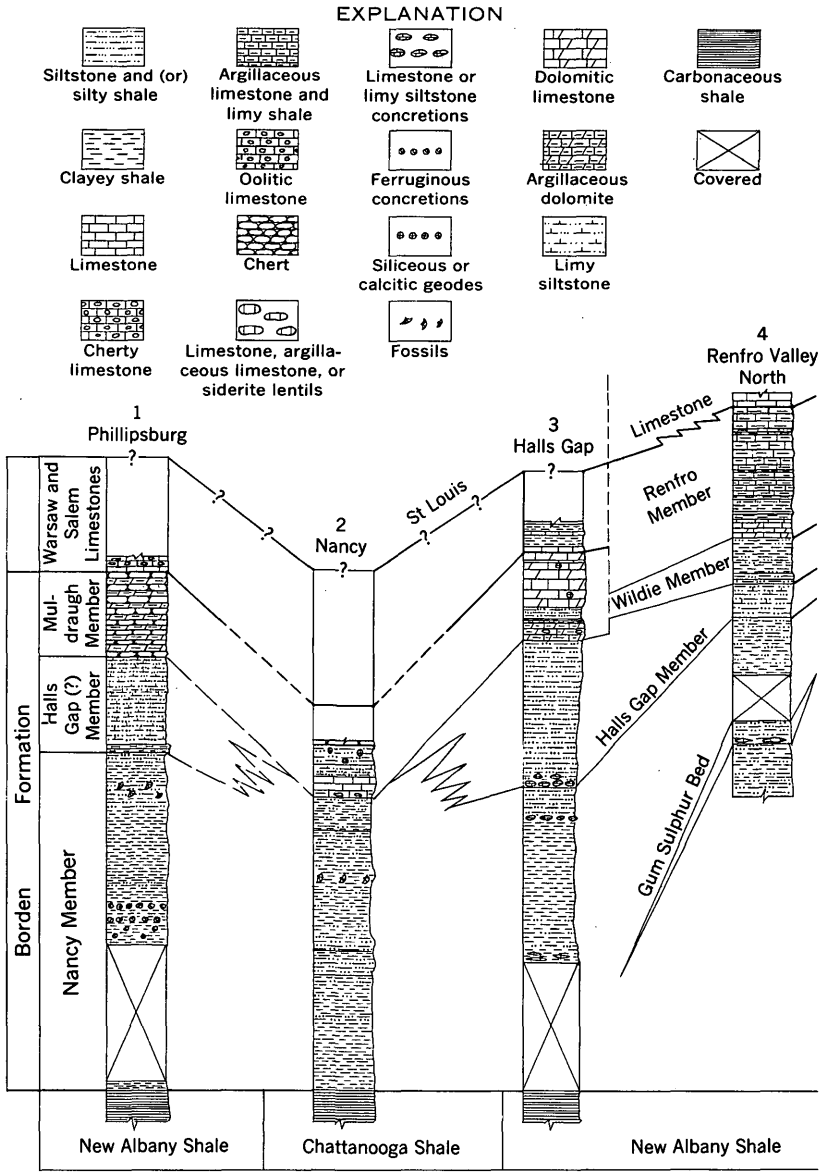

FIGURE 2.—Graphic sections of the Borden Formation in south- and southeast-central Kentucky. See figure 1 for location of sections.

dence Formation. Geologic mapping has demonstrated, however, that the siltstone beds at the two localities are not the same and that one bed overlies the other, as shown in the lower section of figure 3. Furthermore, the siltstone unit forming the mappable part of the type

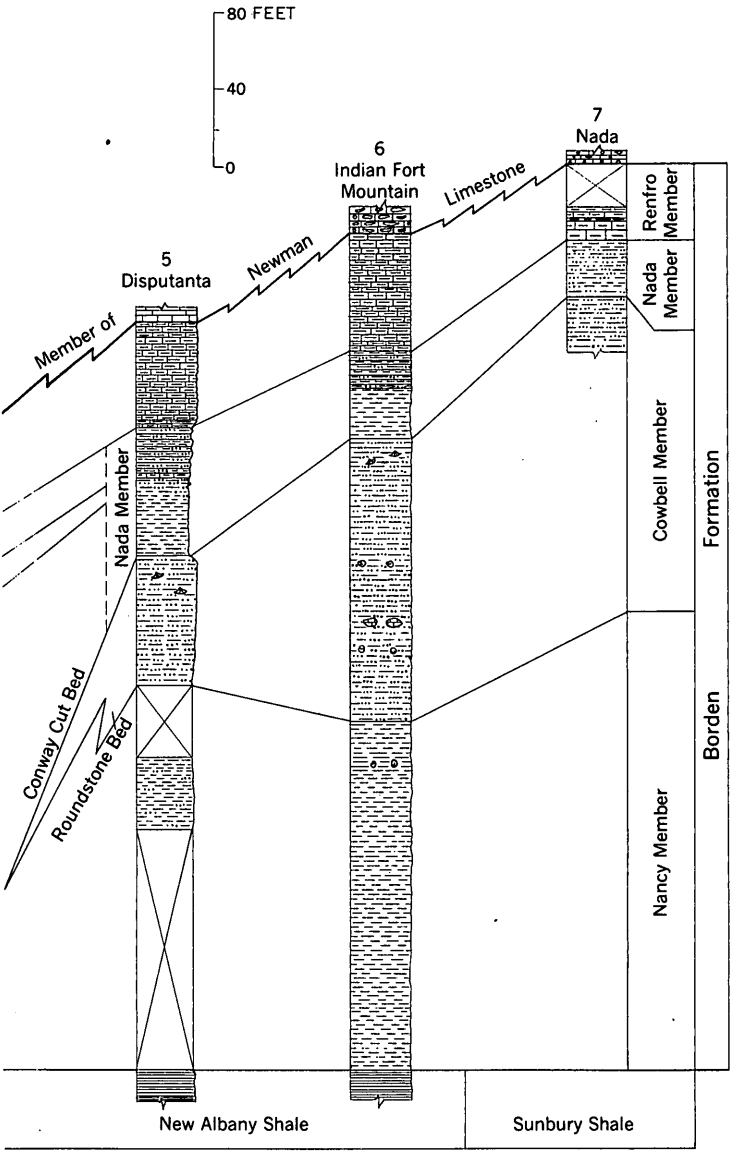

FIGURE 2.—Continued.

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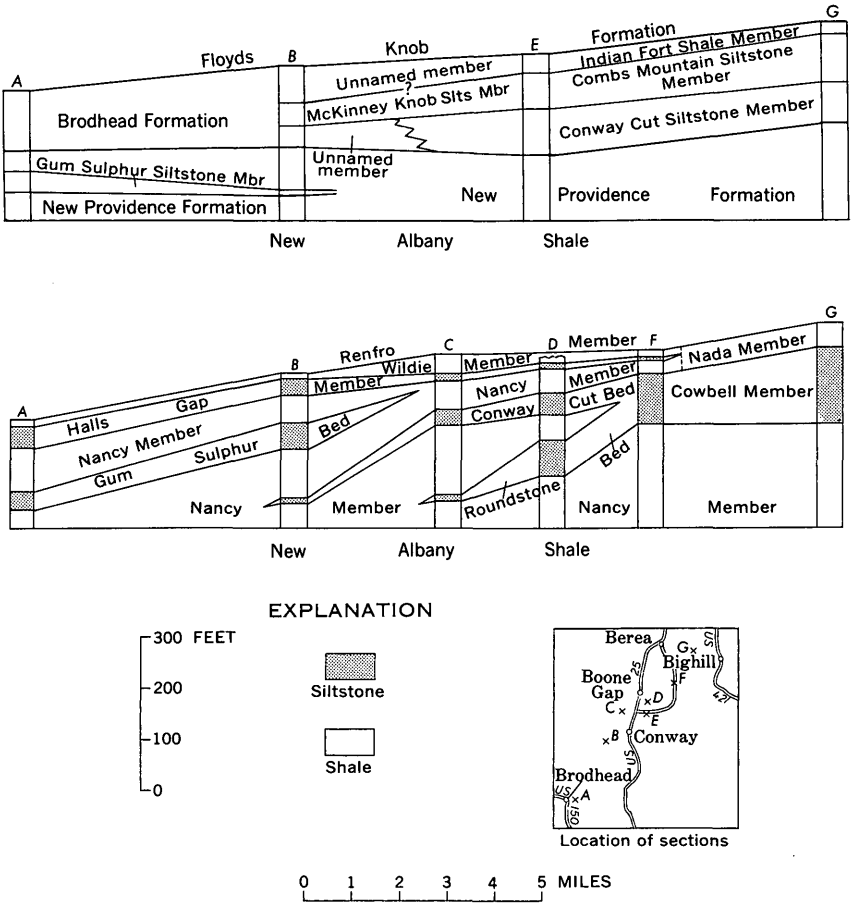

FIGURE 3.—Sections showing relations of siltstone units of Early Mississippian age in the area between Brodhead and Bighill, Ky. Upper section, as inferred by Stockdale (1939, pl. 15, p. 136–137, 164, 172–174). Lower section, as determined by detailed mapping. Explanation of lithologic symbols applies to lower section only.

Brodhead pinches out south of Berea and is not continuous with the mappable unit near Berea (Cowbell Member of the Borden Formation in this report) that Stockdale assigned to his Brodhead formation.

The name Brodhead Formation is abandoned because this unit is not mappable at its type section and because the name has been previously applied to separate units.

FLOYDS KNOB FORMATION

Stockdale correlated a thin unit of glauconitic limestone and siltstone in the Lower Mississippian rocks of central Kentucky with his Floyds Knob Formation (Stockdale, 1929) in Indiana. The Floyds

Knob Formation as used by Stockdale (1939, p. 191) in Kentucky "is a thin nonimpressive feature of varying lithology, generally limestone with one or more associated sheets of greenish-black silt, which constitutes an extremely minor part of the rock column." Stockdale reported thicknesses of the formation ranging from about 2 feet to a fraction of an inch in south- and southeast-central Kentucky.

The Floyds Knob of Stockdale's usage in south-central and eastern Kentucky is a very thin bed of glauconitic siltstone or silty limestone that is commonly well exposed only in fresh roadcuts. In southeast-central and south-central Kentucky the identity of the Floyds Knob of Stockdale's usage is frequently confused by the presence of more than one seam of glauconitic silt, and in some areas as near Stanton the glauconitic silt is absent or so sparse as to make recognition of the glauconitic marker bed impracticable.

The Floyds Knob Formation is not a stratigraphic unit of formational rank in south- and southeast-central Kentucky because it is discontinuous and too thin to map separately. In some areas, however, glauconitic siltstone or glauconitic limestone form marker beds that are useful in interrelating dissimilar stratigraphic sections.

The Floyds Knob Formation as used by Stockdale (1939) separated the Brodhead Formation from the Muldraugh Formation. In a few places, such as near Brodhead and Phillipsburg (Stockdale, 1939, p. 136, 201), the glauconitic seam he identified as Floyds Knob does separate dissimilar lithologic units. More generally, however, the glauconitic silt lies within a lithologic unit a few feet to several tens of feet above a major change in rock types.

MULDRAUGH FORMATION

Stockdale (1939, p. 200–201) applied the name Muldraugh Formation in Kentucky to rocks of the upper part of the Borden Group above the Floyds Knob Formation. The type section (p. F36) is on Muldraugh Hill near Phillipsburg in south-central Kentucky.

At the type section the Muldraugh consists chiefly of cherty and dolomitic limestone and silty limestone. Eastward it becomes more cherty and includes much silty limestone, and minor calcareous siltstone and crinoidal limestone. In southeast-central and east-central Kentucky the Muldraugh Formation as used by Stockdale includes much siltstone overlain by yellowish silty limestone. The yellowish silty limestone was in part assigned to the Muldraugh Formation and in part assigned with a query to the Salem Formation and the St. Louis Limestone (Stockdale, 1939, p. 173, 212, pl. 6).

In this report the Muldraugh is redefined in terms of its lithology at its type section as a member of the Borden Formation.

BORDEN FORMATION

The Borden Formation in south- and southeast-central Kentucky is a heterogeneous unit that ranges from about 220 to 450 feet in thickness. It commonly shows the following general sequence from the base upward: (1) a thick unit of grayish-green to gray clayey shale grading upward into (2) medium-gray silty shale with minor gray siltstone, and (3) gray to grayish-yellow limestone—commonly dolomitic, cherty, or silty and locally crinoidal and crystalline—and minor light-gray, grayish-green, grayish-yellow, and grayish-red shale and siltstone. The formation can be divided into mappable members of relatively homogeneous lithologic character. Recognized in this report are the Nancy, Cowbell, Nada, Halls Gap, Wildie, Renfro, and Muldraugh Members of the Borden Formation. Three minor units useful in understanding the regional stratigraphic relations are named the Gum Sulphur Bed of the Nancy Member and the Conway Cut and Roundstone Beds of the Cowbell Member.

The Borden Formation in Kentucky overlies black shale (fig. 2). In most of south-central and southeast-central Kentucky the black shale is assigned to the New Albany Shale of Devonian age; near Somerset the generally equivalent black shale is the Chattanooga Shale. North of Irvine, black shale underlying the Borden is the Sunbury Shale of Early Mississippian age. The basal greenish-gray to light-gray clayey shale of the Borden contrasts strongly with the underlying brittle, laminated black shale. Exceptionally, the black shale and clayey shale are interlaminated for a few inches. The basal few inches of the Borden Formation, as shown in figure 4, are characterized by sporadic, grayish-brown to light-gray phosphatic nodules ranging in diameter from a fraction of an inch to about 2 inches.

The Borden Formation is overlain by the Salem and Warsaw Limestones [2] in south-central Kentucky (west of Halls Gap) and by the St. Louis Limestone Member of the Newman Limestone in southeast-central Kentucky (east of Halls Gap). Where the Salem and Warsaw Limestones are recognized, the upper contact of the Borden Formation, as shown in figure 5, is placed above unfossiliferous silty, fine-grained dolomitic limestone and calcareous siltstone of the Borden and below the basal shelly medium- to coarse-grained limestone of the Salem and Warsaw Limestones. At many localities a thin but conspicuous layer of calcareous shale occurs several feet above the base of the Salem and Warsaw Limestones.

[2] The Salem and Warsaw Limestones as used in this report locally include the Harrodsburg Limestone as redefined by Sable, Kepferle, and Peterson (1966).

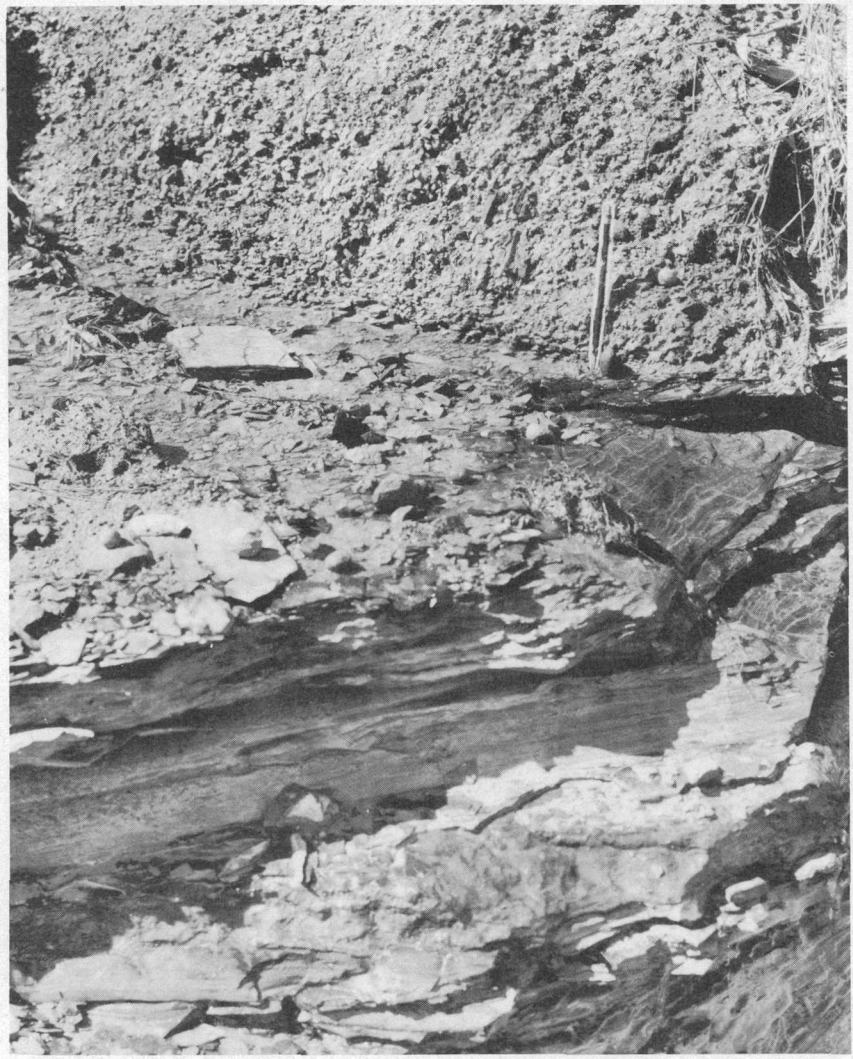

FIGURE 4.—Basal contact of the Borden Formation (at pencil point). Greenish-gray clayey shale of the Nancy Member of the Borden with basal zone of gray phosphatic nodules overlying black shale of the New Albany Shale. West side of U.S. Highway 25, 1.6 miles south of Berea, Ky.

In southeast-central Kentucky, where the Salem and Warsaw Limestones are not recognized, the upper contact, shown in figure 6, is placed between yellowish-gray argillaceous limestone of the Borden Formation and light-gray cherty fine-grained limestone of the St. Louis Limestone Member of the Newman Limestone. Where outcrops

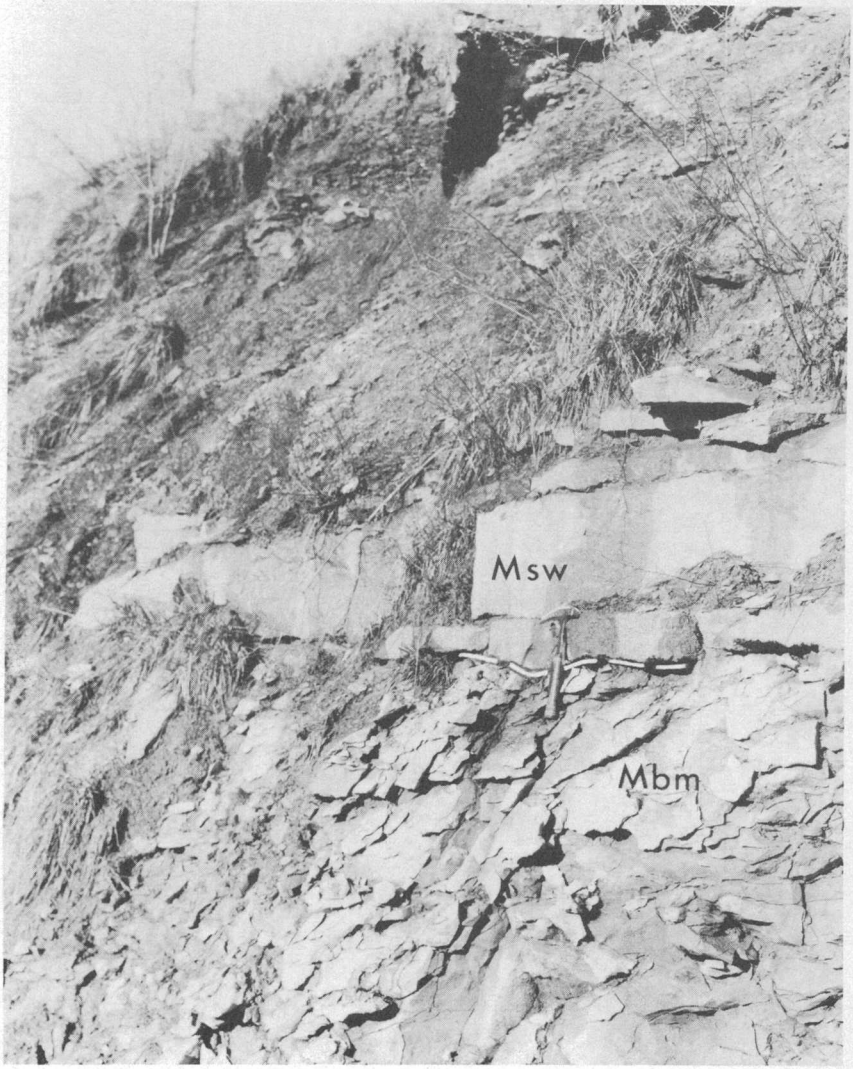

FIGURE 5.—Upper contact of the Borden Formation in south-central Kentucky. Grayish-orange silty dolomitic limestone of the Muldraugh Member of the Borden Formation (Mbm) overlain by light-gray shelly coarse-grained limestone and gray shale of the Salem and Warsaw Limestones (Msw). East side of U.S. Highway 27, Halls Gap, Ky.

are poor, the contact is placed at the base of the dark-red soil which forms on the St. Louis Limestone Member and which contrasts with the yellowish-brown soil developed on the Borden Formation.

This contact is generally a conspicuous diastem, but locally the argillaceous limestone of the Borden Formation interfingers with the

FIGURE 6.—Upper contact of the Borden Formation in southeast-central Kentucky. Yellowish-gray argillaceous limestone of the Renfro Member of the Borden Formation (Mbr) is sharply overlain by gray cherty fine-grained limestone of the St. Louis Limestone Member of the Newman Limestone (Mnsl); the St. Louis Limestone Member is unconformably overlain by gray oolitic limestone of the Ste. Genevieve Limestone Member of the Newman Limestone (Mnsg). Contact between the Borden Formation and the Newman Limestone is here slightly wavy and marked by a thin seam of greenish-gray claystone. West side of U.S. Highway 421, about 1.7 miles south of Bighill, Madison, County, Ky.

fine-grained limestone of the Newman Limestone through a thickness of a few feet; and between Renfro Valley and Brodhead the upper part of the Borden intertongues with the St. Louis Limestone Member of the Newman through a thickness of several tens of feet.

NANCY MEMBER

The Nancy Member of the Borden Formation is here named for the typical section of shale and shaly siltstone exposed in Pulaski County Park about 2 miles east of Nancy, Ky. (p. F23). The Nancy Member includes all of the beds assigned to the New Providence Formation by Stockdale (1939) and in places a large part of the beds that he assigned to the Brodhead Formation.

The Nancy Member is chiefly nonresistant gray clayey to silty shale (fig. 7). Locally it includes much nonresistant shaly siltstone, minor resistant thin-bedded siltstone, and thin discontinuous lenses of crinoidal limestone. At many localities iron-rich siliceous and calcareous concretions, a few inches to a few feet in diameter, like those shown in figure 7, occur sporadically through the member.

Stockdale's (1939, p. 117–119, 137) Gum Sulphur Siltstone Member of the New Providence Formation is here called the Gum Sulphur Bed of the Nancy Member. It consists of ledge-forming spally weathering gray siltstone, and is gradational above and below into silty shale of the Nancy Member. The Gum Sulphur Bed is as much as 80 feet thick, but it feathers out into the Nancy Member in all directions within 10 miles of Brodhead (figs. 2; 3, lower section).

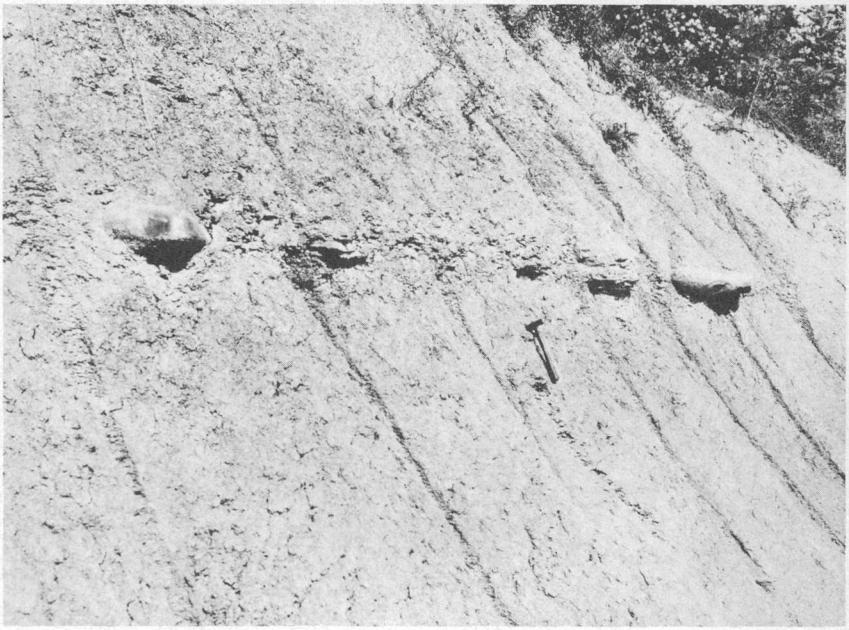

FIGURE 7.—Characteristic outcrop of the Nancy Member of the Borden Formation. Gray slightly silty shale with layer of iron-rich, siliceous concretions about 50 feet below top of member. West side of U.S. Highway 25, about 2.5 miles south of Berea, Ky.

The Nancy Member, the only member of the Borden Formation that extends throughout the area studied, is the basal part of the Borden Formation. It ranges in thickness from about 150 to 300 feet and is generally poorly exposed on long gentle slopes leading up to more resistant members of the Borden. The Nancy Member overlies the

fissile black shales of the New Albany or Chattanooga Shale of Late Devonian age or Sunbury Shale of Early Mississippian age (figs. 2, 4). It is overlain in most of the area south of Berea by the Halls Gap Member (fig. 2) and by the Cowbell Member north of Berea (figs. 2, 8). At its type locality (fig. 2, section 2), it is overlain by cherty and dolomitic limestone of the Muldraugh Member. In a small area south of Mount Vernon, east of the line of sections shown in figure 2, it is overlain by the Renfro Member (N. L. Hatch, Jr., U.S. Geol. Survey, oral commun., 1962).

The contact with the Muldraugh and Renfro Members commonly is sharp, although it is locally gradational through several feet of limy, silty shale that contains thin beds of crinoidal limestone. Where overlain by the Cowbell or Halls Gap Members, the contact is gradational and is mapped at the base of the lowest relatively continuous ledge-forming siltstone.

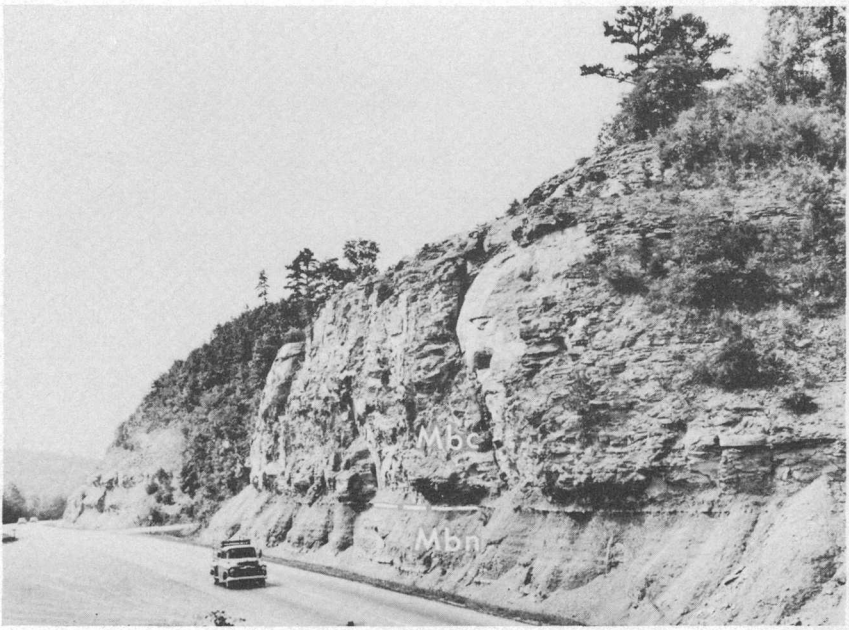

FIGURE 8.—Characteristic lithology and basal contact of the Cowbell Member of the Borden Formation. Resistant grayish-brown siltstone of the Cowbell Member (Mbc) grades through a few feet into underlying gray silty shale of the Nancy Member of the Borden Formation (Mbn). West side of U.S. Highway 25 about 3 miles south of Berea, Ky.

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COWBELL MEMBER

The Cowbell Member of the Borden Formation is here named for the typical section of siltstone that crops out near the head of a minor tributary of Cowbell Creek about 1.5 miles west of Bighill, Ky. (p. F26). The type section is exposed along a forest road on the south ridge of Indian Fort Mountain. The member includes most of the beds that were assigned to the Brodhead Formation by Stockdale (1939, p. 175) near this locality.

The member, as shown in figure 8, is made up chiefly of thick resistant units of gray, brownish-weathering indistinctly bedded siltstone separated by thin discontinuous units of less resistant gray shaly siltstone. Molds of brachiopods and bryozoans occur sparsely. In the area from near Berea to near Stanton the Cowbell ranges from 0 to about 175 feet in thickness.

North of the Disputanta section (fig. 2, section 5) the Cowbell Member conformably overlies the nonresistant Nancy Member (fig. 8).

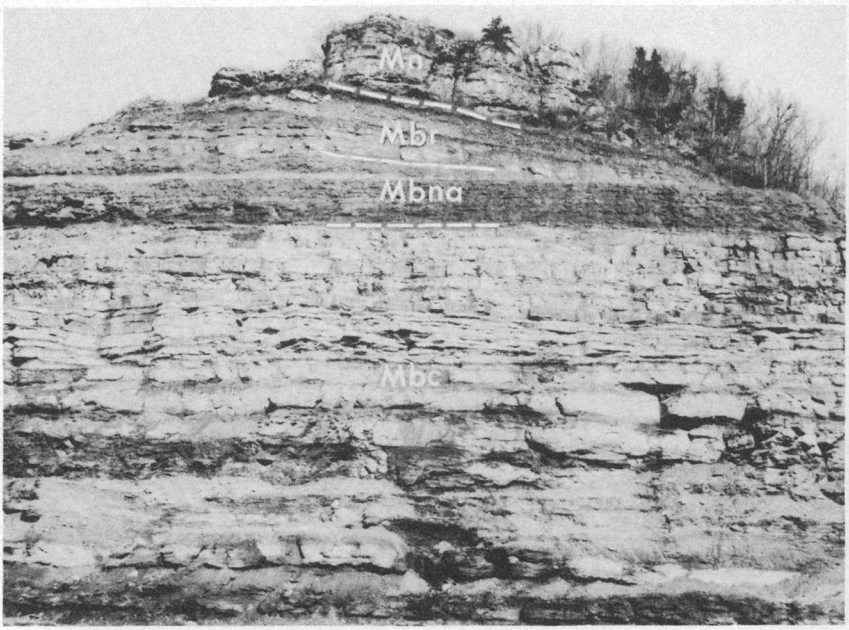

FIGURE 9.—Typical shale and minor siltstone of the Nada Member of the Borden Formation (Mbna) overlying resistant siltstone and minor silty shale of the Cowbell Member of the Borden Formation (Mbc) and underlying argillaceous limestone and minor shale of the Renfro Member of the Borden Formation (Mbr). At top of outcrop is cherty sparsely oolitic very fine grained limestone of the Newman Limestone (Mn). Type locality of the Nada Member, north side of Mountain Parkway 0.1 mile west of Nada (Lombard Post Office), Ky.

It is conformably overlain by less resistant silty shale and minor siltstone of the Nada Member of the Borden Formation (fig. 9). This contact is fairly sharp, but in places it is gradational through a few feet.

South of the Disputanta section, as shown in figures 2 and 3 (lower part), the Cowbell Member splits into two prominent mappable tongues of siltstone that pinch out a few miles southwestward within the Nancy Member. The lower of these tongues is here named the Roundstone Bed for outcrops along Roundstone Creek about 3 miles south of Berea. The upper tongue, the Conway Cut Siltstone Member of Stockdale (1939, p. 170) of the Brodhead Formation, is here called the Conway Cut Bed of the Cowbell Member; the typical outcrops are along the Louisville and Nashville Railroad near Conway about 9 miles south of Berea.

NADA MEMBER

The Nada Member is here named for the typical outcrops, shown in figure 9, of shale and siltstone exposed along the Mountain Parkway near Nada (Lombard Post Office) about 10 miles east of Stanton, Ky. (p. F31). It includes beds assigned to the Brodhead, Floyds Knob, and Muldraugh Formations by Stockdale (1939, p. 189).

The Nada Member is a slope-forming unit that consists of clayey and silty shale with minor siltstone (figs. 2, 9). The shale, which is mostly olive gray with patches of grayish red and grayish purple, locally grades into thin-bedded resistant limy siltstone, which is more abundant near the southern edge of the member. Nonresistant glauconitic siltstone is also locally common. The member ranges from about 30 to 65 feet in thickness.

The drab shale and siltstone of the Nada Member contrast strongly with the yellowish- and grayish-orange silty limestone of the conformably overlying Renfro Member of the Borden Formation. The Nada Member is readily distinguished from the more resistant overlying and underlying units east and northeast of Berea, but south and southwest of Berea its upper part grades into the Wildie Member and its lower part grades into the Nancy Member. Because of the lateral gradation of the members, arbitrary cutoffs for mapping the Nada Member are the south and east edges of the Berea quadrangle (lat 37°30′ N., long 84°22′30″ W.).

HALLS GAP MEMBER

The Halls Gap Member of the Borden Formation is here named for the typical section of siltstone exposed along U.S. Highway 27 on the north side of Halls Gap, about 4.5 miles south of Stanford, Ky. (p.

F30). It includes beds previously assigned by Stockdale (1939) to the upper part of the Brodhead Formation at this locality.

The Halls Gap Member is made up of resistant limy siltstone with minor shaly siltstone and silty limestone (fig. 10). The fresh rock is chiefly medium gray to greenish gray; weathered surfaces are commonly brownish gray from limonite stain. The member is generally in obscure rough beds about a foot thick; locally south of Halls Gap the beds are in broad sweeping lenses 2 to 20 feet thick and several hundred feet long. Lenticular concretions of finely crystalline limestone about a foot thick and a few feet long, geodes of white chert a fraction of an inch to several inches in diameter, and nodules of pyrite less than 1 inch in diameter are sparse to common. Fragments of fossils, chiefly crinoid stems but also brachiopods and horn corals, are common to abundant in very limy siltstone and silty limestone; whole fossils are sparse. The member weathers by spalling to form ledges with convex smooth to hackly surfaces.

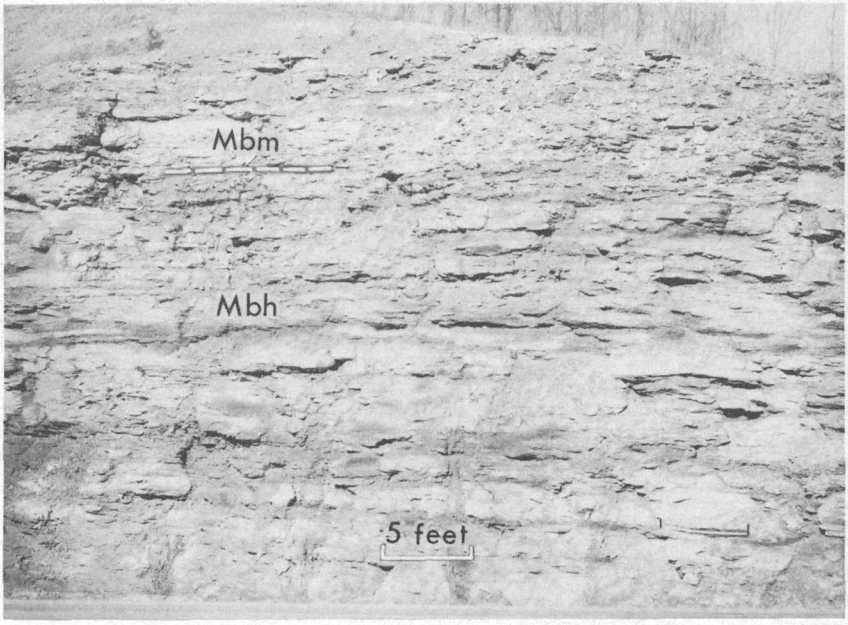

FIGURE 10.—Characteristic lithology and upper contact of the Halls Gap Member of the Borden Formation. Resistant gray and brownish-gray limy siltstone of the Halls Gap Member (Mbh) gradationally overlain by dolomitic siltstone of the Muldraugh Member of the Borden Formation (Mbm). Type locality of the Halls Gap Member, east side of U.S. Highway 27, near Halls Gap, about 4.5 miles south of Stanford, Ky. (Rule in lower right corner is extended 5 ft.)

The Halls Gap Member is conformably overlain by the Muldraugh Member in much of the area (fig. 2). The contact is sharp where persistent beds of limestone of the Muldraugh Member rest on siltstone of the Halls Gap Member. In places, as at Halls Gap, the contact is fairly sharp although gradational through a few feet where siltstone of the Halls Gap Member grades into calcareous, dolomitic, and cherty siltstone of the Muldraugh Member, as shown in figure 10. Less commonly the members are transitional where siltstone of the Halls Gap Member contains scattered lenses of limestone that become more numerous and persistent upward; the contact is placed at the base of the relatively persistent zone of lenses of limestone.

Between Halls Gap and Berea the Halls Gap Member is overlain by nonresistant shale and shaly siltstone and resistant coarse siltstone

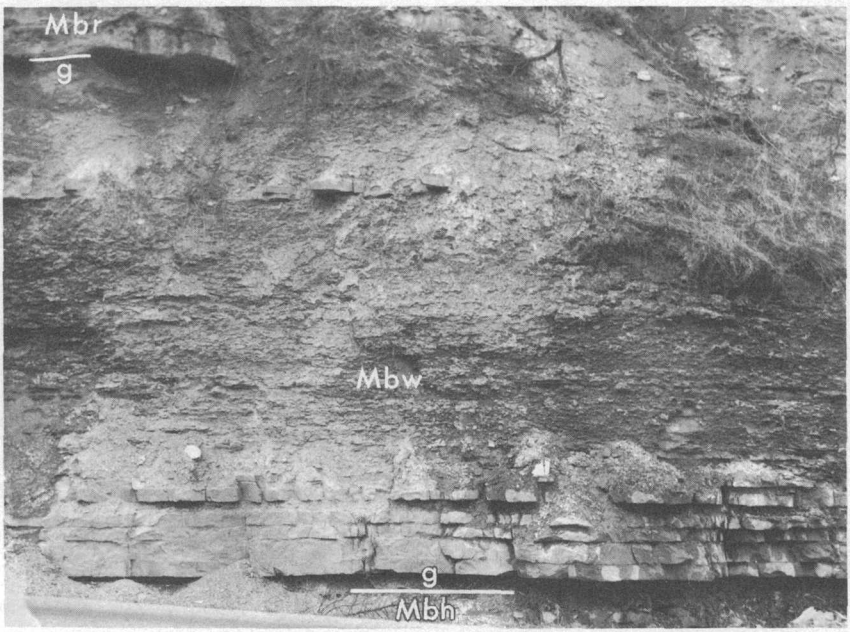

FIGURE 11.—Characteristic lithology, shale and siltstone, of the Wildie Member of the Borden Formation (Mbw). Lower part of the member here is even-bedded coarse siltstone like that making up most of member at type locality near Wildie, Rockcastle County, Ky. Beneath these lower siltstone beds is a seam of greenish-black glauconitic siltstone (g) at the base of the member; below is siltstone and minor shale of the Halls Gap Member of the Borden Formation (Mbh). Projecting ledge near top of photograph is argillaceous limestone of the overlying Renfro Member of the Borden Formation (Mbr). Beneath this ledge at the top of the Wildie Member is another seam of greenish-black glauconitic siltstone (g) like that at the base of the member. West side of U.S. Highway 25 about 3 miles north of Renfro Valley, Ky.

of the Wildie Member of the Borden Formation (figs. 2, 11). The contact commonly is fairly sharp and, as shown in figure 11, is generally conspicuous because of ledges formed by very resistant even-bedded coarse siltstone near the base of the Wildie Member.

The full extent and stratigraphic relations of the Halls Gap Member are not precisely known. The member reaches its greatest thickness of about 100 feet a few miles southeast of Halls Gap; it thins northeastward and pinches out near Berea within the Nada Member of the Borden Formation. It is not a mappable unit north of the south boundary of the Berea quadrangle (lat 37°30′ N.), Kentucky. The Halls Gap Member has been traced southward in numerous sections to Bobtown, but it is not present near Nancy or in the area south of Mount Vernon; and in these areas it apparently grades into nonresistant shaly siltstone and shale of the Nancy Member. The Halls Gap Member has been traced in scattered sections westward with some uncertainty as far as Phillipsburg, Ky. (p. F37).

WILDIE MEMBER

Stockdale (1939, p. 215–216) included the Wildie Sandstone Member of the Warsaw Formation (Butts, 1922, p. 89, 102–104) in his Wildie Siltstone Member of the Muldraugh Formation of the Borden Group. The Wildie Member is here redefined as a siltstone and shale member of the Borden Formation and includes the equivalent Cummins Station Member of Stockdale (1939, p. 213–214), with which it intergrades.

Stockdale (1939, p. 216–217) gives excellent descriptions of the member near and a short distance away from the type locality near Wildie, Ky. Representative outcrops of the Wildie Member are herein described at the Renfro Valley North section (p. F34).

Near Wildie the member is made up almost entirely of thick beds of resistant brownish-weathering, greenish-gray siltstone and very fine grained sandstone with shale in thin seams and partings. Along the outcrop a few miles away from the type locality, the siltstone beds decrease in thickness and number and the amount of shale increases so that siltstone forms a minor part of the member as shown in figure 11 at the Renfro Valley North section. The shale is nonresistant, clayey to silty, in places glauconitic, and mostly greenish gray but locally grayish red and grayish purple. A persistent seam of glauconitic siltstone is present at the base of the unit and another glauconitic seam is at the top.

The contact between the Wildie Member and the underlying Halls Gap Member is sharp and commonly expressed topographically as a pronounced change in slope. The Wildie Member is overlain by

the Renfro Member, whose yellowish-gray silty limestone contrasts strongly with the drab shale and siltstone of the Wildie Member.

The Wildie Member ranges in thickness from a few feet to about 25 feet; in some quadrangles it is too thin to map separately and must be combined with the overlying Renfro Member. The Wildie Member feathers out into the Muldraugh Member of the Borden Formation near the west edge of the Crab Orchard quadrangle (long 84°37′30″ W.). On the north it grades into the upper part of the Nada Member; for mapping purposes the north edge of the Wildie quadrangle (lat 37°30′ N.) is the northern cutoff of the Wildie Member.

RENFRO MEMBER

The Renfro Member of the Borden Formation is here named for exposures near Renfro Valley, Ky. (p. F32). The Renfro Member is made up dominantly of sparsely cherty unfossiliferous light-greenish-gray, yellow- to orange-weathering aphanitic to finely crystalline argillaceous and dolomitic limestone. The argillaceous limestone is commonly in fairly even to wavy beds separated by partings, seams, and thin units of greenish shale. The beds of argillaceous limestone commonly weather by spalling to form rounded ledges as shown in figure 12.

The Renfro Member includes equivalents of the Salem and Warsaw Limestones and of the Muldraugh Member of the Borden Formation (fig. 2). Limestone beds of both the Muldraugh Member and Salem and Warsaw Limestones become more silty and thus more alike eastward from south-central Kentucky; they cannot be readily distinguished east of Halls Gap, although crossbedded fossiliferous sandy, coarse-grained limestone suggestive of the Salem and Warsaw Limestones and geode-bearing knotty-textured laminated calcareous siltstone and limestone like those in the Muldraugh Member are recognizable in the Renfro Member about as far east of Maretburg. Near Berea the Renfro Member includes some beds of yellowish-gray argillaceous limestone that were assigned to the St. Louis Limestone by Butts (1922, p. 123, 125–126, chart) and by Stockdale (1939, p. 173, 212, pl. 6).

The basal contact of the Renfro Member, as shown in figures 9 and 11, is generally a fairly sharp break between the moderately resistant yellowish-gray silty limestone of the Renfro Member and the nonresistant shale and siltstone of the Wildie or the Nada Members. South of Mount Vernon, Ky., both the Wildie and Halls Gap Members pinch out so that the Renfro Member rests on silty shale beds of the Nancy Member (N. L. Hatch, Jr., U.S. Geol. Survey, oral commun., 1962).

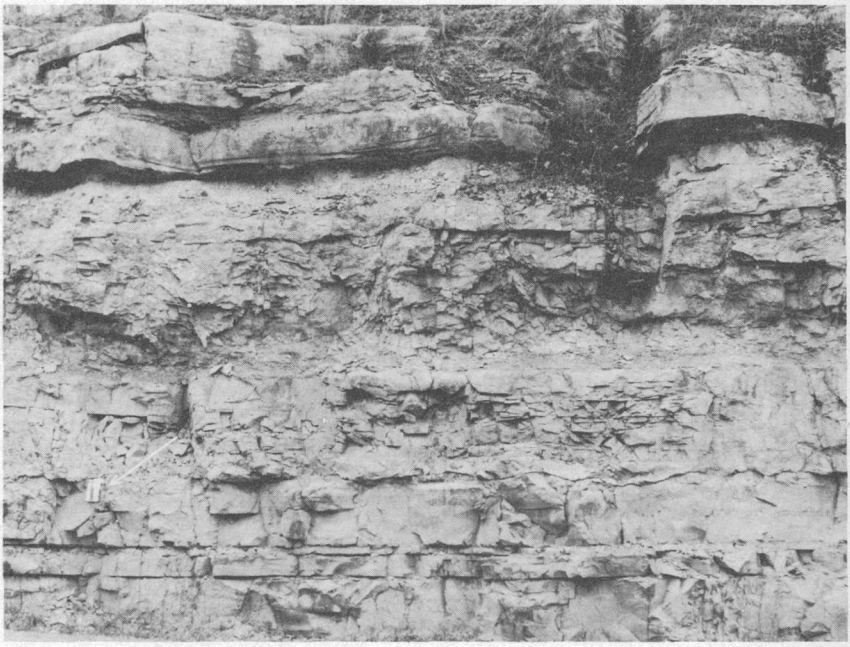

FIGURE 12.—Characteristic argillaceous limestone and minor limestone and shale of the Renfro Member of the Borden Formation. Type locality of the Renfro Member, west side of U.S. Highway 25 about 3 miles north of Renfro Valley, Ky. Geologic pick for scale (see arrow).

The upper contact generally is a conspicuous diastem (fig. 6) that separates yellowish-gray argillaceous limestone of the Renfro Member from the light-gray aphanitic to fine-grained limestone of the St. Louis Limestone Member of the Newman Limestone. In many places the upper part of the Renfro Member contains a few thin beds of gray fine-grained limestone similar to beds of the St. Louis Member. Most of these beds seem to be discrete lentils, but some are tongues of the St. Louis Member. The intertonguing is generally sporadic and limited to a thickness of a few feet. Between Brodhead and Renfro Valley, however, the upper part of the Renfro Member and the lower part of the St. Louis Member intertongue through a thickness of several tens of feet. In this area the St. Louis Member thins by intertonguing from a thickness of about 60 feet to 20 feet, and the Renfro Member thickens from about 50 feet to 80 feet.

The Renfro Member has been traced in sections from near Halls Gap to near Stanton, Ky. The east edge of the Halls Gap quadrangle (long 84°37′30″ W.) is the arbitrary cutoff of the Renfro Member; west of this line the Salem and Warsaw Limestones and the Muldraugh

Member of the Borden Formation can be mapped. The Renfro Member reaches its greatest thickness of about 100 feet a few miles east of Halls Gap; through much of east-central Kentucky it ranges from about 25 to 50 feet in thickness.

MULDRAUGH MEMBER

The Muldraugh Formation (Stockdale, 1939) is here redefined as the Muldraugh Member of the Borden Formation. Its characteristic lithology is well displayed at the type section near Phillipsburg, Ky. (p. F36).

The Muldraugh Member consists chiefly of cherty and dolomitic limestone and cherty, dolomitic, and calcareous siltstone that weather to a yellowish-orange rubble. It is generally about 50 feet thick between Phillipsburg and Halls Gap but is locally as much as 100 feet thick. Laminae in the silty units are commonly contorted around small (less than an inch in diameter) chert or calcareous concretions, which give most of the silty units in the member the characteristic swirl or knotty texture shown in figure 13. Shale and shaly siltstone

FIGURE 13.—Characteristic texture of dolomitic and calcareous siltstone of the Muldraugh Member of the Borden Formation. Irregular knotty texture is an effect of very small siliceous and calcareous concretions and irregularities in dolomite and calcite content of siltstone. East side of U.S. Highway 27 near Halls Gap, Ky.

occur locally as thin beds and partings. The dolomitic limestone is commonly fine to medium grained and silty and contains few fossils.

As redefined the base of the cherty and dolomitic limestone and siltstone of the Muldraugh Member lies generally a few feet to several tens of feet below glauconitic siltstone that Stockdale (1939) assigned to the Floyds Knob Formation. The glauconitic siltstone is here regarded as an informal unit, not a formation boundary, but is useful as a marker bed in parts of Kentucky.

The Muldraugh Member lies conformably upon the Hall's Gap Member or the Nancy Member (fig. 2). The resistant cherty dolomitic or calcareous siltstone of the Muldraugh Member generally forms cliffs or steep slopes above the less resistant siltstone and silty shale of the Halls Gap Member (fig. 10) or the shale and silty shale of the Nancy Member.

The Muldraugh Member is conformably overlain by the Salem and Warsaw Limestones[3] that form a single mappable unit in south-central Kentucky (Nelson, 1962). The basal unit of the Salem and Warsaw, as shown in figure 5, is commonly cherty fossil-fragmental medium- to coarse-grained limestone that contrasts strongly with the sparsely fossiliferous spally weathering much finer grained, more silty and dolomitic limestone of the Muldraugh Member. Calcareous shale generally overlies the basal limestone unit of the Salem and Warsaw and forms a deep recess only a few feet above the top of the Muldraugh Member.

Near Halls Gap the Muldraugh Member of the Borden Formation and the overlying Salem and Warsaw Limestones gradually thin and grade eastward into argillaceous limestone with minor shale and siltstone forming the Renfro Member of the Borden Formation. For mapping purposes the east edge of the Halls Gap quadrangle (long 84°37′30″ W.) is the eastern cutoff of the Muldraugh Member.

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[3] See footnote 2, page F8.

MEASURED SECTIONS

Nancy section

[Type section of the Nancy Member of the Borden Formation. Measured about 2 miles east of village of Nancy, Pulaski County, Ky. (Delmer quadrangle), in Pulaski County Park, beginning at point about 500 ft. below park entrance. Described from outcrops on right side of Kentucky Highway 1248 for basal 35 ft. of section; rest of section described from outcrops on left side of road. Uppermost part of section measured up face of steep nose above sharp curve in road. Elevation at top of New Albany Shale about 790 ft. Measured with barometer and tape by J. L. Gualtieri assisted by J. C. Dills, August 1962]

Mississippian:

Borden Formation (incomplete):

Muldraugh Member (incomplete):

	Feet
11. Chert, light-brownish-gray (5*YR* 6/1),[1] weathering dark yellowish orange; beds as thick as 2 ft interbedded with thin undulatory clay shale units as thick as 6 in. Top of unit not established; basal 10 ft well exposed. Not measured.	
10. Shale, silty, medium-gray (*N* 5), weathering light bluish gray; imperfectly fissile; abundant siliceous geodes as much as 4 in. long	11.5
9. Siltstone, dolomitic and limy, greenish-gray (5*GY* 6/1) and yellowish-gray (5*Y* 7/2), weathering same and pale yellowish orange; weathering of contorted laminae gives surface of rock a gnarly or knotty appearance; numerous shale partings	8
8. Shale, glauconitic, silty and clayey, medium-light-gray (*N* 6); abundant grains of a greenish-black (5*G* 2/1) mineral, probably glauconite. This unit is probably the Floyds Knob Formation as used by Stockdale (1929, 1939)	.3
7. Limestone, medium-gray (*N* 5), coarse-grained; several shale partings as thick as 4 in.; pyrite nodules and irregular chert bodies in basal 1 ft; upward the unit is more coarsely grained, containing anhedral calcite crystals as much as 5 mm long. Fossil debris, especially crinoid stems, very abundant	10
Measured Muldraugh Member (incomplete)	30

Nancy Member:

6. Shale, silty, clayey, medium-gray (*N* 5), well developed to poorly developed shale partings; forms resistant ledge; base indistinct	16
5. Shale, silty, clayey, medium-gray (*N* 5) to medium-dark-gray (*N* 4); shale partings poorly developed in basal part, better developed upward where unit is less silty; resistant, forms prominent overhanging ledge at base. Common brachiopods, crinoids, and fernlike bryozoans	26
4. Shale, silty, clayey; silty shale and siltstone; medium light gray (*N* 6) and medium gray (*N* 7); obscurely and crudely laminated; weathered outcrop yields chips and small plates and blocks; upper part of unit not well exposed but appears more shaly than base; forms prominent ledge at base. Abundant brachiopods, very sparse trilobites; worm(?) trails in clayey shale	37

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

Nancy section—Continued

Mississippian—Continued
Borden Formation (incomplete)—Continued
Nancy Member—Continued

	Feet
3. Shale, clayey, very slightly silty, dark-greenish-gray (5*GY* 4/1), fairly well developed shale partings; fracture surfaces limonite stained; forms prominent ledge	11
2. Shale, clayey, very slightly silty to slightly silty, grayish-yellow-green (5*GY* 7/2), mottled moderate red (5*R* 4/6) at base, changing upward to medium gray (*N* 5), dark greenish gray (5*GY* 4/1), dusky yellow green (5*GY* 5/2) and medium bluish gray (5*B* 5/1); well developed shale partings; limonite stains fracture surfaces where unit is more silty. Basal 7 ft mostly covered but yields small phosphatic nodules. Top 15 ft consists of slightly more resistant rock, forming irregular and discontinuous ledges. A single continuous ledge, 3 to 4 ft thick but otherwise similar to those below it, occurs near top of unit	60
Total Nancy Member	150
Measured Borden Formation (incomplete)	180

Devonian:
Chattanooga Shale:
1. Shale, carbonaceous, black (*N* 1), laminated, weathering to plates and chips. Contact with overlying clayey shale very poorly exposed. Not measured.

Indian Fort Mountain section

[Type section of the Cowbell Member of the Borden Formation. Units 1 and 2 measured along road to reservoirs in Cowbell Creek joining Kentucky Highway 21 about 0.9 mile, west of village of Bighill, Madison County, Ky. (Bighill quadrangle); units 3 and 4 measured westward along Kentucky Highway 21 to top of hill; units 5 through 8 measured along forest road up south point of Indian Fort Mountain, beginning about 300 ft. west of high point on highway; units 9 through 19 measured along abandoned road branching off newer forest road; section then offset to foot trail up southwest spur of south point of Indian Fort Mountain, units 20 through 22 measured along this trail; units 23 and 24 measured over cliff on northwest side of this trail. Measured with barometer, Jacob staff, and tape by G. W. Weir and J. L. Gualtieri assisted by D. R. Siegle, June 1963]

Mississippian:
Newman Limestone (incomplete):
St. Louis Limestone Member:

	Feet
24. Limestone, cherty, very light brownish gray (5*YR* 7/1) and olive-gray (5*Y* 5/1) to yellowish-gray (5*Y* 8/1), chiefly micrograined, in part fine- to medium-grained. Common to abundant grayish-orange chert in irregular masses commonly about 1 ft long and 2 in. thick and as replacement of abundant colonial corals	7.7

Indian Fort Mountain section—Continued

Mississippian—Continued

Newman Limestone (incomplete)—Continued

St. Louis Limestone Member—Continued

	Feet
23. Limestone, very light greenish gray (5*GY* 7/1), fine- to medium-grained; sparse medium to coarse grains of orange chert; in beds 1 to 8 in. thick; sparse small brachiopods. Some argillaceous layers 1 to 4 in. thick interbedded with thin seams of grayish-yellow-green (5*GY* 7/2) claystone; common crinoids, bryozoans in argillaceous limestone and as impressions in the claystone. Base undulatory, thickness ranges from 2 to 2.5 ft	2.3
Total St. Louis Limestone Member of Newman Limestone	10

Borden Formation:

Renfro Member:

22. Limestone, argillaceous, dark-yellowish-orange (10*YR* 6/6), very fine grained, silty and clayey; in uneven beds 1 to 4 in. thick; fairly resistant except in top 5 ft	17
21. Poorly exposed, probably most is yellowish argillaceous limestone similar to overlying and underlying units. About 1 ft above base is argillaceous limestone, pale greenish yellow (10*Y* 3/2), and very fine grained; contains abundant discoidal nodules of chert as much as 3 in. across and ½ in. thick. About 4 ft above base is limestone, light olive gray (5*Y* 6/1); micrograined to very fine grained; a resistant bed about 0.2 ft thick	5.5
20. Limestone, argillaceous, generally similar to limestone of unit 22 but nonresistant, mostly punky weathering. Scattered irregular patches of light-gray chert about 1 in. thick and as much as 12 in. long at 12 to 15 ft above base. On original line of section basal layer of argillaceous limestone, 0.1 to 0.3 ft thick, is silicified to pinkish-gray (5*YR* 8/1) chert	27.5
Total Renfro Member	50

Nada Member:

19. Claystone, glauconitic silty, grayish-yellow-green (5*GY* 7/2); disseminated grains and streaks of grayish-olive-green (5*GY* 3/2) grains of glauconite; nonresistant	.3
18. Siltstone, pale-olive (10*Y* 6/2), weathering light olive gray (5*Y* 5/2) with surface blotches of grayish orange or grayish yellow; coarse silt; internal layering obscure; nonfissile, a "freestone;" contains a few worm(?) markings; forms prominent ledge. Abundant small concretionary nodules imbedded in upper surface; dark gray (*N* 3), weathering lighter gray; silicified, possibly phosphatic in part, in part very fine grained; irregularly rounded; mostly ¼ to ¾ in. in diameter. Unit thickens to 0.8 ft thick 10 ft east of line of section	.4
17. Siltstone, clayey, yellowish-gray (5*Y* 7/4), very thinly bedded; splits along irregular planes about ¼ in. apart; forms slope	2.4

Indian Fort Mountain section—Continued

	Feet
Mississippian—Continued	
Borden Formation—Continued	
Nada Member—Continued	
16. Siltstone, similar to unit 18	0.5
15. Siltstone, clayey, similar to unit 17	9.3
14. Siltstone, similar to unit 18	.2
13. Siltstone, clayey, similar to unit 17	.8
12. Siltstone, similar to unit 18	.8
11. Siltstone, similar to unit 17 but less clayey	7.7
10. Mudstone, silty (60 percent), leached limestone (30 percent), and siltstone (10 percent). From base upward: siltstone with abundant silt-sized to medium grains of greenish-black glauconite, mostly dusky green (5*G* 3/2), in less glauconitic portions pale yellowish brown (10*YR* 6/2); about 2 in. thick. Mudstone, silty, glauconitic, poorly exposed; about 20 in. thick. Leached limestone, weathered to dark yellowish orange (10*YR* 6/6). Unit is Floyds Knob Formation as used by Stockdale (1929, 1939, p. 175)	2.6
9. Shale, clayey; base dark greenish gray (5*GY* 4/1) mottled brownish black (5*YR* 2/1), upper half moderate olive brown (5*Y* 4/4) and grayish red (10*R* 4/2) to moderate brown (5*Y* 4/4); very slightly silty; laminated; outcrop yields thin chips less than ½ in. across. Phosphatic nodules, greenish gray (5*GY* 6/1), ovoid, commonly about ½ in. in diameter and 1 in. long; abundant on weathered slope in basal few feet of unit. Well to poorly exposed; nonresistant; forms narrow bench at base, moderate slope above	22
Total Nada Member	47
Cowbell Member:	
8. Siltstone, mostly pale olive (10*Y* 6/2) and light-olive-gray (5*Y* 6/1), grading at top to grayish olive (10*Y* 4/2) with common dark-brown limonite stain on bedding planes and fracture surfaces; bedding partly obscure, mostly in slightly uneven beds ¼ to 2 in. thick; splits along bedding and along irregular fracture surfaces ¼ in. to 3 in. apart; outcrop yields plates and irregular blocks commonly ¼ to ½ in. thick and 1 to 3 in. across; moderately resistant, forms steep slope. Fossils common near base and abundant near top, chiefly small brachiopods less than 1 in. wide, crinoid columnals, and sparse small tubular bryozoans a few millimeters wide; mostly preserved as molds. Top of unit marked by pronounced flattening of slope	43
7. Siltstone, clayey, moderate-yellowish-brown (10*Y* 5/4) to pale-olive (10*Y* 6/2), very fine micaceous flakes in basal 10 ft; less resistant thar underlying or overlying units but otherwise generally similar to them; poorly exposed in eroded roadbed. Dark-brown ovoid limonite concretions, with pronounced layered structure, about 3 to 4 in. thick and 10 to 12 in. long; occur about 35 ft above base. Unfossiliferous	47

Indian Fort Mountain section—Continued

Mississippian—Continued
Borden Formation—Continued
Cowbell Member—Continued

	Feet
6. Siltstone (85 percent) and clayey siltstone (15 percent); at base moderate olive brown (5*Y* 4/4), mostly yellowish gray (5*Y* 7/2) to greenish gray (5*GY* 6/1) or pale olive (10*Y* 6/2); dark-brown limonite stain common on bedding planes and fracture surfaces; clayey in basal 7 ft; mostly in very thin beds ⅛ to ½ in. thick; splits along bedding planes and irregular surfaces about 1½ in. apart; outcrop yields chips and plates 1 to 3 in. across; fairly well exposed along forest road; moderately resistant, forms steep slope. Limonite concretions, yellowish gray and dark brown, in solid spindly bodies as much as 1¼ in. in diameter and 3 in. long occur sparsely about 37 ft above base; in part sideritic; some have casts of small gastropods at centers. Concretionary bodies of very limy siltstone, greenish gray (5*GY* 6/1), as much as 1 ft thick, 1.5 ft long; weather to rounded surfaces at 51 ft above base. Fossils sparse, consisting of gastropods, curly worm(?) marks, and *Taonurus*(?) ("rooster tail" marking) in upper part of unit	55
Total Cowbell Member	145

Nancy Member:

5. Shale, clayey, grading upward to silty clay shale; mostly dark greenish gray (5*GY* 4/1) to brownish gray (5*YR* 4/1) with sporadic reddish streaks, near top chiefly pale yellowish brown (10*YR* 6/2) to dark yellowish brown (10*YR* 4/2); very slightly silty grading to silty at top; in laminae 3 to 5 mm thick; splits along laminae or irregular surfaces ¼ to 1 in. apart; outcrop yields small platy fragments 1/16 to 1 in. across and irregular blocks commonly about 1 in. thick and 3 in. long; mostly weathers to yellowish-gray soil with minute shale fragments; poorly exposed; nonresistant, forms gentle slope. Upper contact broadly gradational through about 30 ft as clay shale grades upward to siltstone; contact arbitrarily placed at base of lowest relatively persistent siltstone	28
4. Shale, greenish-gray (5*GY* 6/1) and pale-olive (10*Y* 6/2), weathering same; very slightly silty; more fissile than underlying shale, yields chips a few millimeters thick and a few inches across. Iron concretions common, sporadically distributed, interiors olive gray (5*Y* 5/1), surfaces shades of red and brown; ovoidal, commonly 3 to 6 in. diameter, 6 to 12 in. long. Well exposed in roadcut at top of hill on highway. Sparse to common curly worm(?) marks in upper part of unit	38
3. Shale, clayey, pale-olive (10*Y* 6/2) and near top olive-gray (5*Y* 5/1), weathering chiefly yellowish gray (5*Y* 7/2). Mostly covered, about 25 percent outcrop; seems similar to underlying unit	122

Indian Fort Mountain section—Continued

Mississippian—Continued
Borden Formation—Continued
Nancy Member—Continued

	Feet
2. Shale, clayey, chiefly pale olive (10*Y* 6/2), dusky yellow at base; mostly clayey but slightly silty at base; in rough laminae 1/16 to 1/4 in. thick; yields small chips a few millimeters thick and 5 to 15 mm across. Sparse phosphatic nodules at base; moderate-yellowish-brown (10*YR* 5/2) interior, light-gray (*N* 4) surface; fine silt; ovoidal, about 1 in. maximum diameter	12
Total Nancy Member	200
Total Borden Formation	442

Devonian:
New Albany Shale (incomplete):
1. Shale, dark-gray (*N* 3), weathering lighter gray and brownish gray (5*YR* 4/1); laminated; brittle, yielding small plates a few millimeters thick and as much as 3 in. across on weathered outcrops. Not measured; about 20 ft exposed locally.

Halls Gap section

[Type section of the Halls Gap Member of the Borden Formation. Measured up hill along U.S. Highway 27 at Halls Gap, Lincoln County, Ky. (Halls Gap quadrangle). Measured with barometer, Jacob staff, and tape by G. W. Weir and J. L. Gualtieri assisted by J. C. Dills, July 1962]

Mississippian:
Salem and Warsaw Limestones (incomplete):

	Feet
38. Residuum, ferruginous and clayey. Not measured.	
37. Sandstone, grayish-orange (10*YR* 7/4) and pale-orange, fine- to medium-grained, poorly sorted, platy (probably originally limy but now completely leached). Petroliferous residue occurs as scattered small blebs and as local concentrations permeating whole stratum. Ranges from about 2 to 4 ft in thickness	3.6
36. Claystone, silty, medium-light-gray (*N* 6), limonitic. In part may be a residuum from weathering of limestone	1.3
35. Clayey residuum from leached limestone, grayish-orange (10*YR* 7/4); abundant spherical to discoidal siliceous geodes as much as 1 ft long	1.8
34. Shale, clayey and silty, medium-bluish-gray (5*B* 5/1)	1.6
33. Limestone, light-gray (*N* 7), mostly weathered to moderate olive brown (5*Y* 4/4) and dusky yellow (5*Y* 6/4) residuum; fine grained; numerous lentils of fine-grained sandstone as thick as 4 in.; abundant siliceous geodes with ferruginous cores as much as 1.5 ft in diameter	1.8
32. Shale, clayey and silty, medium-bluish-gray (5*B* 5/1) and dusky-yellow-green (5*GY* 5/2)	1.7
31. Clayey residuum from leached limestone, dark-yellowish-orange (10*YR* 6/6), grayish-orange (10*YR* 7/4), and moderate-yellow (5*YR* 7/6); intertongues laterally with silty shale	5.8

Halls Gap section—Continued

	Feet
Mississippian—Continued	
Salem and Warsaw Limestones (incomplete)—Continued	
30. Limestone, medium-light-gray, coarse-grained; abundant large brachiopods. Unit ranges in thickness from 2.2 to 2.6 ft	2.4
Measured Salem and Warsaw Limestones (incomplete)	20
Borden Formation:	
Muldraugh Member:	
29. Limestone, dolomitic, silty, bluish-white (5*B* 9/1), weathering very pale orange; irregular diagonal partings; rubbly weathering; sparse siliceous geodes with calcite centers, very sparse pyrite nodules	4.8
28. Limestone, medium-light-gray (*N* 6), coarse-grained, contains sparse irregular lentils of dolomitic siltstone. Sparse brachiopods and horn corals. As much as 2 ft thick, pinches laterally to thin shale parting	1
27. Limestone, dolomitic, silty, light-gray (*N* 7) and very light gray, (*N* 8) weathering grayish orange to dark yellowish orange; rubbly weathering; very abundant pyrite as sparse nodules and as disseminated grains and concentrations of grains in irregular bodies and lentils. Siliceous pyritic geodes, sparse to abundant, as much as 4 in. in diameter. A few silty shale partings in upper part	26.7
26. Siltstone, light-bluish-gray (5*B* 7/1), weathering same and yellowish gray; very fine wavy laminae. Contains pyrite nodules, siliceous geodes, and pyritic siliceous geodes. Very abundant glauconite in basal 0.5 ft	4.8
25. Shale, glauconitic, silty, dark-greenish-gray (5*G* 4/1). A conspicuous seam, 0.1 to 0.2 ft thick	.2
24. Siltstone, dark-greenish-gray (5*G* 4/1), limonitic at top. Abundant glauconite	.8
23. Siltstone, greenish-gray (5*G* 6/1), structureless to finely laminated. Very abundant glauconite	4.6
22. Shale, glauconitic, silty, similar to unit 25. Unit is probably Floyds Knob Formation as used by Stockdale (1929, 1939, p. 163)	.2
21. Shale, silty, medium-bluish-gray (5*B* 5/1)	.4
20. Limestone, dolomitic, silty, light-gray (*N* 7), weathering grayish orange; structureless. Contains abundant films and grains of bright-green glauconite; lenses, 1.5 to 2 ft thick; interfingers with shale at top	1.8
19. Shale, similar to unit 21	.8
18. Limestone, dolomitic, light-bluish-gray (5*B* 7/1), weathering gray to very pale orange. Contains abundant grains of bright-green glauconite and a few siliceous geodes	.7
17. Limestone, silty, dolomitic, light-bluish-gray (5*B* 7/1); abundant light-olive-gray (5*Y* 6/1) to brownish-gray (5*YR* 4/1) phosphatic(?) nodules. Abundant grains of bright-green glauconite; sparse siliceous and calcitic geodes	.2

Halls Gap section—Continued

	Feet
Mississippian—Continued	
Borden Formation—Continued	
Muldraugh Member—Continued	
16. Siltstone, dolomitic and siliceous, and silty clayey shale; light-greenish-gray (5*GY* 8/1) and grayish orange (10*YR* 7/4), weathering grayish orange; beds lenticular, interfingering. Geodes, 1 to 3 in. across, in upper part	8.3
Total Muldraugh Member	55.3
Halls Gap Member:	
15. Siltstone, very pale orange (10*YR* 8/2) to grayish-orange (10*YR* 7/4), limonite-stained, crudely laminated to thin-bedded, imperfectly fissile. Base of unit marked by 5-ft-thick zone of concretions of finely crystalline limestone; blunt lentils as much as 3 ft long and 18 in. thick. Sparse siliceous geodes; pyrite nodules common near top	74.5
Total Halls Gap Member	74.5
Nancy Member:	
14. Siltstone, greenish-gray (5*GY* 6/1) and medium-light-gray (*N* 6); limonite-stained partings. More resistant siltstone ribs prominent in lower part of unit, less distinct upwards. Base marked by zone of concretions of limy siltstone, as thick as 2 ft and as long as 8 ft	14.5
13. Shale, clayey, dark-greenish-gray (5*GY* 4/1), weathering light olive gray; limonite-stained partings; imperfectly fissile	12
12. Covered	8
11. Shale, similar to unit 13	25.7
10. Siltstone, limonitic (may have been limy), yellowish-gray (5*Y* 7/2) to dark-yellowish-orange (10*YR* 6/6)	.2
9. Shale, similar to unit 13 but more silty. About 3 ft above base more resistant silty beds form ledge about 2 ft thick	11.4
8. Siltstone, limy, light-olive-gray (5*Y* 6/1); forms ledge	.2
7. Shale, similar to unit 9	3.9
6. Siltstone, sideritic, light-olive-gray (5*Y* 6/1), weathering to limonite; 0.1 to 0.3 ft thick	.2
5. Shale, similar to unit 9	4.8
4. Siltstone, limy, light-olive-gray (5*Y* 6/1), weathering light brownish gray; 0.3 to 0.5 ft thick	.4
3. Shale, similar to unit 9. Sparse small calcite nodules in upper part; siderite lentils in lower part, as long as 10 ft and as thick as 1 ft, weathering to limonite	7.7
2. Mostly covered, probably similar to unit 3	67.5
Total Nancy Member	156.5
Total Borden Formation	286.3

Halls Gap section—Continued

Devonian:

New Albany Shale (incomplete):

1. Shale, carbonaceous, black (*N* 1), laminated, brittle, weathering to plates and chips. Not measured.

Nada section

[Type section of the Nada Member of the Borden Formation. Measured up roadcut on north side of Mountain Parkway 0.4 mile northwest of Nada (Lombard Post Office) Powell County, Ky. (Slade quadrangle). Measured with Jacob staff and tape by J. L. Gualtieri assisted by J. C. Dills, August 1962]

Mississippian:

	Feet
Newman Limestone (incomplete):	
18. Limestone, medium-light-gray (*N* 6), weathering very light gray (*N* 8); very fine grained; oolitic in part; sparse pink chert. Not measured.	
Borden Formation (incomplete):	
Renfro Member:	
17. Covered by talus from Newman Limestone	22
16. Limestone, argillaceous, leached, grayish-orange (10*YR* 7/4) and dark-yellowish-orange (10*YR* 6/6), rubbly-weathering	6.1
15. Shale, clayey, slightly silty, dusky-yellow (5*Y* 6/4)	1.2
14. Limestone, argillaceous, leached, dark-yellowish-orange (10*YR* 6/6) and pale-yellowish-orange, thick-bedded, rubbly-weathering	3.9
13. Shale, clayey, slightly silty, dusky-yellow-green (5*GY* 5/2)	1
12. Limestone, argillaceous, similar to unit 14; film of glauconite at base	6.3
Total Renfro Member	40.5
Nada Member:	
11. Shale, clayey, slightly silty, dusky-yellow-green (5*GY* 5/2), laminated, fissile. Several limy siltstone beds, which pinch and swell, averaging about 4 in. in thickness	3.7
10. Shale, clayey, slightly silty, grayish-red (10*YR* 4/2), grades laterally to yellow-green shale; laminated; fissile	.4
9. Shale, similar to unit 11	1
8. Shale, clayey, slightly silty, very dusky red purple (5*RP* 2/2), weathering pale red purple; similar to unit 10	2.3
7. Shale, similar to unit 11	1.5
6. Shale, similar to unit 11 but with glauconite(?) grains on partings	.2
5. Shale, similar to unit 11 but contains brachiopod impressions	1.8
4. Shale, silty, dusky-yellow-green (5*GY* 5/2), at base dark greenish gray (5*G* 4/1); contains brachiopod- and crinoid-bearing limy lentils that are limonite stained on fracture surfaces	8.8
3. Siltstone, slightly limy, greenish-gray (5*G* 6/1); limonite stain on fracture surfaces; forms distinct ledge	.8

Nada section—Continued

Mississippian—Continued
Borden Formation (incomplete)—Continued
Nada Member—Continued

	Feet
2. Shale, silty, greenish-gray (5*G* 6/1); imperfectly fissile; brachiopods, *Taonurus*(?) ("rooster-tail" markings)	10.0
Total Nada Member	30.5

Cowbell Member (incomplete):

1. Siltstone, yellowish-gray (5*Y* 7/2); limonite stain on fracture surfaces; in beds as much as 10 ft thick. Interbedded silty shale, medium bluish gray (5*B* 5/1), in sets, as much as 5 ft thick, of crude laminae. Not measured	
Measured Borden Formation (incomplete)	71

Renfro Valley North section

[Type section of the Renfro Member of the Borden Formation; reference section of the Wildie Member of the Borden Formation. Measured along U.S. Highway 25 beginning about 0.2 mile southwest of the village of Roundstone, about 3 miles north of Renfro Valley, Rockcastle County, Ky. Wildie quadrangle). Renfro and Wildie Members measured with hand level and tape by S. O. Schlanger and J. L. Gualtieri, March 1962; Halls Gap and Nancy Members measured by J. L. Gualtieri assisted by J. C. Dills, August 1962]

Mississippian:
Newman Limestone (incomplete):
St. Louis Limestone Member:

	Feet
49. Limestone, dark-gray (*N* 3), aphanitic to micrograined; abundant nodules of black chert and silicified heads of coral resembling *Lithostrotion*. Sparse endothyrid foraminifera about 10 ft above base	14
48. Limestone, very light gray (*N* 8) and light gray (*N* 7), coarse-grained, clastic; abundant moderately sorted crinoid, brachiopod, and bryozoan debris	5
Measured St. Louis Member of Newman Limestone (incomplete)	19

Borden Formation (incomplete):
Renfro Member:

47. Limestone, argillaceous, light-olive-gray (5*GY* 6/1), fine-grained. Weathers to punky yellowish-orange silt. Base poorly exposed	4
46. Shale, pale-olive (10*Y* 6/2); plastic when wet; poorly exposed	1.5
45. Limestone, argillaceous and silty, grayish-yellow (5*Y* 8/4), aphanitic; weathers to dark-yellowish-orange (10*YR* 6/6) punky silty claystone	4
44. Limestone, light-gray (*N* 7), weathering yellowish gray (5*Y* 7/2); medium to coarse grained, clastic; fragments of brachiopod shells and crinoids common. Probably grades southward into argillaceous limestone like that in unit 43	2.4

Renfro Valley North section—Continued

Mississippian—Continued
Borden Formation (incomplete)—Continued
Renfro Member—Continued

		Feet
43.	Limestone, argillaceous, yellowish-gray (5*Y* 7/2), aphanitic; cut by many irregular veins of clear calcite; 0.1 ft green shale at base. Probably thickens southward	3.5
42.	Limestone, argillaceous and silty, yellowish-gray (5*Y* 7/2) and light-olive-gray (5*Y* 6/1) to pale-yellowish-orange (10*YR* 8/6), very fine grained to aphanitic; bedding irregular and lensing; spalls parallel to exposed face; weathers to punky yellow silty clay. Contains many large masses of clear light-brown calcite. Upper 2.5 ft is contorted and contains twisted thin beds of green shale. Top uneven	13
41.	Shale, dusky-yellow-green (5*GY* 5/2)	.3
40.	Limestone, argillaceous, light-olive-gray (5*Y* 6/1) and yellowish-gray (5*Y* 7/2), similar to unit 42. Base irregular, marked by 0.1 to 0.2 ft of green-stained limestone containing irregular patches and veinlets of quartz	4.8
39.	Limestone, greenish-gray (5*GY* 6/1), very fine grained to aphanitic; a single bed; base gradational	1
38.	Limestone, medium-light-gray (*N* 6), poorly sorted, medium-grained, clastic. Interbedded greenish-gray (5*G* 6/1) shale. Sparse endothyrid foraminifera about 3 ft below top	4.2
37.	Limestone, argillaceous, yellowish-gray (5*Y* 7/2)	3.2
36.	Siltstone, calcareous and dolomitic, dusky-yellow-green (5*GY* 4/2), thin-bedded; yields platy fragments. Poorly exposed; thickness approximate	5.5
35.	Limestone, olive-gray (5*Y* 3/2); poorly sorted calcarenite	.9
34.	Limestone, very argillaceous, yellowish-gray (5*Y* 7/2) and pale-yellowish-orange (10*YR* 8/6); similar to unit 42. Basal 1.0 ft contains calcite- and quartz-filled geodes	3.7
33.	Shale, dusky-yellow-green (5*GY* 5/2); pinches out laterally	.6
32.	Limestone, argillaceous, light-olive-gray (5*Y* 5/2) and dusky-yellow (5*Y* 6/4)	.5
31.	Shale, silty, grayish-yellow (5*Y* 8/4) to light-olive (10*Y* 5/4)	1.6
30.	Siltstone, calcareous, yellowish-gray (5*Y* 7/2) and dark-yellowish-orange (10*YR* 6/6); forms single bed	1.3
29.	Shale, dusky-yellowish-green (5*GY* 5/2) and grayish-olive (10*Y* 4/2), nonresistant; plastic when wet. Upper 0.2 ft glauconitic. Single siltstone bed 0.5 ft thick, 0.5 ft above base	3.7
28.	Limestone, dolomitic, argillaceous, dark-yellowish-orange (10*YR* 6/6) to moderate-yellowish-brown (10*YR* 6/2), finely crystalline; scattered fragments of bryozoans and brachiopods. Contains nodules, a few inches in diameter, of gray chert with included fossil debris. Unit irregular in thickness	2.8
27.	Siltstone, grayish-yellow (5*Y* 8/4) and yellowish-gray (5*Y* 7/2), brittle. Contains conspicuous subspherical quartz-filled geodes as much as 1 ft in diameter	9

Renfro Valley North section—Continued

	Feet
Mississippian—Continued	
Borden Formation (incomplete)—Continued	
Renfro Member—Continued	
26. Limestone, dark-yellowish-orange (10*YR* 6/6), punky; scattered fragments of crinoids and brachiopods; pinches and swells	1
25. Shale, grayish-green (10*GY* 5/2), irregular, probably discontinuous	.3
24. Limestone, dolomitic, pale-yellowish-orange (10*YR* 8/6); fossil debris in streaks. Thin partings of pale-olive (10*Y* 6/2) clay shale. Contains platy to nodular masses of partly iron-stained gray chert oriented parallel to bedding	9.7
Total Renfro Member	82.5
Wildie Member:	
23. Limestone, very silty, yellowish-gray (5*Y* 8/1) to dark-yellowish-orange (10*YR* 6/6); glauconite-streaked, a single bed	1.5
22. Siltstone, glauconitic, dusky-green (5*G* 3/2) to greenish-black (5*GY* 2/1), grading downward into glauconite-streaked gray siltstone	.5
21. Claystone, dusky-yellow-green (5*GY* 5/2) and pale-olive (10*Y* 6/2)	4.7
20. Siltstone, light-greenish-gray (5*G* 8/1), laminated, interbedded with greenish-gray shale	.7
19. Shale, silty; at top, dark greenish gray (5*G* 4/1) mottled grayish red purple (5*RP* 6/2); grades downward into dark greenish gray (5*G* 4/1). Small discoidal phosphatic nodules about 3 ft above base	8.9
18. Siltstone, locally slightly calcareous, light-olive-gray (5*Y* 5/2), dense; in thin, even beds; breaks into small blocks. Contains partings and irregularly lensing thin beds as much as 7 in. thick of greenish-gray silty shale, mostly in upper one-third of unit. Base of unit is discordant owing to northward thinning of beds of shale in units 12 through 17	5.2
17. Siltstone, glauconitic, greenish-black (5*G* 2/1)	.5
16. Shale, light-olive-brown (5*Y* 5/6)	.6
15. Siltstone, siliceous, dark-greenish-gray (5*G* 4/1)	.6
14. Claystone, silty, glauconitic, greenish-black (5*G* 2/1)	.2
13. Limestone, glauconitic, dark-yellowish-orange (10*YR* 6/6) streaked with dark-greenish-gray (5*GY* 4/1). At base is a concentration of round to subangular shiny dark-brown to black phosphatic nodules	.6
Total Wildie Member	24

Renfro Valley North section—Continued

	Feet
Mississippian—Continued	
Borden Formation (incomplete)—Continued	
Halls Gap Member:	
12. Siltstone and silty shale, micaceous, partly limy, light-bluish-gray (5*B* 7/1), weathering same or greenish gray; finely laminated; breaks into platy fragments. Worm(?) trails common; shale units thin northward	16. 5
Total Halls Gap Member	16. 5
Nancy Member (incomplete):	
11. Shale, silty to clayey, dark-greenish-gray (5*GY* 4/1), imperfectly fissile; abundant bryozoans; as much as 4 ft thick	2. 5
10. Siltstone, greenish-gray (5*G* 6/1), finely laminated; breaks into small blocks. Limonite-stained joint surfaces	1. 2
9. Shale, similar to unit 11	3. 9
8. Siltstone, micaceous; similar to unit 10. *Taonurus*(?) markings common	1. 3
7. Shale, similar to unit 11. Abundant lentils, as thick as 1 ft, of very fine grained limestone, light-olive-gray (5*Y* 6/1), limonitic; bryozoans very abundant, crinoid stems common	21. 2
6. Covered, probably shale	23
5. Gum Sulphur Bed. Siltstone, greenish-gray (5*GY* 6/1); limonite-stained joint surfaces; imperfectly fissile; fossiliferous, mainly brachiopods. At base are lentils, as thick as 1 ft, of grayish-olive (10*Y* 4/2) fossiliferous very fine grained limestone. Common siliceous nodules as much as 2 in. in diameter	12
4. Shale, silty, greenish-gray (5*GY* 6/1) and dark-greenish-gray (5*G* 4/1); breaks into rough plates and small blocks; limonite-stained joints; less resistant than above but more resistant than below	7. 4
3. Shale, silty, medium-bluish-gray (5*B* 5/1), weathering about same and pale olive; imperfectly fissile	2. 9
2. Shale, silty; similar to unit 4; abundant limonite spots; common *Taonurus*(?) markings; forms conspicuous resistant bed	1. 8
1. Shale, silty, medium-bluish-gray (5*B* 5/1) to dark-greenish-gray (5*GY* 4/1), weathering same or lighter; imperfectly fissile; spalls along curved surfaces; abundant limonite spots. About 6 ft above base is resistant rib of clayey shale about 1 ft thick. Base of local exposure, not base of member	12. 8
Measured Nancy Member (incomplete)	90
Measured Borden Formation (incomplete)	213

Phillipsburg section

[Type section of the Muldraugh Member of the Borden Formation. Measured along Kentucky Highway 208 about 0.2 mile south of Phillipsburg, Marion County, Ky. (Spurlington quadrangle), beginning immediately south of creek near Our Lady of Fatima Church and continuing about 0.5 mile up hill. Section at base taken from exposures in ditch at east side of road; section above covered interval taken from west side of road and along old abandoned road. Measured with barometer, hand level, and tape by J. L. Gualtieri assisted by J. C. Dills, July 1962]

	Feet
Mississippian:	
Salem and Warsaw Limestones (incomplete):	
17. Limestone, light-gray (*N* 7), mostly weathered to yellowish-orange punky material; fine to coarse grained; very fossiliferous; large whole brachiopods and fragments of crinoid; abundant grayish-white chert. Not measured. Top of section, not top of exposure.	
Borden Formation:	
Muldraugh Member:	
16. Siltstone, dolomitic or limy, interbedded with lesser amounts of cherty siltstone and limestone. Siltstone, very light gray (*N* 8) to medium light gray (*N* 6), weathering light gray, buff, and pale yellowish orange; abundant knotlike contortions of laminae about minute blebs of chert; common pyrite nodules; sparse fossils. Chert, medium gray (*N* 5) and medium dark gray (*N* 4), weathering light gray. Abundant quartz geodes as large as 6 in. in diameter	12.8
15. Shale, silty, greenish-gray (5*GY* 6/1)	.3
14. Limestone, medium-gray (*N* 5), medium-grained, resistant; contains sparse brachiopods; gradational with overlying unit	.8
13. Siltstone, dolomitic and limy, interbedded with chert; similar to unit 16	24.5
12. Chert intermixed with limy and dolomitic siltstone, medium-gray (*N* 5) and medium-dark-gray (*N* 4), weathering light gray and yellowish orange. Unit made up of lenticular cherty bodies surrounded by limy siltstone; abundant quartz geodes less than 2 in. in diameter	2
11. Siltstone, light-greenish-gray (5*G* 8/1); abundant glauconite in basal part; grades upward to more siliceous rock; sparse geodes similar to geodes in unit 12	2
10. Siltstone, medium-light-gray (*N* 6), laminated; contains very abundant glauconite grains, especially at top. (Units 10 through 8 constitute the Floyds Knob Formation as used by Stockdale, 1929, 1939, p. 201)	.8
9. Limestone, medium-light-gray (*N* 6), fine-grained; abundant glauconite grains; resistant	.8
8. Siltstone, greenish-gray (5*GY* 6/1); contains very abundant grains of glauconite which gives the rock a greenish cast; laminated	2
Total Muldraugh Member	46

Phillipsburg section—Continued

	Feet
Mississippian—Continued	
Borden Formation—Continued	
Halls Gap(?) Member:	
7. Limestone and silty to limy siltstone with minor silty shale; medium-light-gray (*N* 7); in wavy discontinuous laminae; shale partings at 26 ft and 28.5 ft above base. Abundant pyrite nodules, less than ½ in. in diameter. Glauconite in films, seams, and disseminated grains in top 7 ft	45.3
6. Siltstone, very limy, light-gray (*N* 7), weathering yellowish orange; fossil debris in irregular lentils as much as 6 in. long and 3 in. thick	1.5
5. Limestone, argillaceous and silty; limy siltstone and chert; light-gray (*N* 7); weathering same and yellowish orange. Chert occurs in more limy beds. Crinoid stems, horn corals, and brachiopods common in more limy beds. Small pyrite nodules common	1.2
Total Halls Gap(?) Member	48
Nancy Member:	
4. Shale, clayey, and silty shale; dark greenish gray (5*GY* 4/1), grayish olive (10*Y* 4/2), and medium dark gray (*N* 4); imperfectly fissile; limonite stain on partings and fractures. Ferruginous concretions from 6 to 12 in. in diameter occur sparsely about 5 ft and 11 ft, and abundantly about 14 ft and 21 ft above base. About 63 ft above the base, beds are more silty and form irregular, ill-defined ledges. Spares brachiopods occur 80 to 85 ft above base of unit	97
3. Covered; probably yellowish-green clay shale. Thickness determined by barometer	69
2. Shale, clayey, dusky-yellow-green (5*GY* 5/2), weathering same and forming buff soil; fissile. Phosphatic nodules in basal few inches	5
Total Nancy Member	171
Total Borden Formation	265
Devonian:	
New Albany Shale (incomplete):	
1. Shale, black (*N* 1), laminated, brittle, weathering to thin plates and chips. Not measured.	

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