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Revision of Stratigraphic Nomenclature and Classification of the Pleasanton, Kansas City, Lansing, and Lower Part of the Douglas Groups (Lower Upper Pennsylvanian, Missourian) in Kansas

by

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Front cover: Photograph from early 1990's, looking northeast across southbound ramps between I–435 and Holliday Road, northern Johnson County, Kansas. Succession includes dark Liberty Memorial Shale in lower half, overlain by light-colored Wyandotte Limestone, with Frisbie Limestone Member behind people, dark line of Quindaro Shale Member at head level, overlain by thick Argentine Limestone Member. Top of section is Lane Shale, with Island Creek Shale Member covered by brush, overlain by limestone and shale beds of Farley Limestone Member. Because it is the principal reference section for many of these units, this section is located in fig. 29 and graphically illustrated in fig. 30.

Back cover: Photograph from 2002 of principal reference section of Canville Limestone Member and black Stark Shale Member of Dennis Limestone, with basal beds of overlying Winterset Limestone Member at top. Outcrop is located along north side of US-59–K-39, about 1.7 mi (3 km) west of Stark, in northeastern Neosho County, Kansas. Exact location is given on p. 23. University of Iowa graduate students Heidi Dowd, Courtney Stewart, and John Paul Pope provide scale.

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Contents

Figures

Abstract

Correction of several long-standing miscorrelations within the Missourian succession in Kansas has resulted from recent field work along outcrop and has been substantiated by near-surface drilling. This requires some revision of nomenclature and classification of this succession of rocks so that its stratigraphy is clarified and sufficiently characterized to facilitate its utilization in the interpretation of geologic history and assessment of resources. The revision also is timely for consideration of the succession in the pending selection of international Series/Stage boundary stratotypes. New formations now recognized in Kansas are the Hepler and Shale Hill Formations in the Pleasanton Group; the Elm Branch Shale and Mound Valley Limestone, both essentially reinstated, in the Bronson Subgroup of the Kansas City Group; the Nellie Bly Formation and Dewey Limestone, both newly extended into Kansas (from Oklahoma) in the Linn Subgroup of the Kansas City Group; the Liberty Memorial Shale, reinstated (from Missouri) in the Zarah Subgroup of the Kansas City Group; and the Cass Limestone, newly extended into Kansas (from Nebraska) in the middle of the Douglas Group. In addition, the Coffeyville Group is now recognized in southern Kansas to more adequately characterize the southward facies transition of the upper Pleasanton and lower Kansas City Groups (most of the Bronson Subgroup). Several formations previously recognized in Kansas have been revised (Tacket Formation, Hertha Limestone, Cherryvale Formation, Wyandotte Limestone, Lane Shale, Stanton Limestone), with members shifted from or to adjacent formations. Two members are raised in rank (Rock Lake Shale and South Bend Limestone); four members are extended into Kansas from surrounding areas (Exline Limestone Member of Shale Hill Formation, Gretna Shale Member of South Bend Limestone, Little Pawnee Shale Member and Shoemaker Limestone Member of Cass Limestone); one member is reinstated (Little Kaw Limestone Member of South Bend Limestone); and two members are newly defined in Kansas (Mantey Shale Member and Guthrie Mountain Shale Member of Shale Hill Formation).

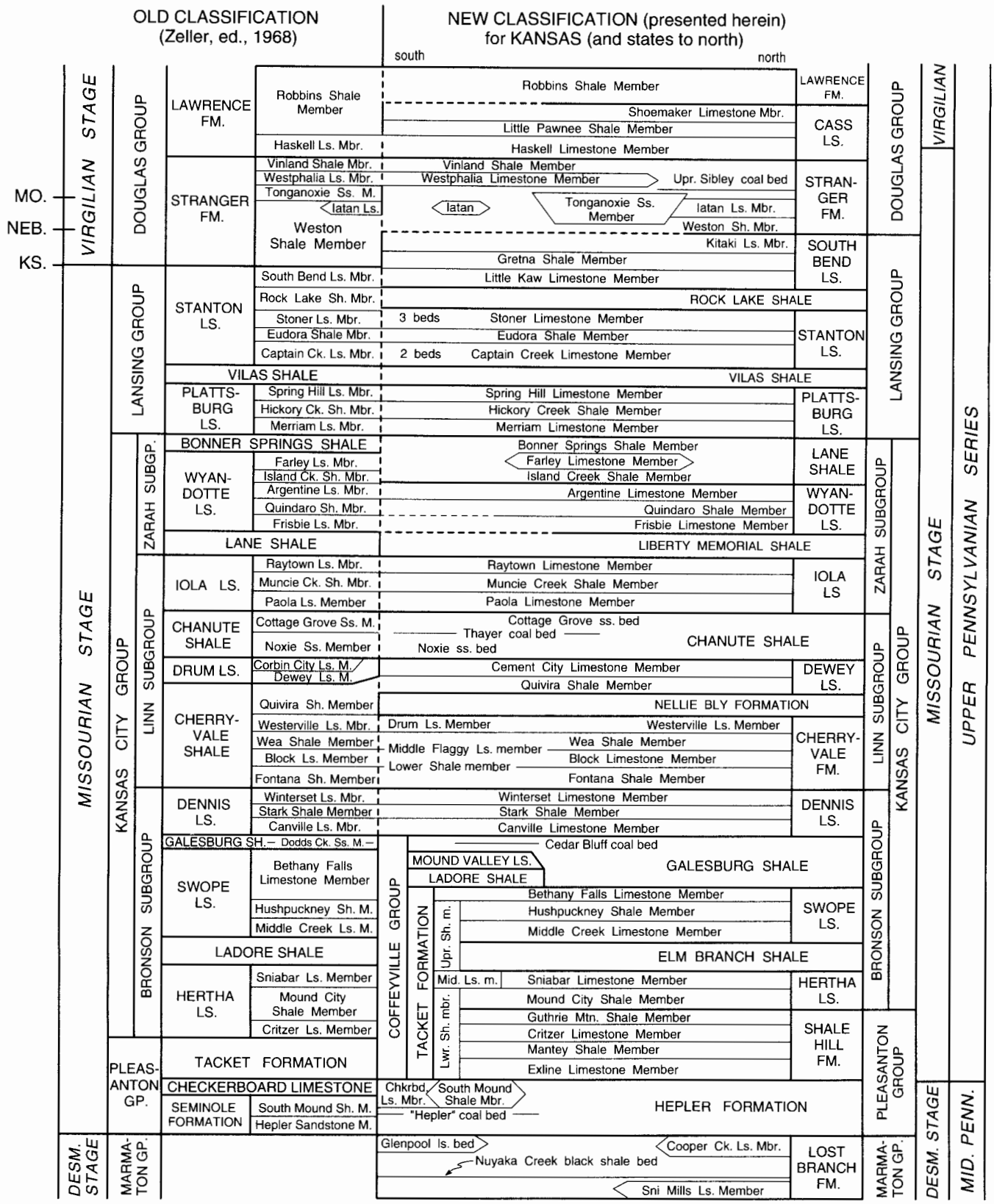
Introduction

Ongoing stratigraphic work since the mid-1960's has uncovered enough miscorrelations among well-known Missourian units along the Kansas outcrop belt to necessitate a revision of the nomenclature and classification of parts of the Pleasanton, Kansas City, Lansing and lower Douglas Groups (fig. 1) in this area. The outcrop belt of eastern Kansas and adjacent northwestern Missouri and northeastern Oklahoma contains not only the type region of the Missourian Stage, but also what appears to be the most complete and well-exposed rock succession of this age in the world that is tectonically undisturbed across such a large region. It essentially serves as an informal body stratotype for rocks of this age in the United States, and its completeness will allow it to play a significant role in the selection of Series and Stage boundaries within the Pennsylvanian Subsystem of the Carboniferous System by the Sub-Commission on Carboniferous Stratigraphy (SCCS) of the International Commission on Stratigraphy (ICS). Therefore, it is imperative that the miscorrelations be rectified and the nomenclature reflect the actual stratigraphic relations among the rock units. These modifications to stratigraphic nomenclature and classification also should provide a more consistent framework within which to realistically interpret geologic history and also to adequately address subtle stratigraphic problems involved in resource appraisal and environmental issues.

Much of the information presented here was extracted and updated from a comprehensive analysis of Missourian stratigraphy prepared by P. H. Heckel (available as Kansas Geological Survey Open-file Report 92–60), an informal report that provides more detailed discussion of the history of nomenclature of the units, more elaboration of the problems that have arisen with lateral tracing of some units along outcrop, locations of more reference sections that help to clarify our increasingly refined understanding of the stratigraphy, more discussion of interpretation of the genesis of the units, and more thorough discussion of biostratigraphic correlations of units within Kansas and with units in adjacent states. Concurrent stratigraphic studies at the Kansas Geological Survey, primarily in the subsurface of Kansas, have utilized thousands of wireline logs and over 100 cores, many adjacent to surface exposures, to substantiate the results of these surface investigations.

In order to rectify the miscorrelations, the lithostratigraphic framework of the succession in this area is modified in accordance with the procedure of the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983). The philosophy of this revision follows two additional basic guidelines appropriate to this particular succession of rocks.

The first guideline is to change the nomenclature currently in use in Kansas (and in many cases in the other states along the midcontinent outcrop belt: Missouri, Iowa, Nebraska, and Oklahoma) as little as possible beyond that which is mandated by the rectification of the miscorrelations. In some cases, this requires setting up new reference sections, including neostratotypes in place of original type sections of several familiar units (Hertha, Wea, Hepler). The names have become familiarly associated with strata consistently across the rest of the midcontinent that do not (or may not) correlate with the original type sections. This


OLD CLASSIFICATION
(Zeller, ed., 1968)
NEW CLASSIFICATION (presented herein)
for KANSAS (and states to north)
south
north
MO.
NEB.
KS.
VIRGILIAN STAGE
MISSOURIAN STAGE
DESM. STAGE
DOUGLAS GROUP
LANSING GROUP
KANSAS CITY GROUP
ZARAH SUBGP.
LINN SUBGROUP
BRONSON SUBGROUP
PLEAS-ANTON GP.
MARMA-TON GP.
LAWRENCE FM.
STRANGER FM.
STANTON LS.
PLATTS-BURG LS.
BONNER SPRINGS SHALE
WYAN-DOTTE LS.
LANE SHALE
IOLA LS.
CHANUTE SHALE
DRUM LS.
CHERRY-VALE SHALE
DENNIS LS.
GALESBURG SH.
SWOPE LS.
LADORE SHALE
HERTHA LS.
TACKET FORMATION
CHECKERBOARD LIMESTONE
SEMINOLE FORMATION
Robbins Shale Member
Haskell Ls. Mbr.
Vinland Shale Mbr.
Westphalia Ls. Mbr.
Tonganoxie Ss. M.
Iatan Ls.
Weston Shale Member
South Bend Ls. Mbr.
Rock Lake Sh. Mbr.
Stoner Ls. Mbr.
Eudora Shale Mbr.
Captain Ck. Ls. Mbr.
VILAS SHALE
Spring Hill Ls. Mbr.
Hickory Ck. Sh. Mbr.
Merriam Ls. Mbr.
Farley Ls. Mbr.
Island Ck. Sh. Mbr.
Argentine Ls. Mbr.
Quindaro Sh. Mbr.
Frisbie Ls. Mbr.
LANE SHALE
Raytown Ls. Mbr.
Muncie Ck. Sh. Mbr.
Paola Ls. Member
Cottage Grove Ss. M.
Noxie Ss. Member
Corbin City Ls. M.
Dewey Ls. M.
Quivira Sh. Member
Westerville Ls. Mbr.
Wea Shale Member
Block Ls. Member
Fontana Sh. Member
Winterset Ls. Mbr.
Stark Shale Member
Canville Ls. Mbr.
Dodds Ck. Ss. M.
Bethany Falls Limestone Member
Hushpuckney Sh. M.
Middle Creek Ls. M.
Sniabar Ls. Member
Mound City Shale Member
Critzer Ls. Member
South Mound Sh. M.
Hepler Sandstone M.
Robbins Shale Member
Shoemaker Limestone Mbr.
Little Pawnee Shale Member
Haskell Limestone Member
Vinland Shale Member
Westphalia Limestone Member
Upr. Sibley coal bed
Iatan
Tonganoxie Ss. Member
Iatan Ls. Mbr.
Weston Sh. Mbr.
Kitaki Ls. Mbr.
Gretna Shale Member
Little Kaw Limestone Member
ROCK LAKE SHALE
3 beds
Stoner Limestone Member
Eudora Shale Member
2 beds
Captain Creek Limestone Member
VILAS SHALE
Spring Hill Limestone Member
Hickory Creek Shale Member
Merriam Limestone Member
Bonner Springs Shale Member
Farley Limestone Member
Island Creek Shale Member
Argentine Limestone Member
Quindaro Shale Member
Frisbie Limestone Member
LIBERTY MEMORIAL SHALE
Raytown Limestone Member
Muncie Creek Shale Member
Paola Limestone Member
Cottage Grove ss. bed
Thayer coal bed
Noxie ss. bed
CHANUTE SHALE
Cement City Limestone Member
Quivira Shale Member
NELLIE BLY FORMATION
Drum Ls. Member
Westerville Ls. Member
Middle Flaggy Ls. member
Wea Shale Member
Lower Shale member
Block Limestone Member
Fontana Shale Member
Winterset Limestone Member
Stark Shale Member
Canville Limestone Member
Cedar Bluff coal bed
MOUND VALLEY LS.
LADORE SHALE
GALESBURG SHALE
Bethany Falls Limestone Member
Hushpuckney Shale Member
Middle Creek Limestone Member
ELM BRANCH SHALE
Sniabar Limestone Member
Mound City Shale Member
Guthrie Mtn. Shale Member
Critzer Limestone Member
Mantey Shale Member
Exline Limestone Member
Chkrbd. Ls. Mbr.
South Mound Shale Mbr.
"Hepler" coal bed
HEPLER FORMATION
Glenpool ls. bed
Cooper Ck. Ls. Mbr.
Nuyaka Creek black shale bed
Sni Mills Ls. Member
COFFEYVILLE GROUP
TACKET FORMATION
Upr. Sh. m.
Mid. Ls. m.
Lwr. Sh. mbr.
LANSING GROUP
DOUGLAS GROUP
KANSAS CITY GROUP
LINN SUBGROUP
BRONSON SUBGROUP
ZARAH SUBGROUP
PLEASANTON GROUP
MARMATON GP.
LAWRENCE FM.
CASS LS.
STRANGER FM.
SOUTH BEND LS.
ROCK LAKE SHALE
STANTON LS.
VILAS SHALE
PLATTS-BURG LS.
LANE SHALE
WYAN-DOTTE LS.
IOLA LS
DEWEY LS.
CHERRY-VALE FM.
DENNIS LS.
SWOPE LS.
HERTHA LS.
SHALE HILL FM.
LOST BRANCH FM.
VIRGILIAN
MISSOURIAN STAGE
DESM. STAGE
UPPER PENNSYLVANIAN SERIES
MID. PENN.

procedure tempers Article 8e of the North American Stratigraphic Code (1983) on the immutability of stratotypes, with Article 7c regarding the preferability of preserving well-established names. Precedence for this procedure in the midcontinent Missourian lies in the discovery by Newell (1935, p. 74) that the original type section of the Stanton Limestone in Kansas is equivalent to the slightly later named Plattsburg Limestone in Missouri. Common usage of the name Stanton was shifted to a higher limestone because of miscorrelation between the type sections. In his pragmatic resolution of the problem, Newell recognized the higher limestone in the Stanton type area as type Stanton Limestone, rather than replacing the name Plattsburg with Stanton, or the name Stanton with a little-used name from southern Kansas. In other cases, slight to moderate revisions of formations, boundaries, and component members are required to adequately characterize the stratigraphic relations of the units as now understood.

The second guideline is to select lithic boundaries that are required to define the basic lithostratigraphic units (formation, member) as close to significant sequence-stratigraphic (allostratigraphic, cyclothemic) boundaries, such as exposure surfaces and major marine flooding surfaces, as is reasonably possible in order to allow the familiar lithostratigraphic terminology to be easily utilized in modern discussions of genesis of the succession (Watney et al., 1989; Heckel, 1994, 2002; Heckel et al., 1999). This permits discrete unambiguous names to be applied to individual, predominantly marine units across much or all of the midcontinent and provides an appropriate format for correlation at all scales. Lateral continuity of the marine units (regardless of lithic changes within them) underpins correlation within the midcontinent basin and provides the framework for detailed correlations with coeval successions in other basins. The principles behind this guideline were discussed and utilized by Moore (1936, p. 20ff; see also Newell, 1935), and are sanctioned in Article 23e of the 1983 Code (p. 858): "Correspondence with genetic units.—The boundaries of lithostratigraphic units should be chosen on the basis of lithic changes and, where feasible, to correspond with the boundaries of genetic units, so that subsequent studies of genesis will not have to deal with units that straddle formal boundaries." This guideline is readily applied in cases where the entirely marine units (e.g., Swope Limestone) consist of a widespread transgressive limestone, offshore condensed-interval shale, and regressive limestone (see Heckel, 1994), which are lithically distinct from the underlying and overlying terrestrial-to-nearshore shales (e.g., Elm Branch Shale, Galesburg Shale). It is relatively straightforward in cases where the transgressive limestone is missing along much of the outcrop (e.g., Dennis Limestone, Dewey Limestone) because the dark phosphatic, offshore, condensed-interval shale members (Stark Shale, Quivira Shale) provide good lithic markers that tend to be distinct from the underlying lighter terrestrial shale to paleosol (Galesburg Shale, Nellie Bly Formation). In the subsurface the dark phosphatic shales show up conspicuously as positive spikes on gamma-ray logs. This type of boundary at the base of the dark shale is typically at or close to the genetically significant major marine flooding surface (Watney et al., 1989, 1995).

The second guideline is less easily applied where the regressive limestone is missing along most of the outcrop. In such cases, the offshore condensed-interval shale grades more transitionally upward into nearshore marine strata, in places coarser detrital deposits, and ultimately into similar terrestrial deposits that typically are difficult to distinguish from the marine regressive sequence. In these cases, it is just as important to separate the marine transgressive to condensed-interval highstand units, which contain most of the fossils useful for distant correlation (conodonts, ammonoids) from the thicker marine regressive deposits and the similar-appearing lowstand terrestrial detrital units that may contain palynomorphs or other terrestrial fossils of distinctly later age. The most useful procedure is to choose the most recognizable lithic change upward from conspicuously fossiliferous marine shale to unfossiliferous silty to sandy shale, siltstone, sandstone, or blocky mudstone. Heckel (1991) so designated the Lost Branch–Hepler formational boundary, recognizing that the boundary is likely to be of slightly different ages in different places. This procedure is a pragmatic compromise between 1) a more rigidly sequence-stratigraphic (but difficult) alternative of trying to distinguish unfossiliferous regressive marine sandy shales and sandstones from lowstand terrestrial shales and sandstones in order to draw a boundary between them; and 2) the strictly lithic alternative of terminating the marine limestone-dominated formation vertically and laterally where the limestone disappears. The latter could place a biostratigraphically important marine

FIGURE 1 (left)—Comparison of old stratigraphic classification of Missourian succession in Kansas (Zeller, ed., 1968), with that revised herein, based on corrections of several long-standing miscorrelations (see figs. 2, 21, 28, 33). Uppercase names are formations or units of higher rank; uppercase and lowercase names are members or beds. Short lines with state abbreviations in upper left show different positions of Missourian–Virgilian Stage boundary currently recognized in those three states. That for Kansas (O'Connor, 1963) was not based on biostratigraphic criteria. Ongoing biostratigraphic work, following the 1983 North American Stratigraphic Code and utilizing mainly conodonts, suggests that the best position for the Desmoinesian–Missourian Stage (and the Middle–Upper Pennsylvanian Series) boundary is at the base of the Exline Limestone (Heckel, Boardman and Barrick, 2002) rather than the base of the Mound City Shale (Barrick et al., 1996), and that the best position for the Missourian–Virgilian boundary may be within the Haskell Limestone (Boardman et al., 1989; Barrick et al., 1995; Heckel et al., 1999). More members are recognized in the Shale Hill Formation above the Mantey Shale Member in Missouri (see figs. 2, 6).

condensed-interval shale into more than one named lithostratigraphic unit in the same part of the same basin and lead to nomenclatural awkwardness and potential confusion when attempting distant correlation by means of its fossil content. This is the situation with the thin but biostratigraphically significant Gretna and Little Pawnee Shale Members (both named from Nebraska where they are lithically distinct from both adjacent units). These members are currently included in the base of the thick, sandy, sparsely fossiliferous Weston and Robbins Shale Members, respectively, in Kansas.

Using these guidelines, formations are typically either 1) the generally limestone-dominated (but occasionally shale-dominated) deposits of a marine transgressive-regressive stratigraphic sequence (cyclothem) resulting from a glacial-eustatic inundation and withdrawal of the sea (see Heckel, 1986, 1994), or 2) the generally sandy shale or mudstone to locally sandstone-dominated deposits of late regression, sea-level lowstand (and locally early transgression) between the marine formations. Named members generally represent a distinctive lithic unit (limestone or shale) deposited during a particular phase of deposition. In the marine limestone formations (1), they correspond to a position of sea-level highstand (condensed-interval shale member), or a trend of sea-level change (deepening for the transgressive limestone member, or shallowing for the regressive limestone member). In the shale-dominated formations (2), they typically represent a minor marine incursion that formed a less-widespread limestone member (e.g., Critzer, Farley) during an interval of generally lower sea-level stands. Both named and unnamed, locally mapped, distinctive rock units are recognized as beds within certain members and formations. Most previously named sandstone members are now recognized only informally as beds in their type regions because of their notorious lenticularity. This localized distribution had led to misleading and sometimes seriously incorrect correlations (e.g., the original Hepler Sandstone) when they were ranked as members and treated with the same presumed scale of lateral extent as the named limestone and shale members.

Stratigraphy

Missourian Stage

The Missourian Stage was originally established as a provincial series (e.g., Moore, 1936, 1949; Bradley, 1956), but is now regarded as the lower stage of the Upper Pennsylvanian Series in Kansas (O'Connor, 1963; Zeller, ed., 1968). Although it is a chronostratigraphic unit, it had not been rigorously biostratigraphically defined, but rather used in a lithostratigraphic sense to comprise the Pleasanton, Kansas City, and Lansing Groups in Kansas and adjacent states (fig. 1). Ongoing biostratigraphic work is in the process of defining the Missourian Stage by means of first appearances of conodont species (see Boardman et al., 1989, 1990; Barrick et al., 1995, 1996; Heckel, Boardman, and Barrick, 2002), and the boundaries selected do not coincide with major lithostratigraphic (group) boundaries. In the meantime, lithostratigraphic work carried out over the past several years by the authors and their students and colleagues, supplemented by biostratigraphic data, has led to discovery of a number of miscorrelations and resulting misuse of commonly used lithostratigraphic names, which must be rectified before further work on these rocks can be published without perpetuating the confusion. The report that follows outlines the revisions that are necessary in the above three groups traditionally associated with the Missourian. It includes, in addition, the lower part of the overlying Douglas Group, traditionally regarded as Virgilian, which is now included biostratigraphically in the Missourian Stage (Boardman et al., 1989; Barrick et al., 1995; Heckel et al., 1999).

Pleasanton Group (revised)

The Pleasanton Group overlies the Marmaton Group (Lost Branch Formation) and is overlain by the Kansas City Group (Hertha Limestone with its base revised). It was named by Haworth (1895) for exposures near Pleasanton in Linn County, Kansas. The Pleasanton Group is approximately 100 ft (30 m) thick near the Missouri border and thins to less than 30 ft (9 m) thick in Neosho and Labette counties. The Pleasanton Group is revised to comprise two new formations, the Hepler Formation overlain by the Shale Hill Formation (fig. 1). The Pleasanton previously included, in ascending order, the Seminole Formation, Checkerboard Limestone, and Tacket Formation. The Seminole Formation contained two members, the Hepler Sandstone Member and South Mound Shale Member. The Seminole Formation had been extended from Oklahoma into Kansas by Jewett et al. (1965), but it is apparently equivalent to just the lower part of the newly revised Hepler Formation of the Pleasanton Group and is dropped from use in Kansas. The Checkerboard Limestone extends only a short distance into southern Kansas, and therefore is lowered in rank from formation to member status and included in the Hepler Formation. The South Mound Shale Member, its apparent lateral equivalent that extends farther into Kansas, also is included as a member of the Hepler Formation. The Tacket Formation is now recognized to be the southern equivalent of both the upper Pleasanton Group (Shale Hill Formation), and the overlying Hertha through Swope formations of the Kansas City Group (fig. 2). Therefore, the Tacket includes strata above the Pleasanton as well as the southern equivalent of the upper Pleasanton Group, and it is treated separately as part of the Coffeyville Group, which is now recognized in southernmost Kansas.

Hepler Formation (revised and reclassified)

The Hepler Formation is raised in rank from member status and revised in Kansas to include all strata from the top of the Lost Branch Formation to the base of the Exline Limestone Member of the overlying Shale Hill Formation. The Hepler Formation comprises mostly unfossiliferous sandy shales, sandstones, and mudstones with an informal coal bed ("Hepler"), and includes the sparsely fossiliferous South Mound Shale Member and locally the thin lower and upper beds of the Checkerboard Limestone Member in southern Kansas. The name Hepler was originally applied to a sandstone by Jewett (1940) based on a type section near center of sec. 14, T. 27 S., R. 22 E. in southern Bourbon County north of the town of Hepler. Work by Sutton (1985), Bennison (1985), and Heckel (1991) showed that sandstone that had been called Hepler is present in three different stratigraphic intervals in Bourbon County, Kansas. The original type Hepler Sandstone of Jewett (1940) overlies the Memorial Shale above the Idenbro Limestone Member of the Lenapah Limestone (Jewett, 1945, p. 103). However, it is not known what unit overlies this sandstone, so it is uncertain whether it lies within the Memorial Shale or is incised downward from a higher unit. Because only sandstone above the more recently named Lost Branch Formation above the Memorial Shale has been recognized as Hepler elsewhere by the Kansas Geological Survey or the Missouri Geological Survey, it is deemed appropriate to designate a new principal reference section for the Hepler nearby in a known stratigraphic position. Also, because this stratigraphic problem arose partly through the dubious practice of formally naming lenticular sandstones with the implicit assumption that they are laterally continuous, the name Hepler is expanded to include all the strata associated with the sandstones in the higher interval.

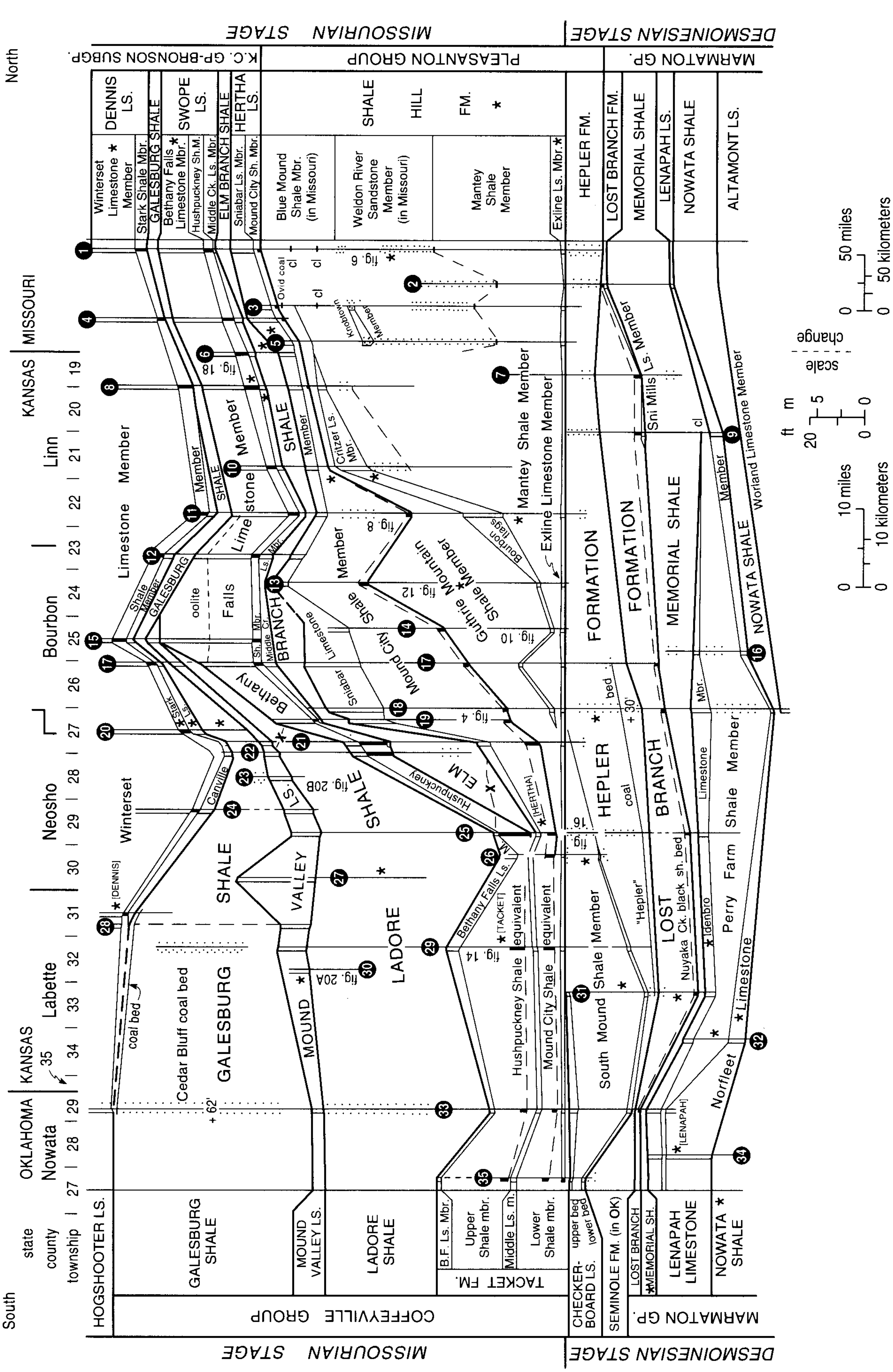
Accordingly, a new reference exposure for the Hepler Formation at its currently recognized stratigraphic position in all the rest of Kansas and in Missouri is designated at a section-line road crossing along Kansas Route 39 at SE corner sec. 4 and NW corner sec. 10, T. 27 S., R. 22 E. (fig. 3), approximately 2 mi (3.2 km) northwest of the original type Hepler Sandstone exposure. Because the dominant, shalier parts of the unit are generally poorly exposed, the boundaries of the Hepler Formation are defined in the Prong Creek Core, taken 1 mi (1.6 km) to the west (Heckel, 1991, p. 41–43), which serves as the neostratotype (fig. 4). The upper boundary is the contact between the topmost Hepler gray shale and mudstone and the overlying Exline Limestone Member of the Shale Hill Formation. The lower boundary is typically the contact between basal Hepler sandstone or sandy shale and fossiliferous shale of the underlying Lost Branch Formation, or between basal Hepler mudstone and argillaceous limestone at the top of the Lost Branch Formation.

The Hepler Formation is nearly 60 ft (18 m) thick in its type region, where it is mainly silty shale to shaly siltstone and micaceous sandstone, mostly poorly exposed. It thins southward to 33 ft (6.6 m) at the type section of the Lost Branch Formation along Pumpkin Creek southwest of Mound Valley in central Labette County. Here it contains the thin "Hepler" coal bed above a gray mudstone at the base, overlain by dark coaly shale and thin sandstone, and ultimately by the fossiliferous South Mound Shale Member and the upper bed of the Checkerboard Limestone Member (fig. 2, sec. 31). It also thins northward to about 21 ft (6.3 m) around the K–3 roadcut, 1 mile (1.6 km) south of Uniontown (fig. 2, sec. 17), where it contains the coal above a mudstone at the base overlain by a thin sandstone, as exposed in a ravine just to the west of the roadcut. The Hepler Formation thins slightly into Linn County, where it locally contains more prominent sandstone, as exposed in the bank of the Marais des Cygnes River at Trading Post (fig. 2, sec. 9), and at various localities to the north (old quarry in SW-NE-NE sec. 25, T. 21 S., R. 24 E.) and east (road corner in NW corner of NE-NE sec. 3, T. 22 S., R. 25 E.) of Pleasanton.

South Mound Shale Member (reclassified)

The South Mound Shale Member is a distinctive marine shale unit with boundaries revised by Heckel (1991, p. 26–27), which is now reclassified as the top of the Hepler Formation in southern Kansas. It consists mainly of sparsely fossiliferous gray shale with a thin shaly skeletal limestone at the base, and a local thin sandstone or coal bed at the top. It overlies the informal "Hepler" coal bed and locally sandstone at the top of the lower part of the Hepler. It underlies argillaceous limestone to fossiliferous calcareous shale of the Exline Limestone Member of the Shale Hill Formation toward the north, and the hard, purer upper limestone bed of the Checkerboard Limestone Member of the Hepler Formation where the latter is present in extreme southern Kansas. The South Mound Shale Member was named by Jewett et al. (1965), who designated the type section just south of Mound Valley in Labette County, Kansas (center SE-SW sec. 2, T. 33 S., R. 18 E.). Better exposed reference sections have been designated by Heckel (1991, p. 44–46) in SW-NE sec. 10, T. 33 S., R. 18 E. near the Lost Branch stratotype, and along the north line of NE-NE-NW sec. 15, T. 30 S., R. 20 E. (fig. 2, sec. 26), which is the principal reference section, near the village of South Mound in southern Neosho County. The South Mound Shale Member ranges in thickness from 28 ft (8.4 m) at Mound Valley to 12 ft (3.6 m) at South Mound, thinning northward to 3 ft (0.9 m) below the argillaceous Exline Limestone Member in the streambank 3.3 mi (5.5 km) east of Kimball (SW-SE-SW sec. 27, T. 27 S., R. 21 E.; fig. 2, sec. 21) in northeastern Neosho County. It thins southward also (fig. 2), ultimately to disappearance as the two beds of the Checkerboard Limestone merge in northeastern Oklahoma.

Cross section of upper Marmaton, Pleasanton, Coffeyville and lower Kansas City Group strata



Checkerboard Limestone Member (lowered in rank and reclassified)

The Checkerboard Limestone Member, as now recognized in extreme southern Kansas, comprises two beds. The upper bed overlies the South Mound Shale Member of the Hepler Formation and underlies the Lower Shale member of the Tacket Formation. The lower bed is equivalent to the thin shaly limestone bed in the base of the South Mound Shale Member. Named from Okmulgee County, Oklahoma, where it is classified as a formation (see Oakes, 1940), the type Checkerboard Limestone is apparently equivalent to the South Mound Shale Member because it seems to split into two beds in northern Oklahoma as seen along Wolf Creek (Heckel, 1991, p. 49) and along Little California Creek (fig. 2, sec. 35). Of these, the lower, relatively pure bed seems to grade into the lower, thin shaly limestone bed of the South Mound Shale, and the upper bed is that which was referred to as simply Checkerboard Limestone by Heckel (1991). Therefore, the Checkerboard Limestone is lowered in rank to member in Kansas, and both lower and upper beds are included with the South Mound Shale Member in the Hepler Formation. The best reference exposure for the upper bed in Kansas is along the top of the high bank of Pumpkin Creek in SW-NE sec. 10, T. 33 S., R. 18 E. above the Lost Branch type section (fig. 2, sec. 31) in Labette County, where it is about 1 ft (0.3 m) of hard, dense skeletal calcarenite. A reference exposure for the lower bed in Kansas in a place where it is classified with the South Mound Shale Member is at the principal reference section of the South Mound Shale Member in southern Neosho County. A reference exposure in a place where the lower bed is thicker (and can more readily be classified with the Checkerboard Limestone) is present in the west bank of the creek southeast of Tackett Mound just north of the road in SW-SE-SW-SE sec. 7, T. 32 S., R 19 E., in Labette County (see fig. 13). Northward for 0.6 mi (1 km) along this creek from this locality (toward the stratotype of the Tacket Formation), thin, hard, yellowish-weathering skeletal limestone beds of Checkerboard lithology occur within the South Mound Shale, lending further support for the facies equivalence of the Checkerboard Limestone Member and South Mound Shale Member.

Shale Hill Formation (new name)

The Shale Hill Formation is recognized in Kansas to encompass the strata of the upper Pleasanton Group, above the Hepler Formation and below the revised Mound City Shale Member of the Hertha Limestone. The name Shale Hill was originally used by Howe (1982, but not a formal publication) for part of this succession from a complete exposure of these strata in a brick pit cut into Shale Hill at Utica, near the center of sec. 18, T. 57 N., R. 24 W., southwest of Chillicothe, Livingston County, Missouri (fig. 5). This is such an appropriate term for this shale-dominated unit in Missouri and Kansas that it is revised with correlatable boundaries for use in both states, an action tentatively accepted by Howe before his death (written communication, Aug. 26, 1992), as the name was never used further in its original more limited sense. The Shale Hill Formation consists predominantly of thick successions of gray shale (so characteristic of the Pleasanton Group), with subordinate limestone and sandstone in Kansas, where it is subdivided into four members, comprising two previously named limestone members and two newly named shale members. These are, in ascending order: Exline Limestone Member, Mantey Shale Member, Critzer Limestone Member, and Guthrie Mountain Shale Member (figs. 1, 2). The latter two members were formerly part of the Hertha Limestone, where the Critzer Limestone was the basal member, and the Guthrie Mountain Shale was the basal part of the overlying Mound City Shale Member. The lower Mound City thickens abruptly southward in southeastern Linn and north-central Bourbon counties and assumes the typical appearance of thick gray Pleasanton shale. Therefore both units are removed from the Hertha Limestone and included in the Shale Hill Formation, where they facilitate both field mapping and understanding of the depositional history of the upper part of the Pleasanton Group.

The upper boundary of the Shale Hill Formation is the contact between upper Shale Hill (Guthrie Mountain) gray shale or mudstone and the base of the widespread black shale bed (locally with thin limestone lenses) at the base of the revised Mound City Shale Member of the Hertha Limestone. The lower boundary of the Shale Hill Formation is the contact between the base of the Exline Limestone Member and gray mudstone at the top of the Hepler Formation. The Shale Hill Formation is 108 ft (32.4 m)

FIGURE 2 (left)—Correlation cross section of uppermost Desmoinesian and lower Missourian strata (upper Marmaton Group, Pleasanton Group, lower Kansas City Group–Bronson Subgroup, Coffeyville Group) from northeastern Oklahoma through southeastern Kansas to north-central Missouri, showing correction of two long-standing major miscorrelations (X-covered dashed lines), which has mandated large-scale revision of nomenclature and classification of lower Missourian strata (fig. 1). Datum is base of Exline Limestone Member. Upper case names are formations or groups, which are separated by thick lines; upper and lower case names are members or beds, which are separated by thin lines within formations. Parallel vertical lines represent limestones, dots represent sandstone, thick black vertical lines represent black phosphatic shale members or black phosphatic parts of thick members, **cl** represents coal bed, * represents type area of named unit. Numbers preceded by + on vertical lines represent footage omitted from diagram because of space considerations. Correlations of Exline Limestone, Hushpuckney Shale and basal Mound City dark shale across region have been confirmed by distinctive conodont faunas at many localities. Locations and references for measured sections indicated by black circled numbers are given in Appendix.

thick at its stratotype (fig. 6; fig. 2, sec. 1), and it thins gradually southward through west-central Missouri and eastern Kansas nearly to disappearance in southern Neosho and Labette County, where its position is in the base of the Lower Shale member of the Tacket Formation (fig. 2). The principal reference section of the Shale Hill Formation in Kansas is the set of roadcuts along US–69 (fig. 7), 4 to 5 mi (7–8 km) south of Pleasanton in Linn County, where it is 54 ft (16.2 m) thick (fig. 8; fig. 2, sec. 11). Here the Critzer Limestone Member (Bourbon flags facies) is well exposed, and the Mantey Shale Member (stratotype) is less well exposed beneath a recent cover of vegetation. The Exline Limestone Member has been dug out in tbe northern roadcut (W line NW-NW-SW sec. 19, T. 22 S., R. 25 E.), and the interval of the Guthrie Mountain Shale Member is measurable in the southern roadcut (E line NE-SE-NE sec. 25, T. 22 S., R. 24 E.).

Exline Limestone Member (newly recognized in Kansas)

The Exline Limestone Member is now recognized in Kansas. It overlies the Hepler Formation (including the north end of the South Mound Shale Member to the south), and it underlies the Mantey Shale Member. Long recognized in Missouri, the Exline Limestone was named by Cline (1941) from a stream bed exposure south of Exline in Appanoose County, Iowa, just north of the Missouri border. The Exline ranges from argillaceous fossiliferous limestone to calcareous crinoid-rich shale in Kansas, rarely more than 1 ft (0.3 m) thick and generally poorly exposed. The principal reference section for the Exline Limestone Member in Kansas is in a road ditch east of Turkey Creek (fig. 9), 3 mi (5 km) northeast of Uniontown in Bourbon County (north side, in center NW-NW-NW sec. 12, T. 25 S., R. 22 E.), where it is 1 ft (0.3

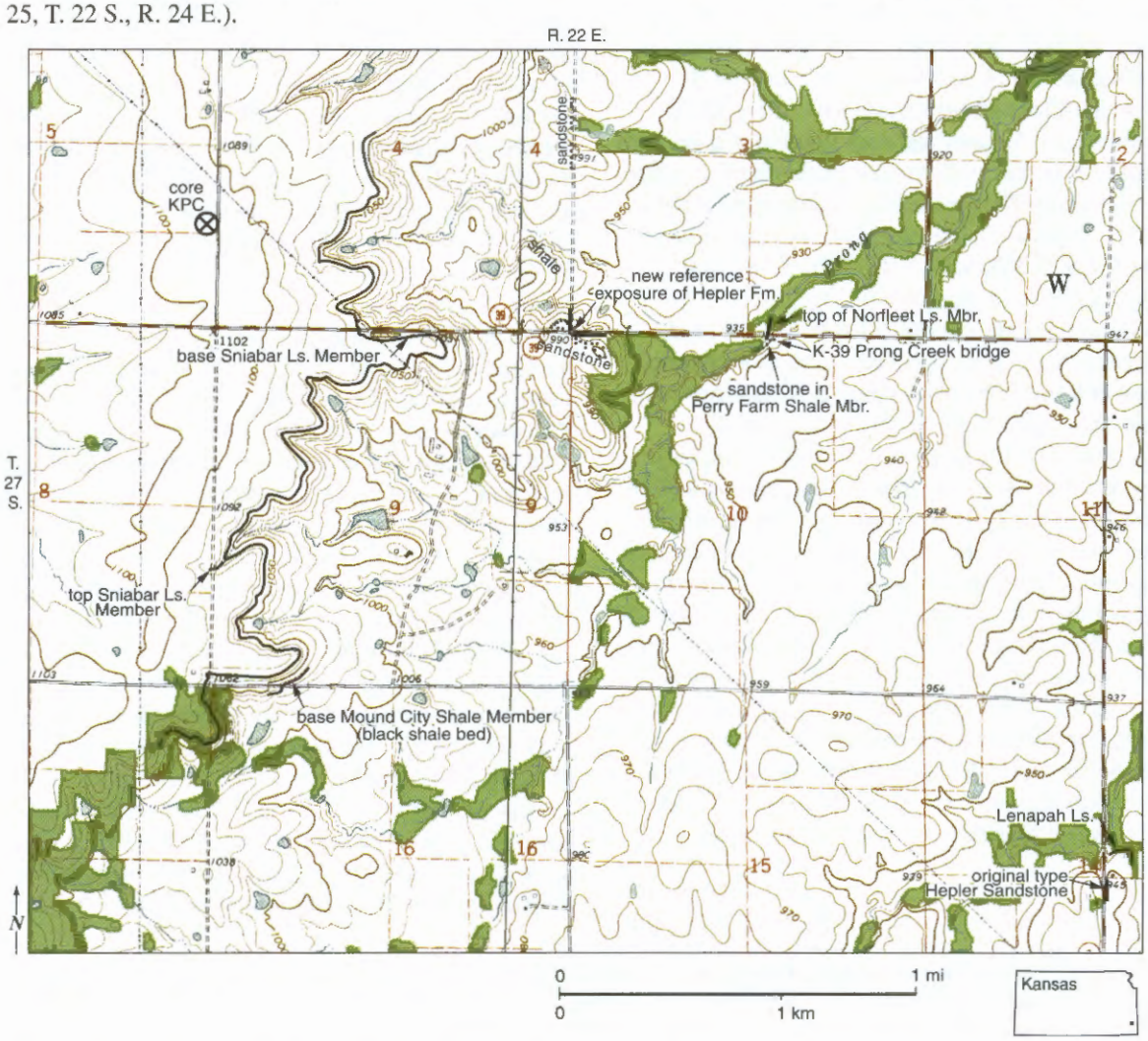


FIGURE 3—Map of parts of 1973 Porterville and 1973 Hepler, Kansas, 7 1/2-minute quadrangles, showing location of new reference exposure of Hepler Formation and location of Prong Creek Core (KPC) within which boundaries of Hepler Formation are defined and illustrated. Also shown are locations of older sandstone within Perry Farm Shale Member of Lenapah Limestone in bank of Prong Creek south of the K–39 bridge, and of original type section of Hepler Sandstone of Jewett (1940) to southeast, with which correlation is uncertain. Once thought to correlate with sandstone in Perry Farm Shale Member (Heckel, 1991, p. 43), the type exposure was described by Jewett (1945, p. 103) as lying above the Idenbro Limestone Member, which has been more recently confirmed by A. P. Bennison based on field work in E half sec. 22, T. 27 S., R. 22 E., 1 mi (1.6 km) to southwest.

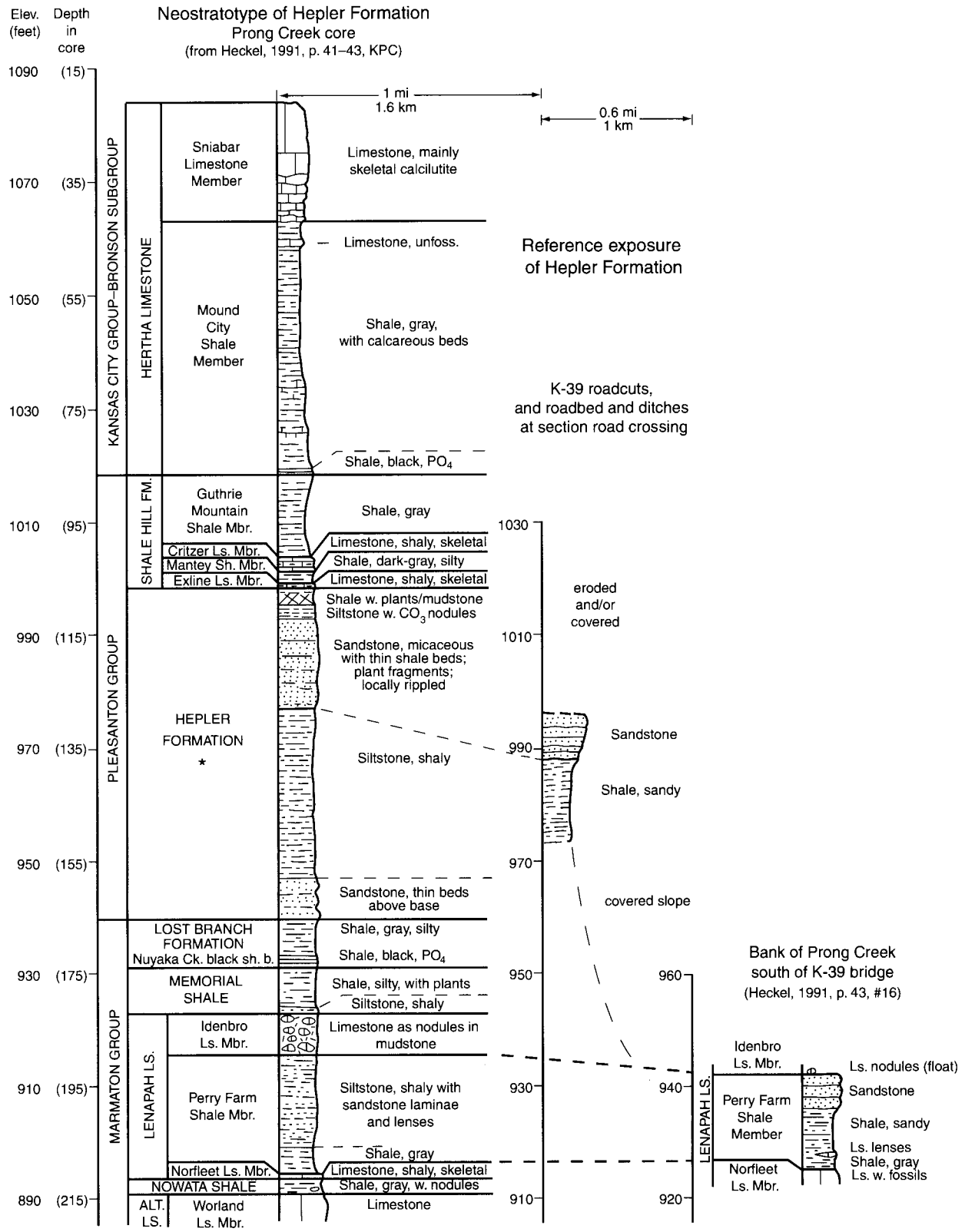


FIGURE 4—Measured section of Hepler Formation neostratotype and associated units in Prong Creek Core (taken near SE corner of NE SE sec. 5, T. 27 S., R. 22 E., and reposited at Kansas Geological Survey), showing relations with new reference exposure of Hepler Formation 1 mile (1.6 km) to east at SE corner of sec. 4 (fig. 3), and with lower sandstone in Perry Farm Shale Member of Lenapah Limestone 0.6 mi (1 km) farther east (just east of center of N line of sec. 10). It is not certain which sandstone horizon correlates with original type section of Hepler Sandstone of Jewett (1940), 2 mi (3 km) farther southeastward (center of sec. 14, all in same township). Vertical positioning of sections is based on modern elevations corrected for estimated regional westward dip of 20 ft per mi (~ 4 m/km).

m) of thin bedded argillaceous skeletal calcilutite (fig. 10; fig. 2, sec. 14). The Exline Member is well exposed as 0.5 ft (15 cm) of similar limestone, with sharp upper and lower contacts with adjacent shales, in the streambank 3.3 mi east of Kimball (SW-SE-SW sec. 27, T. 27 S., R. 21 E.; fig. 2, sec. 21) in northeastern Neosho County. It has been exposed more recently as a thin layer of shalier crinoid-rich limestone to calcareous shale with more diffuse contacts, 15 ft (4.5 m) below the limestone (Critzer) that is just downstream from the culvert beneath K–3 at the roadcut 1 mi (1.6 km) south of Uniontown (SE-NE-NW sec. 34, T. 25 S., R. 22 E.; fig. 2, sec. 17; see also Heckel et al., 1999, p. 32, Stop B1). In northern Oklahoma, the Exline Member changes facies into a bed of black shale above the upper bed of the Checkerboard Limestone (Heckel et al., 1999, p. 44, Stop B8; Heckel et al., 2002).

Mantey Shale Member (new name)

The Mantey Shale Member is newly defined in Kansas to encompass the strata above the Exline Limestone Member and below the Critzer Limestone Member. It is named from the crossroads settlement of Mantey in southeastern Linn County, where the upper part is exposed below the Bourbon flags facies of the Critzer Limestone Member 3 mi (5 km) north of town in two roadcuts, one along K–7 (east line of SE-SE sec. 30, T. 22 S., R. 24 E.), and the other along a gravel road (center of west line of NW sec. 33, T. 22 S., R. 24 E). The stratotype is selected 6.7 mi (10.8 km) northeast of Mantey at the principal reference section of the Shale Hill Formation in Kansas in the northern roadcut along US–69 (west line of NW-NW-SW sec. 19, T. 22 S., R 25 E.) where the position of the Exline Limestone Member is known (fig. 7). The Mantey Shale Member is 22 ft (6.6 m) thick at its type section (fig. 8; fig. 2, sec. 11), where it consists mainly of gray micaceous shale, becoming siltier toward the top, with a very thin bed of darker gray shale at the top in contact with the Bourbon flags facies of the Critzer Limestone Member. The lower contact is abrupt to transitional depending on how shaly the underlying Exline Limestone Member is in a particular place. The Mantey Shale Member thins southward

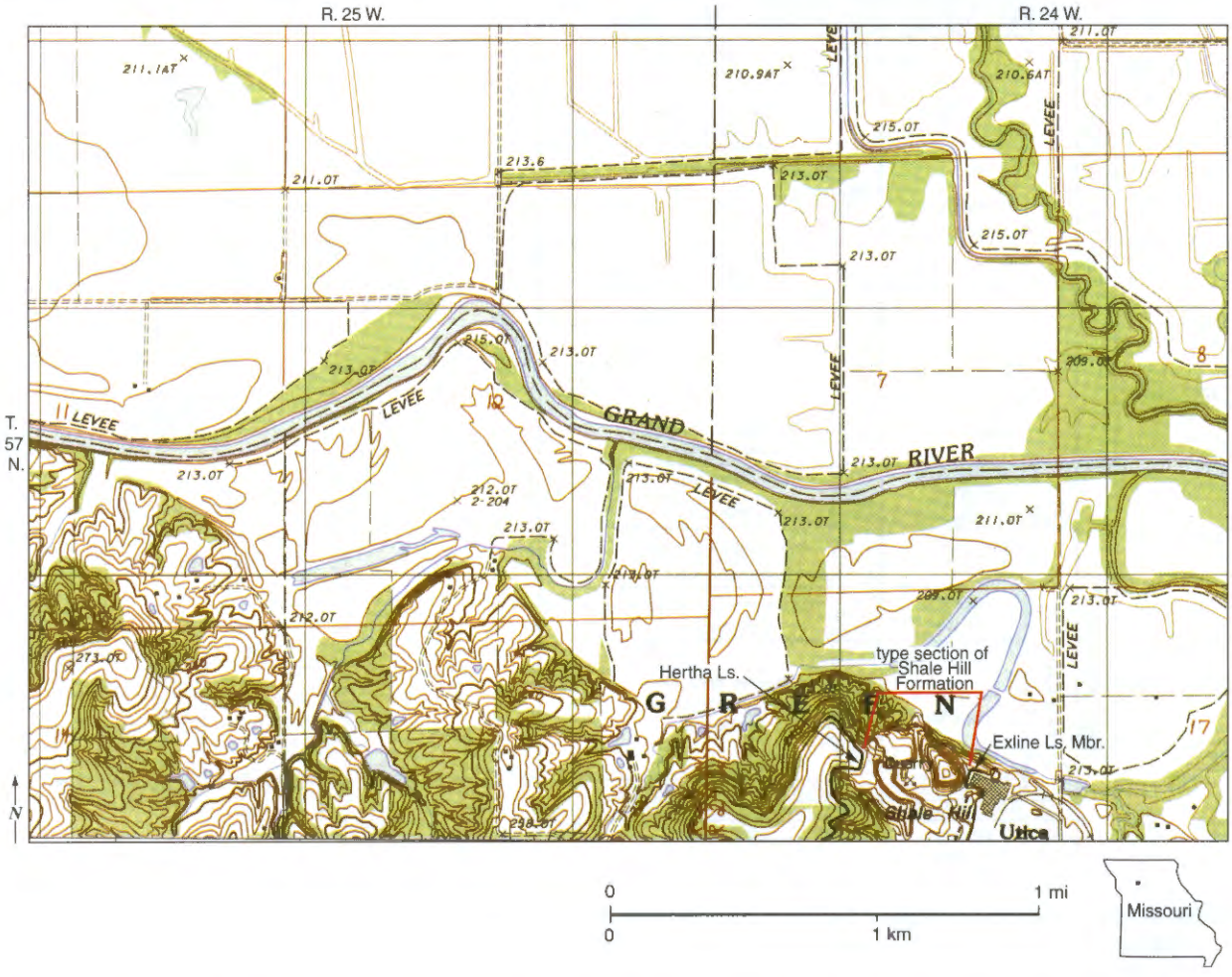


FIGURE 5— Map of part of 1984 provisional edition of Sampsel, Missouri, 7 1/2-minute quadrangle, showing location of type section of Shale Hill Formation in Glen–Gery Brick (formerly Midland Brick and Tile) Company quarry on northwest side of Utica, southwest of Chillicothe in Livingston County. Exline Limestone Member forms floor of pit and is exposed at top of cut behind main building to east. Hertha Limestone is exposed and accessible in slope above west face.

through central Bourbon County (fig. 2) to disappearance as the thinned Critzer and Exline Limestone Members appear to converge in Neosho County. It thickens northward to at least 100 ft (30 m) in northern Linn County, where it constitutes most of the Pleasanton Group. The Mantey Shale Member contains sandstone of various thickness locally in the upper part, which is well exposed and 2 ft (0.6 m) thick at the second reference section north of Mantey, and well exposed and 14 ft (4.2 m) thick along a road leading down a hill west of the north end of Pleasanton (near north line NW-NW sec. 34, T. 21 S., R. 24 E.; fig. 2, sec. 10). Here the upper contact with the overlying Critzer Limestone Member is abrupt above a thin gray shale capping the sandstone. Northeastward in Missouri, the Missouri Geological Survey now recognizes several new members above the Mantey Shale Member (R. J. Gentile and T. L. Thompson, in preparation); these include the Weldon River Sandstone Member overlain by the Blue Mound Shale Member (figs. 2, 6), and locally in the Kansas City area, the Knobtown Member, a fossiliferous sandstone to sandy limestone (fig. 2). The name Mantey replaces the name "Unity Farm" introduced by Howe (1982, an informal publication) for shale above the Exline Limestone Member and used for this unit in several informal working documents. This replacement is made because 1) the name Unity Farm, derived from a farm at Unity, Jackson County, Missouri, does not appear on any official topographic or county highway map, and 2) the type section designated by Howe (1982) in an abandoned and now water-filled brick pit has become increasingly slumped and covered to the point that only the top is still accessible.

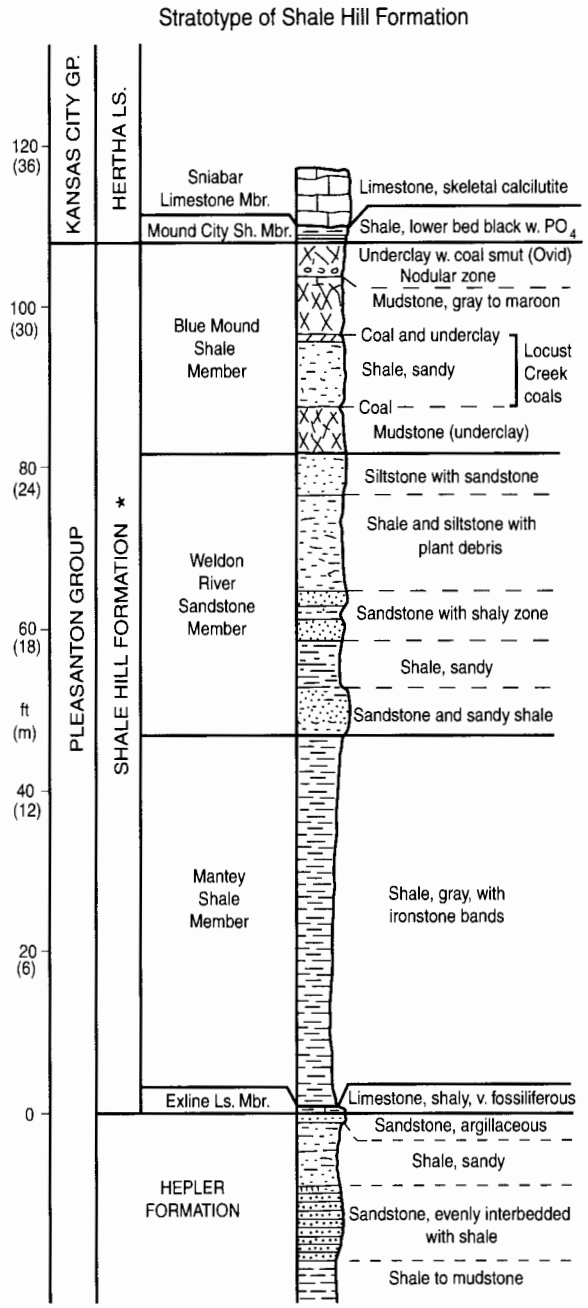


FIGURE 6— Measured section of Shale Hill Formation stratotype in shale pit of Glen-Gery Brick Company (formerly Midland Brick and Tile), cut into Shale Hill (fig. 5) at Utica, at and east of center of sec.18, T. 57 N., R. 24 W., Livingston County, Missouri; modified at top and base from Stratigraphic Section 25 of Howe (1982) with classification of units slightly modified. Missouri Geological Survey now recognizes members in sandstone-dominated upper part (Gentile and Thompson, in preparation), which are absent or not yet definitely recognized in Kansas.

Critzer Limestone Member (reclassified)

The Critzer Limestone Member overlies the Mantey Shale Member and underlies the Guthrie Mountain Shale Member (fig. 1, 2). It was named by Jewett (1932) from a type locality in sec. 17, T. 22 S., R. 23 E., just south of the former town of Critzer, 5 mi (8 km) west of Mound City in Linn County. It was previously classified as the lower member of the Hertha Limestone (Moore, 1949), but is now included as a member of the Shale Hill Formation in the Pleasanton Group because the southward-thickening Guthrie Mountain Shale Member, which is more characteristic of typical Pleasanton (Shale Hill) lithology, is now recognized as occurring between it and the main traceable part of the Hertha Limestone. Typical Critzer limestone facies is largely brown-weathering, typically massive, fine skeletal calcarenite, which is well exposed in reference sections at the hill west of the north end of Pleasanton (near center N line NW sec. 34, T. 21 S., R. 24 E.; fig. 2, sec. 10), and a roadcut northwest of Xenia (south line SW-SE-SE sec. 20, T. 23 S., R. 22 E.) in northwesternmost Bourbon County. Thicknesses in east-central Kansas range from 9 ft (2.7 m) in Bourbon and central Linn counties, thinning to commonly 1 or 2 ft (0.3 or 0.6 m) of shaly nodular limestone to the north.

The **Bourbon flags** are now recognized as a southeastern facies of the Critzer Limestone Member in east-central Kansas. This correlation resulted from

careful bed tracing through the elongate area of abrupt southeastward thinning of the underlying Mantey Shale Member and corresponding thickening of the overlying Guthrie Mountain Shale Member (fig. 2) along a line extending from southeastern Linn into northwestern Bourbon County. The Bourbon flags consist of alternating 0.3–1-ft (0.1–0.3-m)-thick beds of very sparsely fossiliferous flaggy calcilutites and gray silty shales of equal or lesser thickness. The flags seem to be a slope facies (above thinning Mantey Shale Member: see Underwood, 1984) of the Critzer Limestone Member, which is more typically developed upon thick Mantey shale facies north of the flags. Maximum thickness of the Bourbon flags is approximately 35 ft (10.6 m). Good reference sections are along the northern US–69 roadcut 4 mi (7 km) south of Pleasanton (west line NW-NW-SW sec. 19, T. 22 S., R. 25 E.), the principal reference section for the Shale Hill Formation in Kansas and the stratotype of the Mantey Shale Member (fig. 8; fig. 2, sec. 11) in Linn County; the spillway to Hidden Valley Lake 4 mi (7 km) west of Mapleton (SE-SW-SE sec. 23, T. 23 S., R. 22 E.) and nearby roadcuts (where the unit is thick), and below the type Guthrie Mountain Shale Member (fig. 12; fig. 2, sec. 13) south of Mapleton (where the unit is thin) in Bourbon County.

Guthrie Mountain Shale Member (new name)

The Guthrie Mountain Shale Member is newly defined in Kansas to encompass the strata lying above the Critzer Limestone Member and below the black shale bed at the base of the revised Mound City Shale Member of the Hertha Limestone (figs. 1, 2). It is a stratigraphically distinct gray shale unit that previously had been included as the lower part of the Mound City Shale Member where it is thin in central Linn County, but which had been commonly identified as the upper part of the Pleasanton

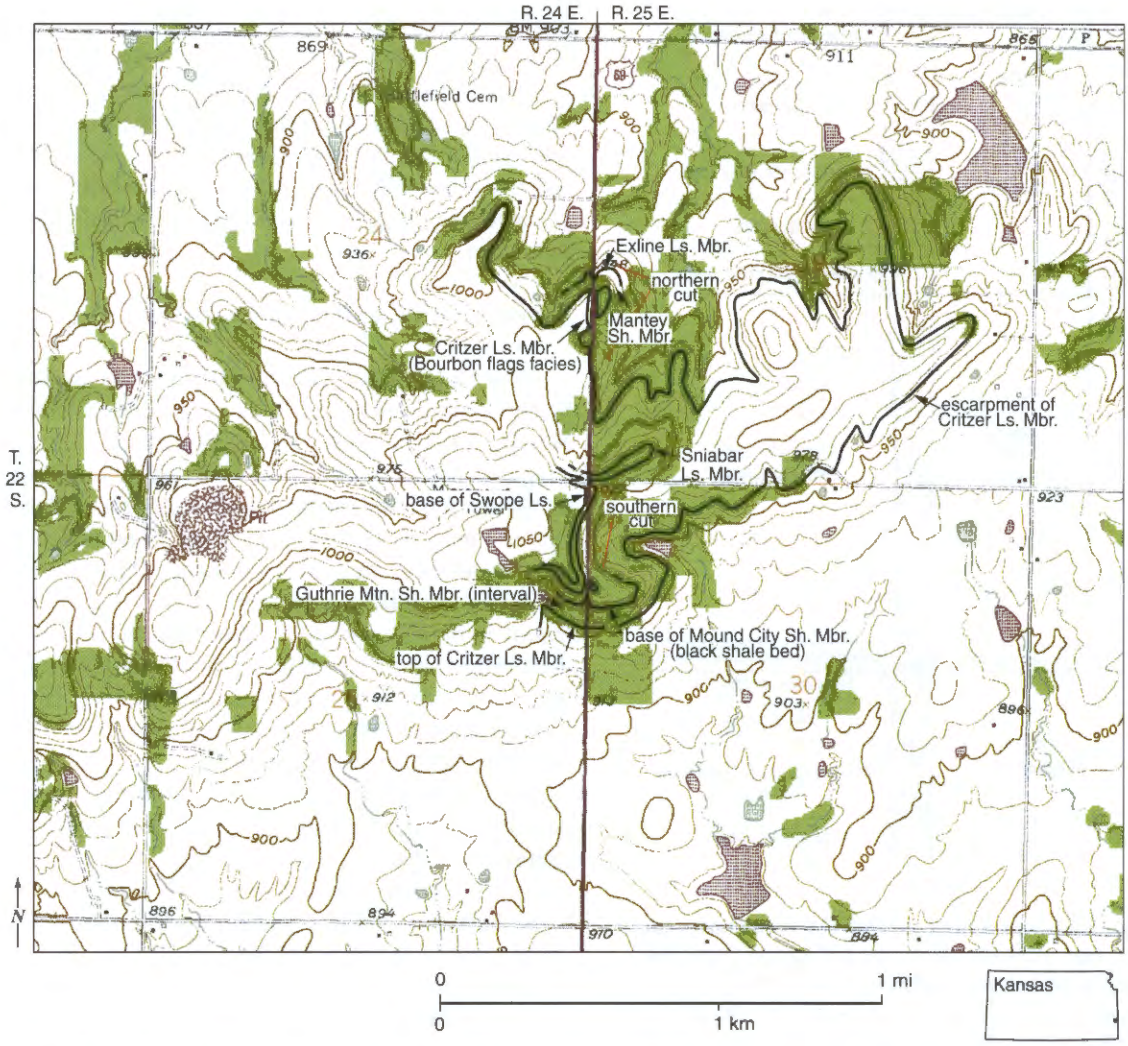


FIGURE 7— Map of part of 1958 (photorevised 1978) Prescott, Kansas, 7 1/2-minute quadrangle, showing location of principal reference section of Shale Hill Formation in Kansas, and stratotype of Mantey Shale Member in roadcuts along US–69, 4 to 5 mi (6.5–8 km) south of Pleasanton. Lower three members (including Mantey Shale Member stratotype) are exposed in northern cut (east side), although Exline Limestone Member must now be dug out because of recent vegetative cover of much of shale slope; upper member (Guthrie Mountain Shale Member) interval is measured in southern cut (west side).

Group where it is thick in southeastern Linn County and most of Bourbon County. Because it closely resembles the older, typically "Pleasanton" Mantey Shale Member of the Shale Hill Formation, it is removed from the Mound City Shale Member and the Hertha Limestone and reclassified (along with the intervening Critzer Limestone Member) with the Mantey Shale Member and thin Exline Limestone Member in the Shale Hill Formation of the Pleasanton Group. The name is derived from Guthrie Mountain, south of Mapleton in Bourbon County, where the upper part of the unit is exposed around the base of the hill. The type section is designated 1.5 miles (2.5 km) southwest of Guthrie Mountain (fig. 11) in a good complete exposure along the road running west from the center of NW sec. 8, T. 24 S., R. 23 E., where it is 60 ft (18 m) of gray, monotonous, silty,

Principal reference section of Shale Hill Formation in Kansas; stratotype of Mantey Shale Member

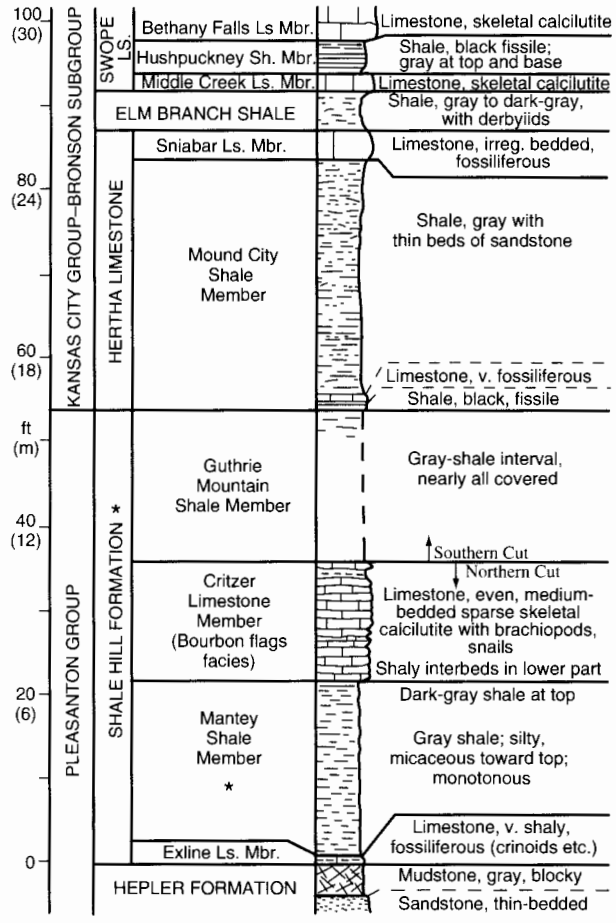


FIGURE 8—Measured section of principal reference section of Shale Hill Formation in Kansas, and stratotype of Mantey Shale Member, composited in roadcut 4 to 5 mi (6.5–8 km) south of Pleasanton, along east side of US–69 on W line of NW-NW-SW sec. 19, T. 22 S., R. 25 E. (fig. 7) for lower three members, and in roadcut along west side of US–69 (E line NE-SE-NE sec. 25, T. 22 S., R. 24 E.) for interval of upper (Guthrie Mountain Shale) member.

micaceous shale (fig. 12). The upper boundary is the contact between gray shale and the basal black phosphatic shale bed (with local limestone lenses) of the revised Mound City Shale Member, or its dark-gray equivalent where both units are thin. The lower boundary is the abrupt contact of gray shale above Critzer Limestone Member (including the Bourbon flags). The Guthrie Mountain Shale Member thins southward from its type section to only 1 or 2 ft (0.3–0.6 m) in the base of the Lower Shale member of the Tacket Formation in southern Kansas (fig. 2). It thins northward to 2 to 4 ft (0.6–1.2 m) of gray shale to mudstone, which becomes an underclay capped by the Ovid coal in Missouri. A reference section north of the type area is in the second roadcut along US–69 north of LaCygne Junction (NW-NW-SE sec. 31, T. 19 S., R 25 E.; fig. 2, sec. 8) in Linn County, where a complete section of the thin shelf facies of the gray Guthrie Mountain Shale Member, 3 ft (0.9 m) thick, is exposed beneath the black facies of the Mound City Shale Member.

Coffeyville Group (now recognized in Kansas)

The Coffeyville Formation was named by Schrader and Haworth (1905) from Coffeyville, Kansas. The name has been used mainly in Oklahoma (Oakes, 1940) to encompass the strata from the top of the Checkerboard Limestone to the base of the Hogshooter (Dennis) Limestone. It is now extended as a group into southern Kansas because of its usefulness in delineating the dominantly siliciclastic stratigraphic interval equivalent to the top of the Pleasanton Group (Shale Hill Formation) and base of the Kansas City Group (all of the Bronson Subgroup except the Dennis Limestone). The Coffeyville Group is defined here to include, in ascending order, the Tacket Formation (revised), Ladore Shale, Mound Valley Limestone (reinstated), and Galesburg Shale (figs. 1, 2). The group is restricted to an area in southern Kansas (Labette and southern Neosho counties) where the upper part of the Pleasanton Group (Shale Hill Formation) thins conspicuously and most of the overlying Bronson Subgroup of the Kansas City Group is predominantly siliciclastic. Locally thick sandstone bodies occur in the Galesburg Shale between the Mound Valley Limestone below and the Dennis (Hogshooter) Limestone above, and this part of the group is well exposed in the bluffs along the Verdigris River north of Coffeyville. The most accessible exposure for a reference section of the upper part of the group is in a shale pit at the south end of the bluffs (SW-NW sec. 26, T. 34 S, R. 16 E.). Formations above the Tacket Formation are discussed under the Bronson Subgroup of the Kansas City Group.

Tacket Formation (revised)

The Tacket Formation overlies the Hepler Formation and underlies the Ladore Shale in southernmost Kansas. It is revised to include all the dark-shale-dominated strata in southern Kansas equivalent to the stratigraphic interval extending from the top of the Checkerboard Limestone Member or the South Mound Shale Member of the Hepler Formation (Pleasanton Group) up through the Bethany Falls Limestone Member of the Swope Limestone (figs. 1, 2). The Tacket Formation was named by Jewett et al. (1965) from a type exposure about 1 mi (1.6 km) southeast of Tackett (*sic*) Mound between Parsons and Mound Valley in Labette County, to comprise the strata between the Checkerboard Limestone and the Hertha Limestone as it was then correlated, and it was regarded as the upper formation of the Pleasanton Group. Recent field work initiated as a result of biostratigraphic observations by Pavlicek (1986) has shown that the Tacket Formation as mapped in its type area encompasses strata equivalent to not only the Shale Hill Formation of the Pleasanton Group, but also to the overlying Hertha, Elm Branch, and Swope formations of the Bronson Subgroup of the Kansas City Group as well (see fig. 2). The main reason for this revision was the discovery that the Tacket Formation as defined in its type area includes two phosphatic black shale units, which are the southerly extensions of similar facies in the Mound City Shale Member of the Hertha Limestone and the Hushpuckney Shale Member of the Swope Limestone. Therefore the Tacket Formation is mostly younger than any part of the Pleasanton Group (even as revised upward herein) within which it was originally included.

Because the type exposure of the Tacket Formation designated by Jewett et al. (1965, p. 7–8) along the west side of sec. 17, T. 32 S., R. 19 E. is now very poorly exposed (and probably equivalent to only the Upper Shale member), a neostratotype is established on the northeast side of Tackett Mound, from near the NE corner of SW sec. 7, into the adjacent creek bank in SW-SW-NE sec. 7, T. 32 S., R. 19 E. (fig. 13) in Labette County, Kansas. The Tacket interval consists of about 40 ft (12 m) of dark-gray to black shale with thin limestone beds and nodule

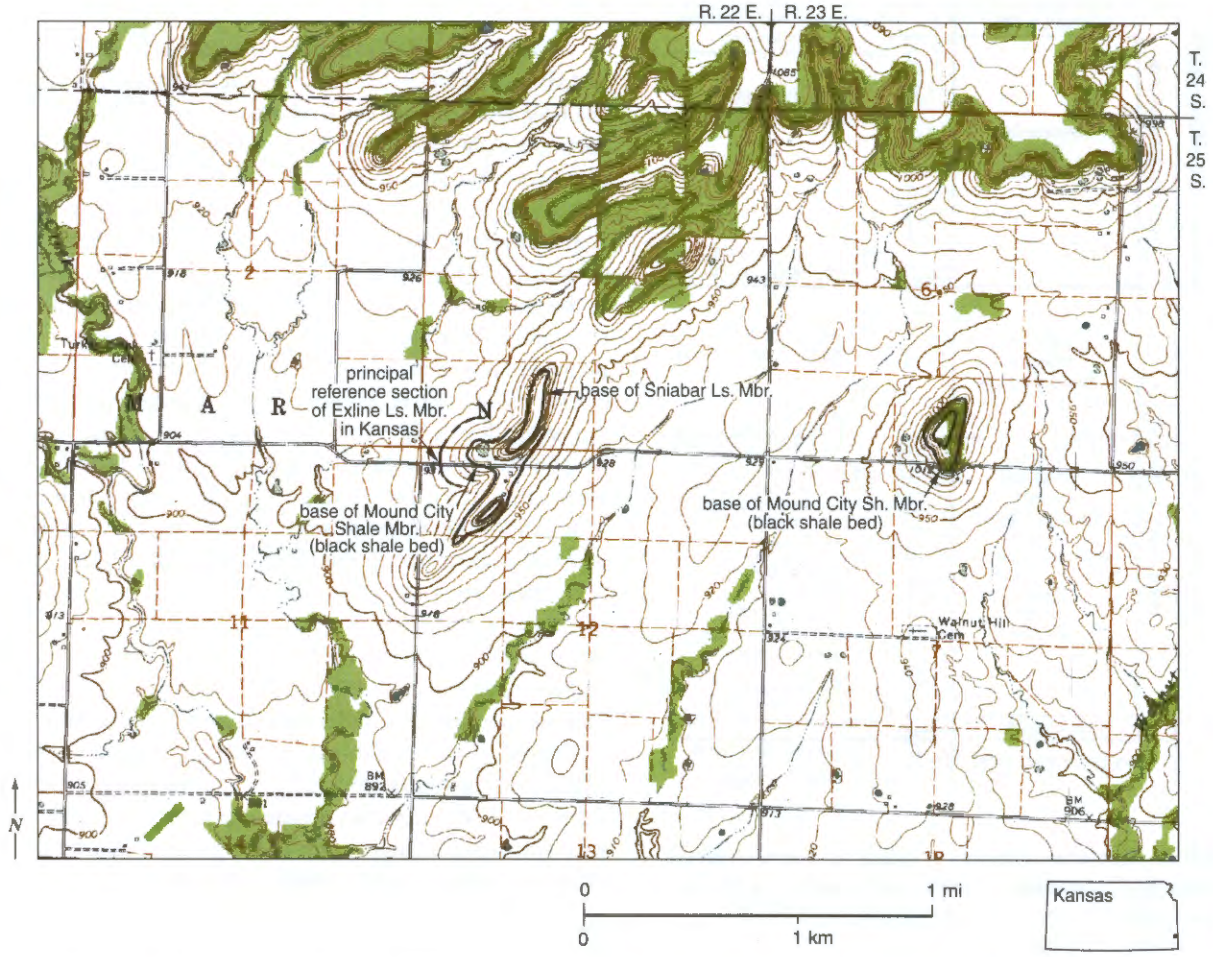


FIGURE 9—Map of part of Xenia, Kansas, 7 1/2-minute quadrangle, showing location of principal reference section of Exline Limestone Member in Kansas (discovered by A. P. Bennison), along with overlying units in north roadditch east of Turkey Creek, 3 mi (5 km) northeast of Uniontown, Bourbon County, Kansas.

horizons and includes the thin Bethany Falls Limestone Member at the top (fig. 14). The lower boundary is the contact between dark fossiliferous shale (with local argillaceous limestone lenses that resemble the Exline Limestone Member) above gray silty shale, mudstone, or sandstone at the top of the South Mound Shale Member of the Hepler Formation; southward it is the contact between similar dark shale and the purer limestone at the top of the Checkerboard Limestone Member, as is seen generally in exposures in northern Oklahoma. The upper boundary is the abrupt contact between the Bethany Falls Limestone Member and gray overlying Ladore Shale. Northward from central Neosho County, the Tacket interval thickens as the various units to which it is equivalent (Shale Hill Formation, Hertha Limestone, Elm Branch Shale, Swope Limestone) become better differentiated and thicken (fig. 2) and are more readily classified as members and formations in the Pleasanton and Kansas City Groups. Southward the Tacket Formation can be traced at the base of the Coffeyville interval to the area south of Tulsa, Oklahoma.

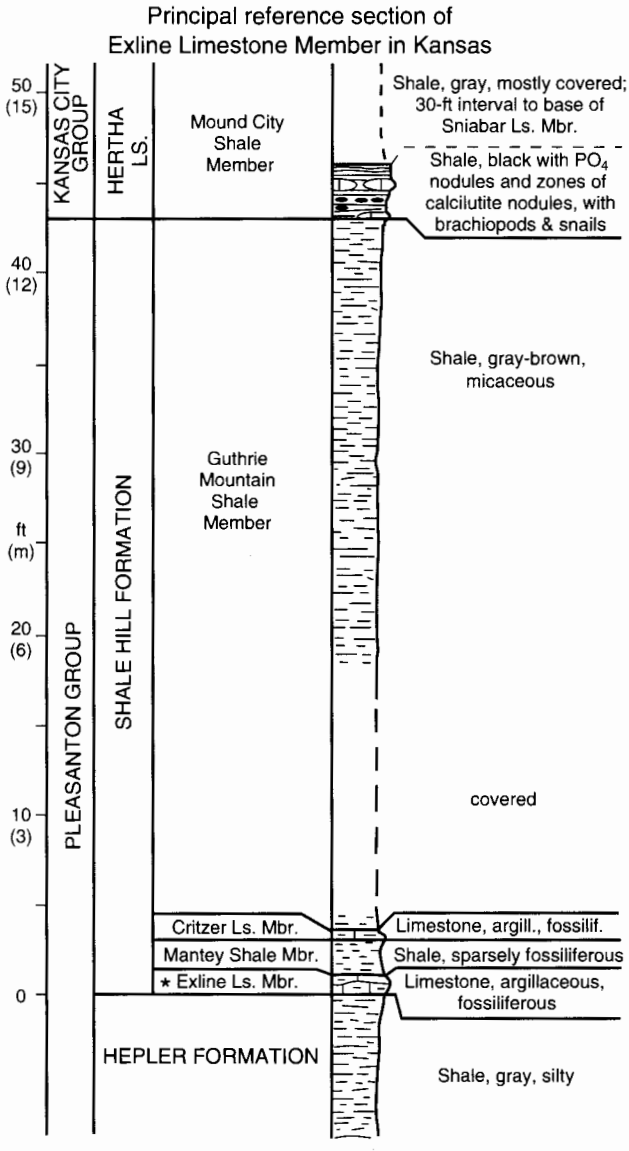


FIGURE 10—Measured section of principal reference section of Exline Limestone Member in Kansas and overlying units in road ditch east of Turkey Creek, along center of N half of NW-NW sec. 12, T. 25 S., R. 22 E. (fig. 9), 3 mi (5 km) northeast of Uniontown, Bourbon County, Kansas.

As revised, the Tacket Formation comprises three informal members and one formal member, in ascending order: Lower Shale member, Middle Limestone member, Upper Shale member, and Bethany Falls Limestone Member (fig. 1). The type sections of all three informal members are at the type section for the entire formation at Tackett Mound (fig. 14). The **Lower Shale member** is 9 ft (2.7 m) of dark-gray shale at the type section with a zone of large limestone nodules overlain by black phosphatic shale in the middle, which is the lateral equivalent of the black shale bed at the base of the Mound City Shale Member of the Hertha Limestone northward. Local lenses of skeletal limestone at the base seem to represent the Exline Member of the Shale Hill Formation, and the 3 ft (0.9 m) of dark-gray shale above this represent the southern featheredge of the upper three members of the Shale Hill Formation. The **Middle Limestone member** is 1 ft (0.3 m) of dark-gray, hard, argillaceous fossiliferous calcilutite at the type section, which is largely equivalent to the Sniabar Limestone Member of the Hertha Limestone. This member can be traced throughout the entire extent of the Tacket Formation, averaging about 0.5 ft (15 cm) in thickness and separating the two shale members with abrupt lithic boundaries. The **Upper Shale member** is 27 ft (8 m) of dark-gray shale at the type section, with several zones of essentially unfossiliferous limestone nodules and beds, and, in the middle of the lower half, a bed of black phosphatic shale, which is the lateral equivalent of the same facies of the Hushpuckney Shale Member of the Swope Limestone. This member is the most commonly exposed part of the Tacket Formation in southern Kansas, and is easily accessible along the road south of Wilsonton Cemetery (along E line SE sec. 17, T. 32 S., R. 19 E.) just to the east (fig. 13). The **Bethany Falls Limestone Member** (see later section), extending southward from eastern Kansas, is 4 ft (1.2 m) of pale-orange-weathering fossiliferous limestone at the Tacket type section. It is classified as the upper member of the Tacket Formation south of the disappearance of the Middle Creek Limestone Member in central Neosho County where the Swope Limestone (which contains these two members northward) becomes undefined at the base. Thus, the Tacket Formation is the exact equivalent of the interval from the base of the Shale Hill Formation through the top of the Swope Limestone of northeastern Kansas.

Kansas City Group (lower boundary revised)

The Kansas City Group overlies the Pleasanton Group and underlies the Lansing Group. It comprises the Bronson, Linn, and Zarah Subgroups in ascending order. The boundary between the Linn and Zarah Subgroups is moved from the top to the base of the Iola Limestone (fig. 1). The base of the Kansas City Group (and the Bronson Subgroup) is moved from the base of the Critzer Limestone (now part of the Pleasanton Group) up to the base of the Mound City Shale as revised to coincide with the base of its widespread black phosphatic shale facies.

BRONSON SUBGROUP (lower boundary revised)

The Bronson Subgroup of the Kansas City Group consists of the following formations in northeastern and eastern Kansas, in ascending order: Hertha Limestone (as revised by removal of the Critzer Limestone Member and the lower part of the Mound City Shale Member below the black phosphatic shale facies), Elm Branch Shale (new), Swope Limestone, Galesburg Shale, and Dennis Limestone. In southern Kansas, the Ladore Shale and Mound Valley Limestone (reinstated) occur between the Swope Limestone and the Galesburg Shale (figs. 1, 2), but as the shale units thicken southward, usage of the Coffeyville Group for strata below the Dennis Limestone becomes more practical.

Hertha Limestone (revised, restricted)

The Hertha Limestone overlies the Shale Hill Formation of the Pleasanton Group and underlies the Elm Branch Shale (fig. 1). Originally named by Adams (1903) from exposures around the former town of Hertha situated at center south line, sec. 29, T. 29 S., R. 20 E., in Neosho County, the type locality of the Hertha Limestone as stabilized by Moore (1936) was incorrectly correlated (fig. 2). The conspicuous limestone at this locality is actually the Bethany Falls Limestone Member of the younger Swope Limestone. The Sniabar Limestone and the underlying black Mound City Shale, both currently recognized as the constituents of the Hertha Limestone north of central Neosho County and in states to the north, were discovered by A. P. Bennison along a western

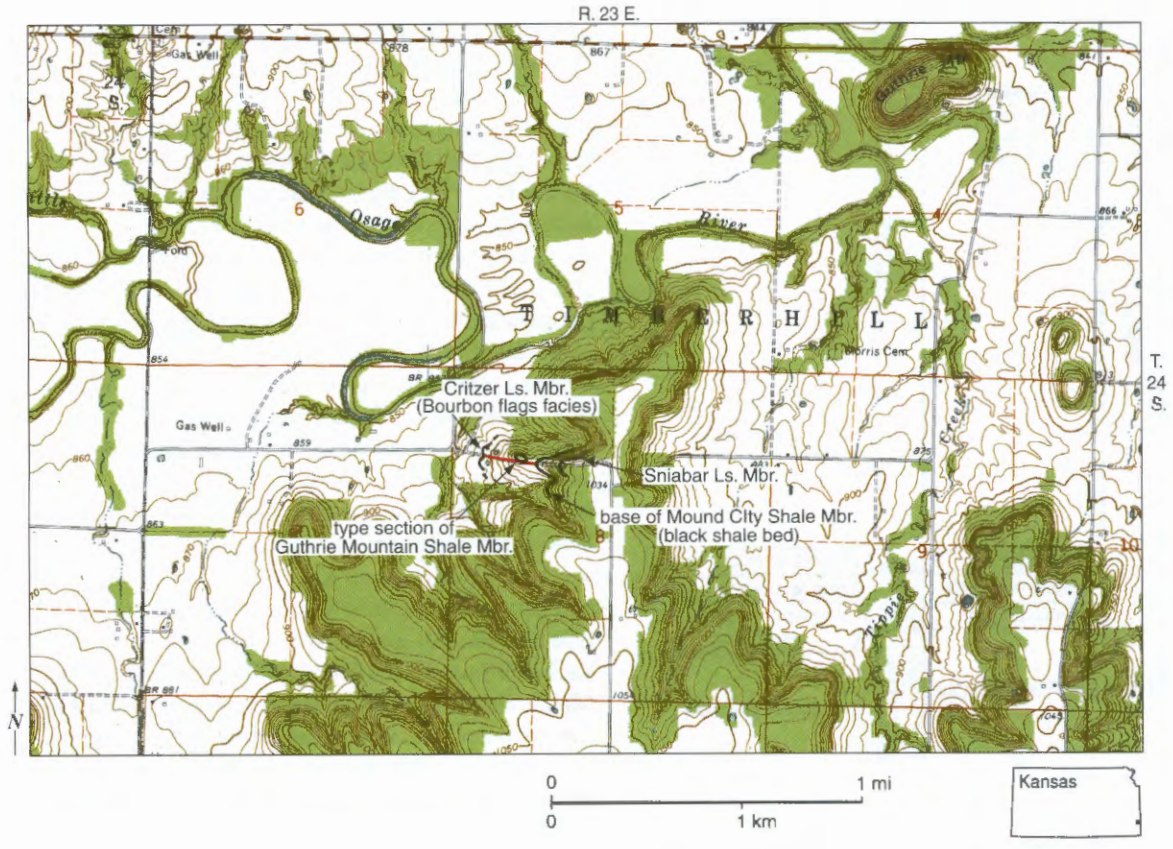


FIGURE 11—Map of part of 1966 Xenia, Kansas, 7 1/2-minute quadrangle, showing location of type section of Guthrie Mountain Shale Member of Shale Hill Formation in roadcut southwest of Guthrie Mountain. Base is marked by Critzer Limestone Member (Bourbon flags facies) in road ditch by abandoned house, and top is marked by black phosphatic shale bed at base of Mound City Shale Member of Hertha Limestone, which also caps small knob north of road.

tributary to Bachelor Creek just to the southeast (fig. 15) in SE-NW-NE sec. 32, T. 29 S., R. 20 E. This nearby exposure provides a new principal reference section or neostratotype (fig. 16; fig. 2, sec. 25) for the Hertha Limestone and maintains the stability of nomenclature at the base of the Bronson Subgroup and Kansas City Group, which is preferable to renaming the Hertha Limestone northward. The Hertha Limestone also is revised to include only the Sniabar Limestone Member and Mound City Shale Member (with its lower boundary revised upward to the base of its widespread black phosphatic shale facies). The former base of the Mound City Shale Member (now Guthrie Mountain Shale Member) and the former basal Critzer Limestone Member of the Hertha are reclassified as members of the underlying Shale Hill Formation in the Pleasanton Group, based on greater similarity of lithic content with

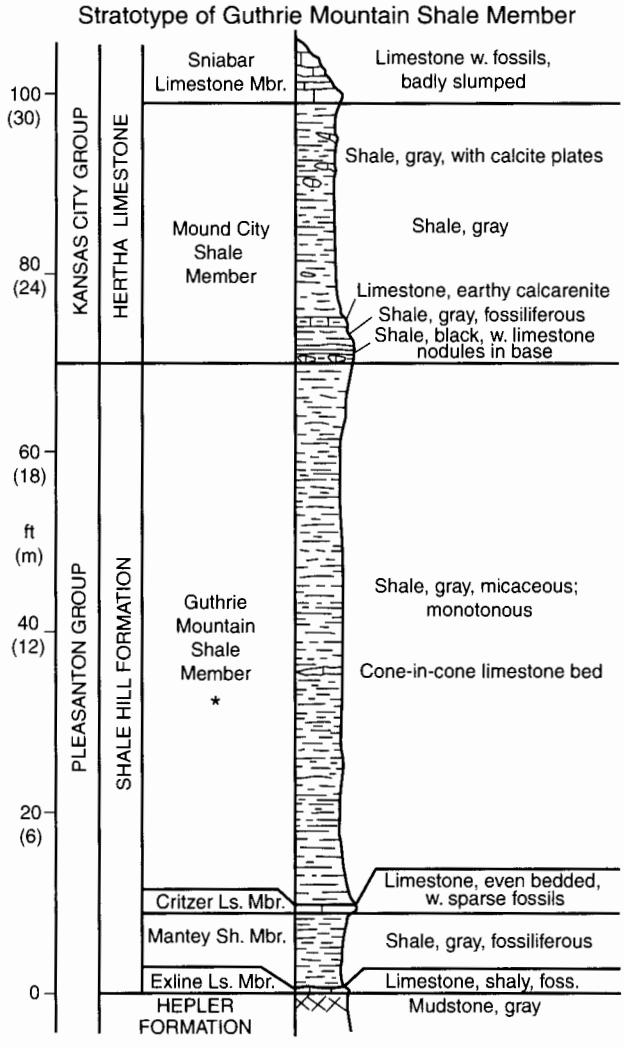


FIGURE 12—Measured section of Guthrie Mountain Shale Member stratotype in roadcut 1.5 mi (2.5 km) southwest of Guthrie Mountain and 0.3 mi (0.5 km) southeast of new bridge over Little Osage River along north line of south half of NW sec. 8, T. 24 S., R. 23 E. (fig. 11), south of Mapleton, Bourbon County, Kansas.

that group as discussed previously. Good reference sections of the Hertha Limestone include the K–3 roadcut 1 mile (1.6 km) south of Uniontown (fig. 2, sec. 17; Heckel et al., 1999, p. 32, Stop B1) in Bourbon County, where both members are thick, totaling about 60 ft (18 m), and the second US–69 roadcut north of LaCygne Junction (NW-NW-SE sec. 31, T. 19 S., R. 25 E.; fig. 2, sec. 8) in Linn County where both members are thin, totaling about 7 ft (2.1 m).

Mound City Shale Member (lower boundary revised)

The Mound City Shale Member of the Hertha Limestone overlies the Guthrie Mountain Shale Member of the Shale Hill Formation (Pleasanton Group) and underlies the Sniabar Limestone Member (figs. 1, 2). It was named by Jewett (1932) from Mound City in Linn County as the thin shale between the Critzer and Sniabar Limestone Members in that area. The Guthrie Mountain Shale Member is now removed from the lower part of the original Mound City Shale Member because of its immense southward thickening and closer resemblance to typical Pleasanton shale (see previous sections). The lower boundary of the Mound City Shale Member is revised to be the contact of the base of the distinctive black to dark-gray phosphatic shale bed (and included underlying thin lenticular limestones) above gray, essentially unfossiliferous Guthrie Mountain shale facies (or mudstone northward). This black shale bed is a regional marker unit that is traceable across eastern Kansas from Iowa to Oklahoma.

The Mound City Shale Member now comprises three lithic units, in ascending order: 1) thin 0.3–2-ft (0.1–0.6-m) widespread black phosphatic shale bed, which becomes lighter in color (dark-gray to green-gray) across some of the area where the entire member is thinnest above thin Guthrie Mountain Shale Member, typical Critzer Limestone Member, and thick Mantey Shale Member (from central to southwestern Linn County into northwesternmost Bourbon County). This is overlain by 2) a thin 0.3-ft (0.1-m) crinoidal limestone across most of Linn County, which thickens slightly and becomes argillaceous and separated by gray shale from the black shale southward in most of Bourbon County. This is overlain by 3) gray shale, which is thin (2 ft / 0.6 m) where the entire unit is thinnest from northeast to southwest across central Linn County, but thickens both southeastward to 28 ft (8.4 m) where it becomes sandy in southeastern Linn County (fig. 8; fig. 2, sec. 11) and southward to similar thicknesses in central to western Bourbon County (e. g., the Uniontown roadcut: fig. 2, sec. 17), where it contains local flaggy and nodular limestone beds but no sandstone (Heckel et al., 1999, p. 32, Stop B1); it then thins southward in Neosho County (fig. 2).

Exposures of the Mound City Shale Member around Mound City are currently badly slumped, obscuring the internal subdivision and precluding designation of a stratotype in that region. Good reference sections of the

Mound City Shale Member where it is thin include the second US–69 roadcut north of LaCygne Junction (NW-NW-SE sec. 31, T.19 S., R.25 E.) in Linn County (fig. 2, sec. 8) and a roadcut northwest of Xenia in northwestern Bourbon County, Kansas (SW-SE-SE sec. 20, T. 23 S., R. 22 E.). Good reference sections where it is thick include the second US–69 roadcut 5 mi (8 km) south of Pleasanton (center of west line of NW sec. 30, T. 22 S., R. 25 E.) part of the principal reference section for the Shale Hill Formation (fig. 8; fig. 2, sec. 11), and the K–3 roadcut 1 mi (1.6 km) south of Uniontown (NE-SE-NW sec. 34, T. 25 S., R. 22 E.), where it is 40 ft (12 m) thick (fig. 2, sec. 17; Heckel et al., 1999, p. 32, Stop B1). Stratal content of the Mound City also is shown in figs. 4, 6, 10, 12, and 16. The basal black shale bed of the Mound City Shale Member is laterally continuous with the black shale in the Lower Shale member of the Tacket Formation in southern Kansas (figs. 2, 14).

Sniabar Limestone Member (unchanged)

The Sniabar Limestone Member overlies the Mound City Shale Member and underlies the Elm Branch Shale (fig. 1). It was named by Jewett (1932) from Sni-A-Bar Creek in Jackson County, Missouri. In Kansas, it is commonly a massive ledge of skeletal calcilutite ranging in thickness from 2 to 20 ft (0.6–6 m). Well-exposed reference sections include the second US–69 roadcut north of LaCygne Junction (fig. 2, sec. 8) where it is 4 ft (1.2 m) thick, the top of the second US–69 roadcut south of Pleasanton (SW corner of sec. 19, T. 22 S., R 25 E.; fig. 2, sec. 11) where it is conspicuously fossiliferous,

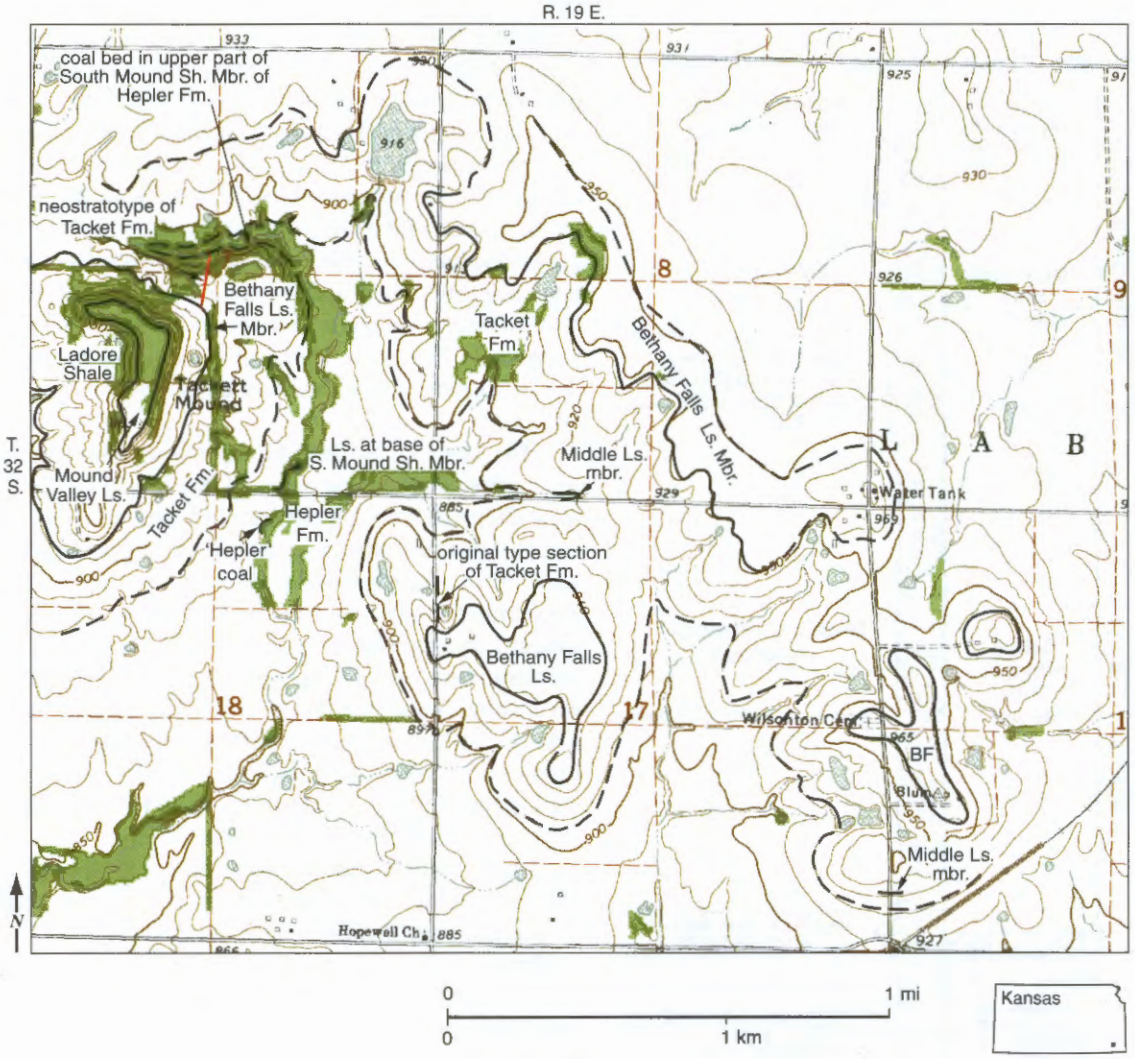


FIGURE 13—Map of part of 1973 Parsons West, Kansas, 7 1/2-minute quadrangle, showing location of neostratotype of Tacket Formation in gully down northeast side of Tackett (*sic*) Mound and in adjacent creek bank, discovered by A. P. Bennison. This section is located on the property of Bill Chapman, who lives just to the northeast and should be contacted for permission before visiting the exposure. This replaces original type section of Jewett et al. (1965) along west side of sec. 17 just to the southeast, which is very poorly exposed today and which may have included only the upper part of the unit as now recognized, based on comparison of the original description with the better exposure at Tackett Mound.

and the Uniontown roadcut (fig. 2, sec. 17; Heckel et al., 1999, p. 32, Stop B1) where it is about 20 ft (6 m) of algal mound facies. From there it thins southward to several feet of cherty skeletal calcilutite exposed at NE corner of sec. 17, T. 27 S., R 22 E. (fig. 2, sec. 19) in southwestern Bourbon County, in the streambank east of Kimball (SW-SW-NE-NW sec. 27, T. 27 S., R. 21 E.; fig. 2, sec. 21), and in the roadbed 1.3 mi (2 km) to the west (NW corner sec. 33, T. 27 S., R 21 E.), in northeastern Neosho County. It is about 1 ft (0.3 m) of argillaceous skeletal calcilutite at the Hertha neostratotype (fig. 16; fig. 2, sec. 25).

Elm Branch Shale (new name)

The Elm Branch Shale overlies the Hertha Limestone (Sniabar Limestone Member) and underlies the Swope Limestone (Middle Creek Limestone Member).

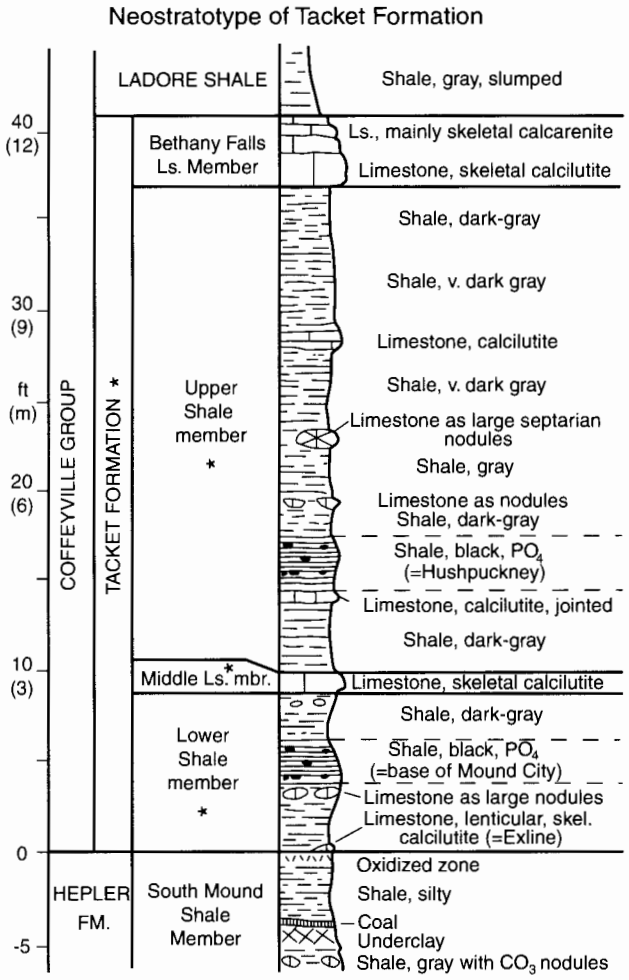


FIGURE 14—Measured section of Tacket Formation neostratotype in gully down northeast side of Tackett (*sic*) Mound near NE corner of SW sec. 7 and into SW-SW-NE sec. 7, T. 32 S., R. 19 E. (fig. 13), Labette County, Kansas, based on section measured by Pavlicek (1986). Informal member names were first used by Bennison (1984).

The name Elm Branch is proposed (informally reinstated) for the unit previously called Ladore Shale in east-central and northeastern Kansas (fig. 1). Replacement of the name Ladore from Bourbon County northward is required now that the northward miscorrelations of the type sections of the Hertha Limestone, Ladore Shale, and Mound Valley Limestone in Neosho and Labette counties have been corrected (fig. 2, dashed lines marked with X). The name Elm Branch Shale was originally planned to be proposed by N. D. Newell (as mentioned by Jewett, 1932) for this unit, but was never formally adopted, apparently because it was correlated southward (incorrectly) with the type Ladore Shale of southern Neosho County when the Bethany Falls Limestone was incorrectly correlated southward with the type Mound Valley Limestone. Now that the Bethany Falls Limestone Member of the Swope Limestone has been traced southward below the type Ladore Shale (fig. 2), the shale unit below the Swope and above the Hertha Limestone in east-central Kansas and northward requires a new name. The name Elm Branch initially considered by Newell is appropriate because it has never been used for any other unit. The measured section reported by Newell (1935, p. 26, 144–145) for this unit near Elm Branch, a creek that empties into the Marais des Cygnes River 4 mi (7 km) north of Fontana, is now covered, and a nearby section is only partly exposed. Therefore, a roadcut mentioned by Newell (1935, p. 26) 1 mi (1.6 km) southwest of Fontana in Miami County (fig. 17) is selected as the stratotype (E line SE-SE-NW sec. 10, T. 19 S., R. 23 E.).

The type Elm Branch Shale comprises 9 ft (2.7 m) of gray shale to mudstone with 0.5 ft (15 cm) of light-gray, barren earthy limestone above the middle (fig. 18). The lower 6 ft (1.8 m) is unfossiliferous gray mudstone with small irregular limestone nodules, and the upper 2.5 ft (0.75 m) is fossiliferous gray shale with brachiopods (particularly derbyiids), bryozoans, crinoid debris, and ostracodes. The intervening earthy limestone is only locally present, but the vertical succession of unfossiliferous mudstone overlain by fossiliferous shale is characteristic of good exposures of the Elm Branch Shale throughout eastern Kansas (see Heckel et al., 1999, p. 18, Stop A2). Both lower and upper boundaries of the Elm Branch Shale are abrupt contacts of mudstone or shale with fossiliferous limestones of the underlying and overlying limestone members of the adjacent formations. Southward, thin sparsely fossiliferous limestones appear in the upper shale unit of the Elm Branch, and one collected from the K–52 roadcut 3 mi (5 km) southwest of Mound City (near center SW sec. 23, T. 22 S., R. 23 E.) in Linn County yielded a clump of linoproductid brachiopods with a remarkable fauna of small crinoids described by Strimple and Heckel (1978). Farther southward, thin limestones in the upper Elm Branch are dominated by phylloid algae, as seen at the K–3 roadcut south of Uniontown (where they were classified with the

overlying Middle Creek Limestone Member by Heckel et al., 1999, p. 32). The entire Elm Branch Shale ranges from 1 to 12 ft (0.3–3.6 m) thick in east-central Kansas and northward, but southward from the Uniontown roadcut, it thickens to 40 ft (12 m) with local sandstone (along the road at center of W line SW sec. 6, T. 28 S., R. 21 E.) near Page's pasture south of Kimball in northeastern Neosho County (fig. 2, sec. 22) before merging into the thin dark-gray shale in the base of the Upper Shale member of the Tacket Formation.

Swope Limestone (unchanged)

The Swope Limestone overlies the Elm Branch Shale. It underlies the Galesburg Shale in northeastern to east-central Kansas and underlies the Ladore Shale in southeastern Kansas (figs. 1, 2). The term Swope Limestone from Swope Park in Kansas City, Missouri, was first used by Moore (1932) and defined by Newell (1935). The Swope comprises three members, in ascending order: Middle Creek Limestone, Hushpuckney Shale, and Bethany Falls Limestone. The principal reference section for the Swope Limestone in Kansas is the roadcut 2 mi (3 km) northwest of Xenia (center S line SE sec. 20, T. 23 S., R. 22 E.) in northwestern Bourbon County (fig. 2, sec. 12), where all three members are well exposed.

Middle Creek Limestone Member (unchanged)

The Middle Creek Limestone Member overlies the gray Elm Branch Shale and underlies the black Hushpuckney Shale Member. It was named by Jewett (1932) and defined by Newell (1935, p. 26, 148) from exposures east of Middle Creek with a type section on the highway 3 mi (5 km) east of LaCygne (W of SE corner sec. 36, T. 19 S., R. 24 E.) in Linn County, Kansas. It is a dense skeletal calcilutite about 2 ft (0.6 m) thick in eastern Kansas, and it thickens southward to 4 or 5 ft (1.2–1.5 m) in western Bourbon County before it pinches out in Neosho County (fig. 2).

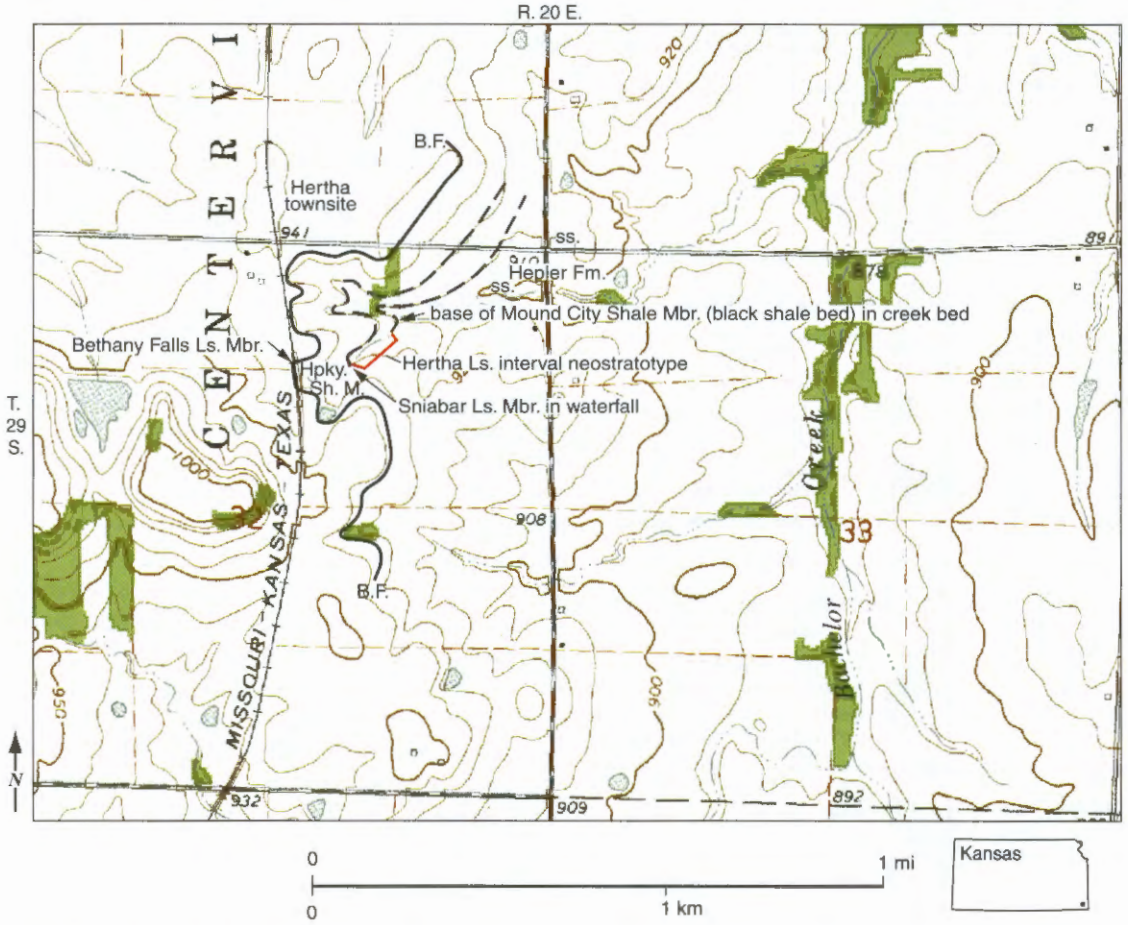


FIGURE 15—Map of part of 1973 South Mound, Kansas, 7 1/2-minute quadrangle, showing location of old and new type sections of Hertha Limestone near Hertha townsite, where the most conspicuous limestone is now known to be the Bethany Falls Limestone Member in its characteristic position above the black Hushpuckney Shale Member (Hpky). Interval of the unit long considered to be Hertha Limestone elsewhere in Kansas and Missouri was discovered by A. P. Bennison downsection in creek bed to east and now serves as the neostratotype of the Hertha Limestone interval, in order to minimize nomenclatural change along the Midcontinent outcrop belt. ss = sandstone in Hepler Formation.

Hushpuckney Shale Member (unchanged)

The Hushpuckney Shale Member overlies the Middle Creek Limestone Member and underlies the Bethany Falls Limestone Member. The name was introduced by Jewett (1932) and defined by Newell (1935, p. 27) from Hushpuckney Creek in south-central Miami County (fig. 17). The principal reference section is selected several miles southward in the roadcut along the west line SW-NE sec. 27, T. 19 S., R. 23 E., and the shale also is exposed high in the roadcut 1.5 mi (2.4 km) farther southward along center east line SW sec. 34, T. 19 S., R. 23 E., 5 mi (8 km) west of La Cygne. Another good section is on US–169 south of Pleasanton (fig. 8, fig. 2, sec. 11) at the road intersection (NE corner sec. 25, T. 22 S., R. 24 E.). The Hushpuckney Shale Member ranges throughout Kansas from 1.5 to 5 ft (0.5–1.5 m) of dominantly black phosphatic shale with overlying gray shale, which are continuous southward with the black and thicker gray shale beds in the Upper Shale member of the Tacket Formation in southern Kansas (figs. 2, 14).

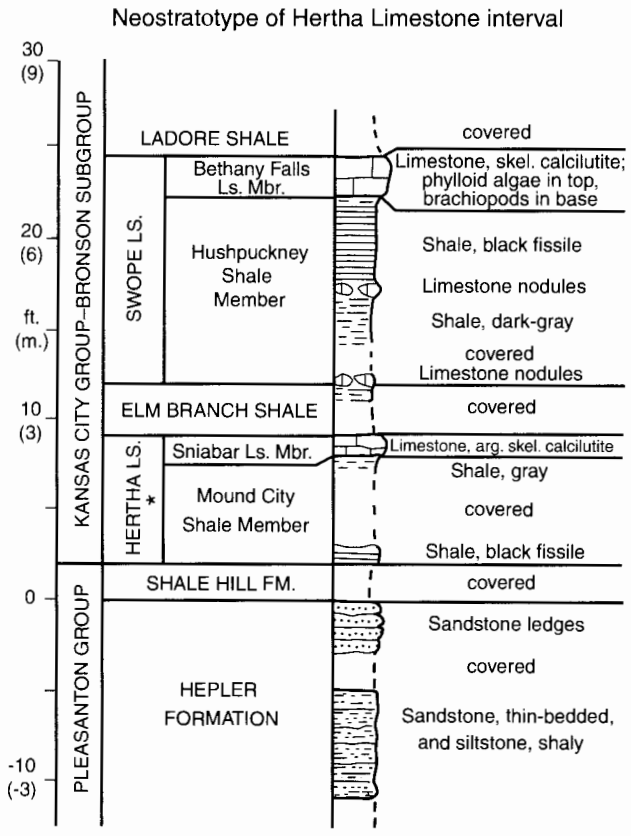


FIGURE 16—Measured section of Hertha Limestone interval neostratotype and associated units in bed of western tributary of Bachelor Creek in NE sec. 32, T. 29 S., R 20 E. (fig. 15), 4 mi (7 km) north of South Mound, Neosho County, Kansas. Sniabar Limestone Member forms small waterfall in creek bed. Hertha Limestone in this section also could be classified as Middle Limestone and part of Lower Shale members of Tacket Formation (see fig. 14).

Bethany Falls Limestone Member (unchanged, but recorrelated southward)

The Bethany Falls Limestone Member overlies the Hushpuckney Shale Member and underlies the Galesburg Shale in northern Kansas and the Ladore Shale in southern Kansas. The Bethany Falls Limestone was named by Broadhead (1868) from exposures at the falls in Big Creek near Bethany in northwestern Missouri. The principal reference section in Kansas is in the roadcut 2 mi (3 km) northwest of Xenia (center S line SE sec. 20, T. 23 S., R. 22 E.) in northwestern Bourbon County (fig. 2, sec. 12). The Bethany Falls Limestone Member averages 15 to 35 ft (4.5–10.6 m) thick from central Kansas northward and comprises a lower, typically conspicuously mottled, skeletal calcilutite facies commonly overlain by various thicknesses of typically oomoldic oolite facies at the top. This oolite is 16 ft (5 m) thick in the quarry west of Schubert Creek (NW-NE sec. 24, T. 25 S., R. 21 E.; fig. 2, sec. 15). The Bethany Falls Limestone Member thins southwestward in northeastern Neosho County through about 8 ft (2.4 m) of mottled calcilutite in a roadbed (S line at SE corner of sec. 20, T. 27 S., R. 21 E) about 1 mi (1.6 km) southeast of Stark. From there, it is traced through exposures along N line NW-NE-NW sec. 32 (fig. 2, sec. 21) and E half SW-NW sec. 32 and center of E line SE sec. 31, into the Page's pasture section (fig. 2, sec. 22) in center of N half of NW sec. 6, T. 28 S., R. 21 E. There it lies 25 ft (7.5 m) below the Mound Valley Limestone, with which it had been erroneously correlated for many years. Farther southward, the Bethany Falls becomes about 4 ft (1.2 m) of pale-orange-weathering skeletal calcilutite in the Hertha Limestone type area in southeastern Neosho County and Labette County, where it becomes the upper member of the Tacket Formation (figs. 1, 2, 14).

Ladore Shale (restricted because of recorrelation)

The Ladore Shale overlies the Swope Limestone (Bethany Falls Limestone Member) and underlies the Mound Valley Limestone (reinstated, see below) in southern Kansas. It was named by Adams (1896) from the former town of Ladore in sec. 27, T. 30 S., R. 19 E. in southern Neosho County. Because the original type locality indicated by Moore (1936) is only an interval between the bounding limestones, the principal reference section is designated at the exposure of the upper two-thirds of the unit in the spillway of Lake Parsons (NW-NW-NE sec. 33, T. 30 S., R. 19 E.; fig. 2, sec. 27), about 1 mi (1.6 km) southwest of the type locality. Early miscorrelation of the underlying and overlying limestones with the Hertha and Bethany Falls Limestones, respectively, in northeastern Kansas caused the Ladore to have long been mistakenly correlated northward with the older shale unit now termed Elm Branch Shale (fig. 2). The Ladore Shale consists of up to about 60 ft (18 m) of gray shale with thin sandstone

beds, occasional marine fossiliferous zones, common plant debris and thin local coal beds throughout its type area in southern Kansas, including a nearly complete exposure on the western slope of Tackett Mound (S half of NW-SW sec. 7, T. 32 S., R. 19 E.; fig. 2, sec. 29) in west-central Labette County. It thins northward to about 25 ft (7.5 m) at the Page's pasture locality in northeastern Neosho County (fig. 2, sec. 22), and eventually pinches out as the Bethany Falls and Mound Valley Limestones converge in western Bourbon County as seen at the quarry west of Schubert Creek (fig. 2, sec. 15).

Mound Valley Limestone (reinstated)

The name Mound Valley Limestone is reinstated for the limestone that overlies the Ladore Shale and underlies the Galesburg Shale in southern Kansas (figs. 1, 2). Adams (1896) first applied the name Mound Valley to the limestone capping the hills northwest of Mound Valley in Labette County. It was later discarded by Moore (1936, p. 86), who believed that limestone to be equivalent to the Bethany Falls Limestone Member. Careful tracing of beds in northeastern Neosho County, supplemented by subsurface data, shows that the Mound Valley Limestone is a separate unit occurring in southern Kansas well above the Bethany Falls Limestone Member (fig. 2), a relationship suggested early by Haworth and Bennett (1908). The stratotype is designated in an exposure at the top of Dixon Mound (fig. 19A) along the road near center of the south line of SE sec. 27, T. 32 S., R. 18 E., about 1 mi (1.6 km) northwest of Mound Valley. Here it consists of 6 ft (1.8 m) of medium-bedded skeletal calcilutite, but without the top exposed (fig. 20A; fig. 2, sec. 30). The principal reference section of the Mound Valley Limestone is chosen 26 mi (42 km) northward along US–59, 2 mi (3 km) north of Erie (W line NW-NW sec. 20, T. 28 S., R 20 E) (fig. 19B) in Neosho County where both lower and upper contacts of the limestone with adjacent shales are exposed (fig. 20B; fig. 2, sec. 23). Here it is 8 ft (2.4 m) of mainly skeletal calcilutite, with brachiopods conspicuous in the base, phylloid algae in the middle, and a mottled zone at the top, which undoubtedly had given credence to its previous miscorrelation with the Bethany Falls Limestone Member. Between these two reference localities, the Mound Valley Limestone reaches 30 ft (9 m) of dominantly phylloid algal mound facies above the type Ladore Shale in the roadcut (SW-NW-NE sec. 33, T. 30 S., R. 19 E.; fig. 2, sec. 27) south of the Lake Parsons spillway.

The Mound Valley Limestone thins northeastward from Erie to a few feet of skeletal calcilutite with local phylloid algal facies and generally well-preserved oolite, which can be traced through NE-NW-NW sec. 6, T. 28 S., R. 21 E. in Page's pasture (fig. 2, sec. 22), 1 mi (1.6 km) south of Kimball and an exposure on the south side of the road nearly 1 mi (1.6 km) east of Kimball (north line of NE-NW-NE-NE sec. 31, T. 27 S., R. 21 E.; fig 2, sec. 21) above the thinning Ladore Shale and thickening Bethany Falls Limestone Member in northeastern Neosho County. Locally the Mound Valley oolite rests upon the often oolitic (but consistently oomoldic) top of the Bethany Falls Limestone Member where the Ladore Shale has pinched out, as in the Schubert Creek quarry in western Bourbon County (fig. 2, sec. 15). The Mound Valley Limestone thins southwestward from Mound Valley to about 3 ft (0.9 m) on the west side of US–169 north of the railroad crossing (N half of SE sec. 7, T. 33 S., R. 17 E.) northeast of Liberty in Montgomery County. It is 3 ft (0.9 m) of shaly limestone in northernmost Oklahoma, as shown in the South Coffeyville core (fig. 2, sec. 33).

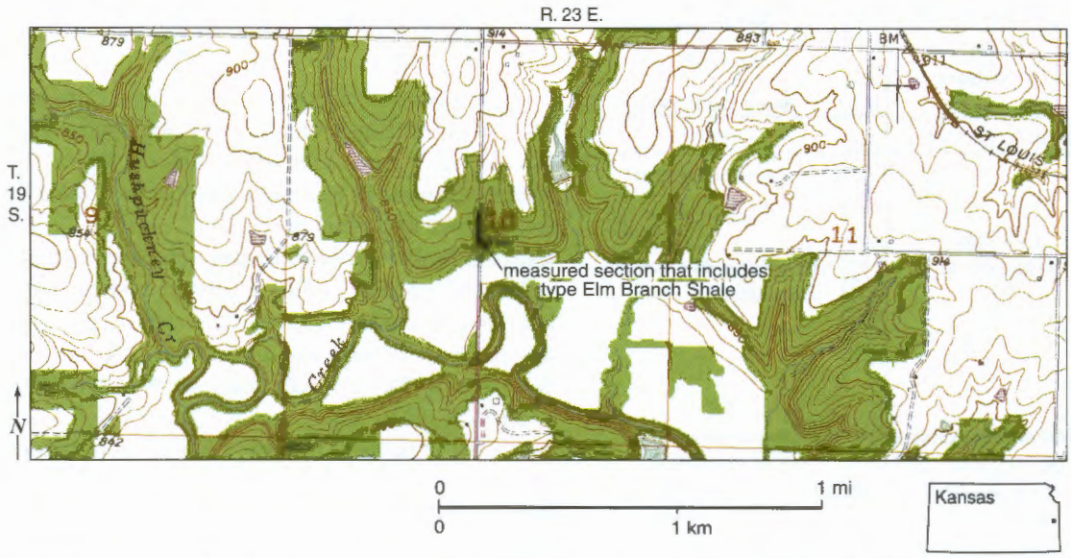


FIGURE 17—Map of part of 1958 (photorevised 1978) Fontana, Kansas, 7 1/2-minute quadrangle showing location of stratotype of Elm Branch Shale in roadcut 5 mi (8 km) south-southwest of mouth of Elm Branch into Marais des Cygnes River and 1 mi (1.6 km) southwest of Fontana, Miami County, Kansas.

Galesburg Shale (unchanged)

The Galesburg Shale overlies the Mound Valley Limestone in southern Kansas and the Bethany Falls Limestone Member from central Bourbon County northward (figs. 1, 2); it underlies the Dennis Limestone everywhere. It was named by Adams (1903) from Galesburg in Neosho County, where it forms the slope south of town (Moore, 1936). The principal reference section is designated about 18 mi (30 km) to the northeast in the bank of Canville Creek, south of the US–59 bridge (NE corner sec. 22, T. 27 S., R. 20 E.; fig. 2, sec. 20). Here it is 16 ft (4.8 m) thick consisting of sandy shale with sandstone and two thin coal beds (Heckel et al., 1979, p. 26), and it rests upon the Mound Valley

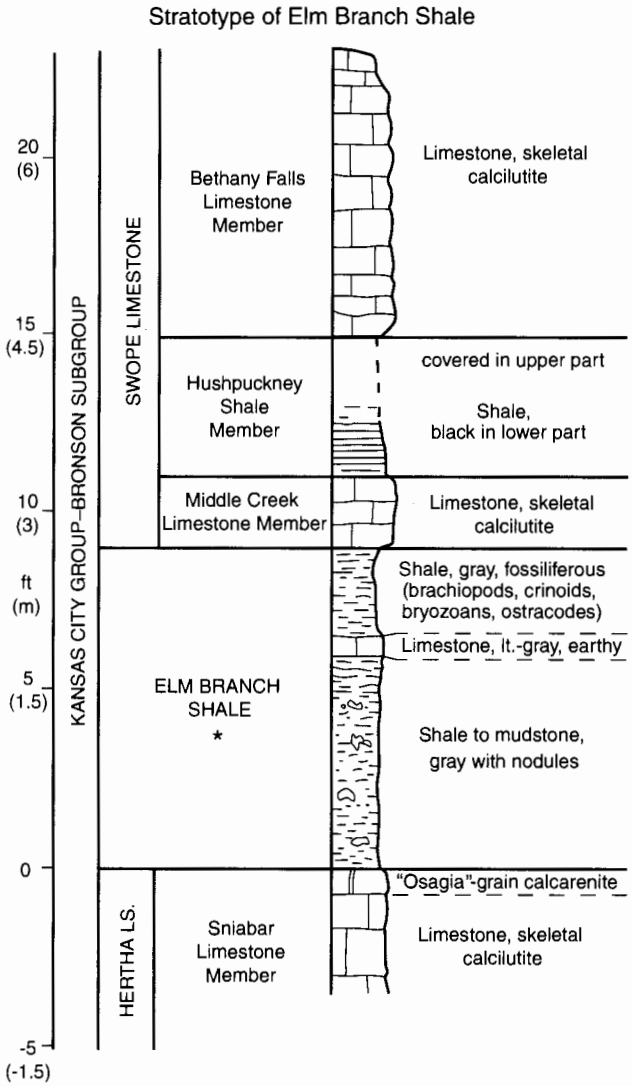


FIGURE 18—Measured section of Elm Branch Shale stratotype in roadcut along west side of county road on E line of SE-SE-NW sec. 10, T. 19 S., R. 23 E. (fig. 17), 1 mi (1.6 km) southwest of Fontana, Miami County, Kansas. Thin earthy limestone in upper middle of Elm Branch Shale is normally exposed in ditch, and shale portions can easily be dug out in bank.

Limestone. The Galesburg Shale is mainly 2–12 ft (0.6–3.6 m) of gray mudstone from Bourbon County northward, but is quite variable southward where sandstone locally becomes dominant. It attains perhaps 130 ft (39 m) in the Verdigris River bluffs north of Coffeyville, where it is the upper formation of the Coffeyville Group. The prominent **Cedar Bluff coal bed** near the middle of the Galesburg Shale southward was named by Jewett (1932) from a river bluff north of Coffeyville. Another coal bed occurs near the top of the Galesburg, as seen in a roadcut (center of east line of NE sec. 21, T. 31 S, R. 18 E.; fig. 2, sec. 28) south of US–160 southwest of Dennis, and in the South Coffeyville core (fig. 2, sec. 33). The Dodds Creek sandstone also was named by Jewett (1932), but from an unspecified locality near a creek in western Labette County that has not been found named on recent topographic maps. This name is dropped from use because of the lack of a type section in combination with confusion as to whether it applies to sandstone above the Cedar Bluff coal (as originally indicated by Jewett) or to sandstone below the Cedar Bluff coal (as indicated by Zeller, ed., 1968). These beds often are referred to as the Layton sandstones in the subsurface.

Dennis Limestone (unchanged)

The Dennis Limestone overlies the Galesburg Shale and underlies the Cherryvale Formation. It was named by Adams (1903) from exposures near Dennis in northwestern Labette County. The formation comprises three members in ascending order: Canville Limestone, Stark Shale, and Winterset Limestone. Because the typical outcrops listed by Moore (1936) are now poorly exposed, the principal reference section (Heckel, 1988, p. 54) is designated in a roadcut 1 mi (1.6 km) southwest of Dennis (center E line NE sec. 21, T. 31 S, R. 18 E.; fig. 2, sec. 28), and an excellent reference section for east-central Kansas is exposed along the west and south lines of SE sec. 31, T. 18 S, R 25 E. along US–69, north-northeast of Jingo in Miami County (Heckel, 1988, p. 51).

Canville Limestone Member (unchanged)

The Canville Limestone Member overlies the Galesburg Shale and underlies the Stark Shale Member. It was named from Canville Creek in northern Neosho County by Jewett (1932). Because original type exposures are now poorly exposed, the principal reference section is designated in a roadcut along US–59, 1.3 mi (2 km) east of Canville Creek, and 1.7 mi (3 km) west of Stark (S line SW-SE-SW sec. 13, T. 27 S., R. 20 E.; fig. 2, east of sec. 20). The Canville Limestone Member typically consists of 2–3 ft (0.6–0.9 m) of dense skeletal calcilutite in Neosho and Bourbon counties, but ranges up to 6 ft (1.8 m) at the principal reference section where phylloid algae appear in the top. It thins gradually northward to disappearance in southern Miami County, and it becomes lenticular but

FIGURE 19—A) Map of part of 1974 Mound Valley, Kansas, 7 1/2-minute quadrangle showing location of type section of Mound Valley Limestone in roadcut up Dixon Mound northwest of Mound Valley; because Mound Valley Limestone caps Dixon Mound and nearby hills, overlying Galesburg Shale is not exposed in this vicinity. B) Map of part of 1973 Shaw, Kansas, 7 1/2-minute quadrangle showing location of principal reference section of Mound Valley Limestone in roadcuts along US–59, 2 miles north of Erie, where both upper and lower contacts are exposed.

locally thicker southward in Montgomery County, as in the quarry east of Drum Creek, 3.5 mi (6 km) north of Cherryvale (south of center of N line of NE sec. 29, T. 31 S., R. 17 E.), where it attains at least 18 ft (5.4 m) of phylloid algal facies. The Canville also appears as 5 ft (1.5 m) of skeletal calcarenite in the nose of the Verdigris River bluff (SE-SW-SW sec. 14, T. 34 S., R. 16 E.), 2.5 mi (4 km) north of Coffeyville. The Canville Limestone Member is equivalent to the Lost City Limestone of the Tulsa region of Oklahoma, which also underlies the Stark Shale (Niemann, 1986).

Stark Shale Member (unchanged)

The Stark Shale Member overlies the Canville Limestone Member and underlies the Winterset Limestone Member. It was named from the town of Stark in northeastern Neosho County by Jewett (1932). Because the original type exposures are now poorly exposed, the principal reference section is established along US–59, 1.7 mi (3 km) west of Stark, in the same roadcut as that of the Canville Limestone (S line SW-SE-SW sec. 13, T. 27 S., R. 20 E.; fig. 2, east of sec. 20). The Stark Shale in its type region and generally throughout Kansas ranges from 1 to 6 ft (0.3–1.8 m) of black fissile phosphatic shale, overlain by gray fossiliferous shale in the thicker sections.

Winterset Limestone Member (unchanged)

The Winterset Limestone Member overlies the Stark Shale Member and underlies the Cherryvale Formation (Fontana Shale Member). It was named by Tilton and Bain (1897) from Winterset in Madison County, Iowa. The principal reference section of the Winterset Limestone in Kansas is a complete exposure in a roadcut along US–69 north-northeast of Jingo (along W line SW-SW-SE sec. 31, T. 18 S., R. 25 E.) in southern Miami County (Heckel, 1988, p. 51). Here the member is 34 ft (10.2 m) thick, mostly bedded skeletal calcilutite, and divisible into two separate depositional units. The lower unit (about two-thirds of the member) comprises three shallowing-upward minor cycles, the lower capped with thin oolite, the middle capped with peritidal calcilutite, and the upper capped by a mottled subaerial exposure surface (Heckel and Watney, 1985). The upper one-third of the Winterset Limestone Member, above the exposure surface, is a separate cycle of deposition consisting here mainly of medium-bedded skeletal calcilutite, which northward becomes dark and cherty in the Kansas City area. Both units become dominated by phylloid algal mound facies and oolite southward. The exposure surface separating the upper and lower units of the Winterset Limestone Member can be distinguished across the Kansas outcrop region and seems to become erosional southward (see fig. 21B). The upper Winterset unit appears to be lithologically equivalent to most of the

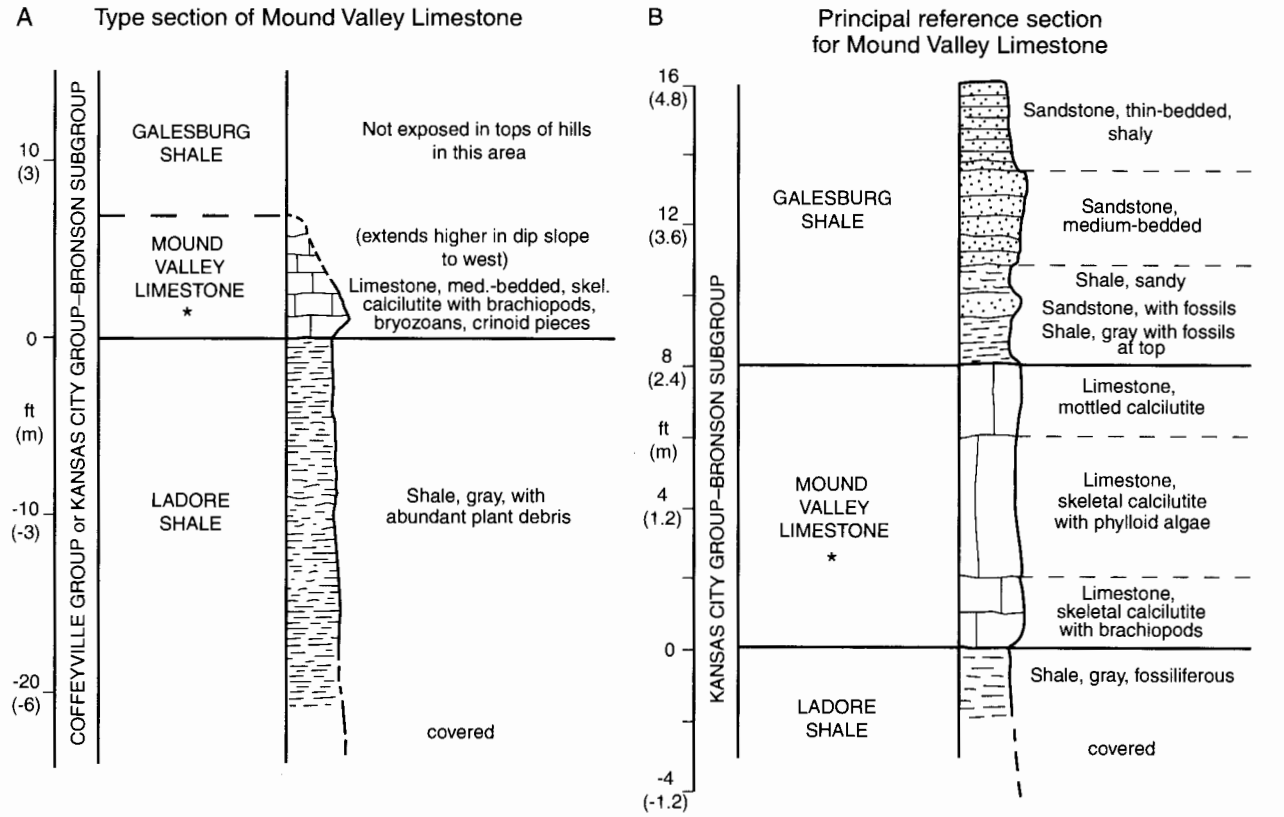


FIGURE 20—A) Measured section of Mound Valley Limestone type section in roadcut up Dixon Mound, along center of S line of SE sec. 27, T. 32 S., R. 18 E. (fig. 19A), 1 mi (1.6 km) northwest of Mound Valley, Labette County, Kansas. B) Measured section of principal reference section of Mound Valley Limestone in roadcuts along both sides of US–59, along W line of NW-NW sec. 20, and E line of NE-NE sec. 19, T. 28 S., R. 20 E. (fig. 19B), 2 mi (3 km) north of Erie, Neosho County, Kansas.

Hogshooter Limestone, named by Ohern (1910) from a locality east of Bartlesville in Washington County, Oklahoma.

LINN SUBGROUP (revised)

The Linn Subgroup of the Kansas City Group is revised to include the following formations in ascending order (figs. 1, 21B): Cherryvale Formation, Nellie Bly Formation (newly extended into Kansas from Oklahoma), Dewey Limestone (as now reclassified in Kansas to include what has been incorrectly termed Drum Limestone in northeastern Kansas), and Chanute Shale. The Iola Limestone is removed from the Linn Subgroup and now is included in the overlying Zarah Subgroup because of its closer stratigraphic association with those strata (see later section).

Cherryvale Formation (revised)

The Cherryvale Formation overlies the Dennis Limestone (Winterset Limestone Member) and underlies the newly recognized Nellie Bly Formation throughout Kansas (fig. 1). Named by Haworth (1898) from bluffs around Cherryvale in Montgomery County, usage and subdivision of the Cherryvale was stabilized by Moore (1948, 1949). Previously containing five members (figs. 1, 21A), the Cherryvale Formation in northeastern Kansas now comprises four members, in ascending order: Fontana Shale, Block Limestone, Wea Shale, and Westerville Limestone (figs. 1, 21B). The Quivira Shale, once included above the Westerville (fig. 21A), is now recognized as a member of the overlying Dewey Limestone (as reclassified; see later section). All members were named from northeastern Kansas except for the Westerville Limestone, which was named from Iowa. In parts of southern Kansas the formerly undivided Cherryvale Formation now comprises, in ascending order: Lower Shale member, Middle Flaggy Limestone member, and Drum Limestone Member. The Drum Limestone Member, once thought to correlate with the higher Dewey Limestone of Oklahoma (fig. 21A), is now included as a member of the Cherryvale Formation in southern Kansas because it is now known to lie below the Dewey Limestone and to occupy the same stratigraphic position as the Westerville Limestone Member of the Cherryvale Formation in northeastern Kansas (fig.21B). The Lower Shale and Middle Flaggy Limestone members are recognized only in those parts of Montgomery County in southern Kansas where the Block Limestone Member is not identified.

The type section of the Cherryvale Formation is designated in the exposure on the hillside and road ditch just south of the road intersection along the E line of SE-SE-SE sec. 32, T. 31 S., R. 17 E., and down to the top of the Winterset Limestone Member in the bed of Cherry Creek, 2 mi (3 km) north of Cherryvale (fig. 22A). This exposure includes in ascending order, the upper 60 ft (18 m) of the Lower Shale member, 4 ft (1.2 m) of Middle Flaggy Limestone member, and about 4 ft (1.2 m) or more of the Drum Limestone Member, mostly in the dip slope (fig 23A). The total thickness of the Cherryvale interval in this area is at least 104 ft (31+ m). A good reference section nearby for the Cherryvale Formation where it comprises the Fontana Shale, Block Limestone, Wea Shale, and Drum Limestone Members (fig. 23B) is at a new roadcut east of the US–160-169 junction, about 3 mi (5 km) south of Cherryvale along N line NE sec. 31, T. 32 S., R. 17 E. (fig. 22B). In southern Montgomery County, the Cherryvale Formation thins and becomes more dominated by the Middle Flaggy Limestone member as the Block Limestone Member disappears, the Lower Shale member thins, and the Drum Limestone Member pinches out and/or grades into the top of the Middle Flaggy Limestone member (fig. 21B). In northeastern Kansas, the Cherryvale Formation ranges generally from about 30 to 50 ft (9–15 m) thick in the Kansas City area. Here, a reference section that exposes all four members is accessible (but with some difficulty) in a rill above the main quarry wall behind the transformer station at the north end of the cold storage plant quarries along Inland Drive (south of center of N line of NW-NE sec. 27, T. 11 S., R 24 E.). The lower boundary of the Cherryvale Formation is the basal contact of gray shale or mudstone with the top of the Winterset Limestone Member. The upper boundary of the Cherryvale Formation is the contact between limestone of the Drum or Westerville Limestone Members (where they are present) with shale, mudstone, or sandstone of the overlying Nellie Bly Formation. Where the capping limestone members are absent (as across most of eastern Kansas), this boundary is rarely exposed and difficult to place (see later section on Wea Shale Member).

Fontana Shale Member (unchanged)

The Fontana Shale Member overlies the Winterset Limestone Member of the Dennis Limestone and underlies the Block Limestone Member (figs. 1, 21B). It was named by Moore (1932) and defined by Newell (1935) from exposures near Fontana in Miami County. Because neither of the two original type exposures are well exposed today, the principal reference section is designated on the east side of the US–69 roadcut along W line SW-NE sec. 6, T. 19 S., R. 25 E., 8 mi (13 km) east of Fontana, just south of the Winterset Limestone Member reference section north-northeast of Jingo. The Fontana Shale Member in its type area ranges from 12 to 18 ft (3.6–5.4 m) of gray shale to mudstone with small carbonate nodules and, in the upper part, scattered marine fossils. It thins northward to 5 ft (1.5 m) in the Kansas City area, where it consists of blocky mudstone overlain by fossiliferous shale with a local thin sandstone. Southward, it thickens to form the main mass of gray shale that dominates the Cherryvale Formation in its type area (fig. 23B), and is equivalent to most of the Lower Shale member in that area (fig. 21B).

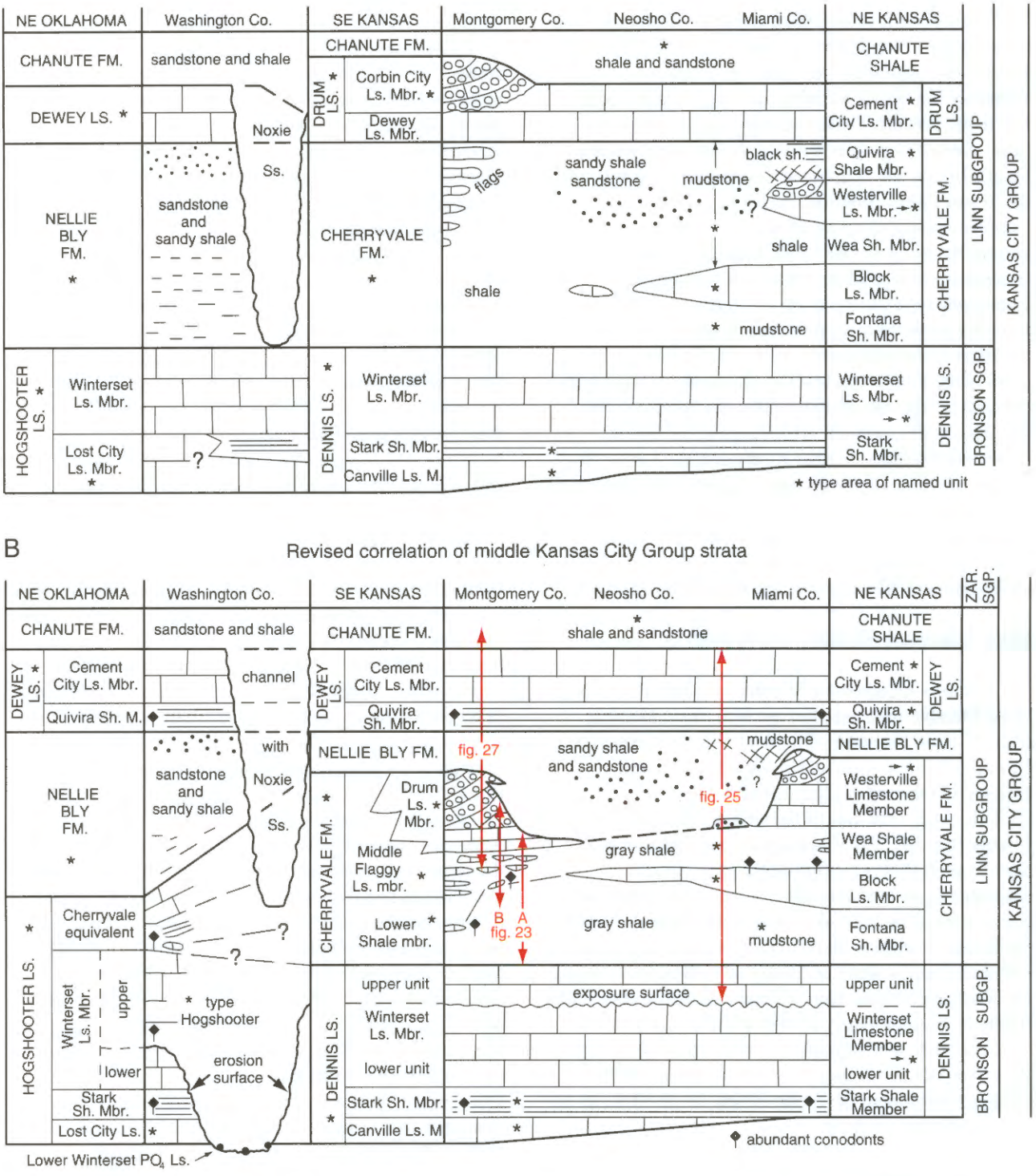


FIGURE 21—Comparison of previous correlation, nomenclature, and classification (A) of middle Missourian (mainly Linn Subgroup) strata with revised correlation, nomenclature, and classification (B) mandated by correction of long-standing miscorrelation of Dewey Limestone of Oklahoma and Cement City Limestone of Missouri with Drum Limestone of southern Kansas. Neither vertical nor lateral dimensions are to exact scale, but locations of measured sections in figs. 23, 25, and 27 are shown in (B) to provide evidence for stratigraphic control. Tailed diamond symbols indicate correlations based on conodont faunas. Section for Cherryvale Formation in northeastern Kansas is based on reference section along Inland Drive (south of center of N line NW-NE sec. 27, T. 11 S., R. 24 E.; see text). Section for Hogshooter Limestone in northeastern Oklahoma is based on its type section in quarry 3.5 mi northeast of Hogshooter and east of Bartlesville in SW sec. 9, T. 26 N., R. 14 E. (for upper part) and in roadcut 1 mi south of Hogshooter along north line of NE-NW-NE sec. 6, T. 25 N., R. 14 E. (for lower part), Washington County, Oklahoma.

Lower Shale member (new)

The informal Lower Shale member is recognized in those parts of Montgomery County, Kansas, where the Block Limestone is not identified. It overlies the Winterset Limestone Member, and thus is partly equivalent to the Fontana Shale Member (figs. 1, 21B). Its upper contact is gradational with the informal Middle Flaggy Limestone member and is placed at the base of the lowest flaggy limestone bed. The Lower Shale member consists of about 95 ft (28 m) of essentially unfossiliferous gray shale with scattered limestone concretions at its principal reference section, the Cherryvale type section north of Cherryvale (fig. 23A). It thins southward to 15 ft (4.5 m) in the west bank of the Verdigris River near center of sec. 28, T. 33 S., R. 16 E., north of the mouth of Clear Creek, where its lower part contains a very thin shaly fossiliferous limestone bed that may be the southern featheredge of the Block Limestone Member. Farther southward, the Lower Shale member thins nearly to disappearance between the top of the Winterset Limestone Member and the base of the overlying Middle Flaggy Limestone member in an outcrop along the north side of US–166 west of Coffeyville (N line west of NE corner of sec. 6, T. 35 S., R.16 E.).

Block Limestone Member (unchanged)

The Block Limestone Member overlies the Fontana Shale Member and underlies the Wea Shale Member (figs. 1, 21B). Named by Moore (1932) and defined by Newell (1935), its type locality is still fairly well exposed in the road ditch at center N line NW sec. 7, T. 18 S., R. 24 E., just east of the village of Block in Miami County (fig. 24). The Block Limestone Member averages 3 to 5 ft (0.9–1.5 m) of dense gray skeletal calcilutite in its type area (fig. 25) and thins northward to 1 ft (0.3 m) in the Kansas City area. In southern Kansas the Block Limestone Member occurs at the Cherryvale reference section south of Cherryvale where it is 1 ft (0.3 m) of dense conodont-rich skeletal calcarenite (fig. 23B). It may be present locally southward as a very thin, conodont-rich, shaly fossiliferous limestone bed within the Lower Shale member, as in the west bank of the Verdigris River near the center of sec. 28, T. 33 S., R. 16 E. (see previous section).

Wea Shale Member (revised)

The Wea Shale Member overlies the Block Limestone Member everywhere, and underlies the Westerville Limestone Member in northeastern Kansas, the Nellie Bly Formation in east-central Kansas, and the Drum Limestone Member in southeastern Kansas (figs. 1, 21B). It was named by Moore (1932) and defined by Newell (1935) from exposures near Wea Creek in northeastern Miami County, and its usage was stabilized by Moore (1948, 1949) to apply to the shale between the Block and Westerville Limestone Members in the Kansas City area. The Westerville Limestone Member is absent in the Wea type area, and the original type sections of Newell (1935) expose only strata now known to belong to the Nellie Bly Formation above the position of the Westerville Limestone Member (see later sections on Drum Limestone Member and Nellie Bly Formation). Therefore, a neostratotype for the Wea Shale Member is designated in the road ditch above the type exposure of the Block Limestone along N line NE-NW sec. 7, T. 18 S., R. 24 E. (fig. 24). Here the Wea Shale Member interval is 27 ft (8.2 m) thick, with about 1 ft (0.3 m) of conodont-rich gray clay shale at the base, and it is overlain by brown sandstone (best seen on the north side of the road) assigned to the Nellie Bly Formation (fig. 25). The Wea Shale Member is generally very poorly exposed across most of eastern Kansas, but where seen, it is typically gray sparsely fossiliferous shale with thin limestone beds ranging from moderately to sparsely fossiliferous. The lower boundary of the Wea Shale Member is the contact of gray shale upon the Block Limestone Member. The upper boundary is the contact of gray shale below limestone of the Westerville or Drum Limestone Members where they are present. Where these overlying limestone members are absent (as across most of eastern Kansas), the upper contact is rarely exposed, but would be chosen where gray fossiliferous shale is overlain by coarser detrital beds (as at the neostratotype), or by plant-bearing shale or unfossiliferous mudstone, all of which are more typical of the overlying Nellie Bly Formation. Northward, the Wea Shale Member ranges from 30 ft (9 m) of gray shale along Tomahawk Creek (N line at NE corner sec. 21, T. 13 S., R. 25 E.) in Johnson County, to 7 ft (2.1 m) of gray shale with two thin limestone beds (one in the middle with conspicuous brachiopods and one in the lower part with dark burrow mottling) at the Cherryvale reference section above Inland Drive in Wyandotte County. In southern Kansas at the Cherryvale reference section south of Cherryvale (fig. 23B) in central Montgomery County, the Wea Shale Member is 3 ft (0.9 m) of gray shale containing flaggy limestone beds with brachiopods appearing toward the top. It thickens westward in 2 mi (3 km) to at least 10 ft (3 m) above the Block Limestone Member in the roadcut along US–160 (S line SW-SW-SW sec. 25, T. 32 S., R. 16 E.). Elsewhere in this region where the Block Limestone Member is not identified, the Wea Shale Member is equivalent to the Middle Flaggy Limestone member and probably to the upper part of the Lower Shale member of the Cherryvale Formation as well.

Middle Flaggy Limestone member (new)

The informal Middle Flaggy Limestone member overlies the Lower Shale member and underlies the Drum Limestone Member where the Block Limestone

Member is not identified and the Wea Shale Member is not differentiated, in parts of Montgomery County in southern Kansas (figs. 1, 21B). This unit ranges in thickness from about 4 ft (1.2 m) of gray shale with scattered flaggy limestone beds at its principal reference section at the type section of the Cherryvale Formation (fig. 23A) to about 20–30 ft (6–9 m) of interbedded flaggy limestone and shale southward in scattered outcrops along Clear Creek in SW sec. 28, T. 33 S., R. 16 E. and in roadcuts in sections 3, 10, 15, 22, and 27, in T. 34 S., R. 16 E., north of Coffeyville. In this area, it contains sparse fossils, mainly snails and brachiopods. Its lower boundary is the basal contact of the lowest flaggy limestone bed above the Lower Shale member, and its upper boundary is the top of the highest gray shale bed below the Drum Limestone Member. It is considered to be largely equivalent to the Wea Shale Member, which contains similar flaggy limestone beds where it can be differentiated in this area. The Middle Flaggy Limestone member thins and loses shale beds toward the southern border of Kansas, where it becomes a 3-ft (0.9-m)-thick ledge of dense, laminated calcilutite, which may include the southern equivalent of the Drum Limestone Member as well (see later section). This ledge forms nearly all of the Cherryvale Formation above the Winterset Limestone Member in a roadcut along the north side of US–166 west of Coffeyville (NE corner sec. 6, T. 35 S., R. 16 E.), and it can be traced southward to the Oklahoma border in the SE corner of sec. 16, T. 35 S., R. 16 E.

Westerville Limestone Member (unchanged)

The Westerville Limestone Member overlies the Wea Shale Member and underlies the recently recognized Nellie Bly Formation in northeastern Kansas (figs. 1, 21B). It now forms the top of the Cherryvale Formation in northeastern Kansas and is now considered to be equivalent to the Drum Limestone Member of southern Kansas. The Westerville Limestone Member was named from Westerville in northwestern Decatur County, Iowa (Bain, 1898), and was grouped by Moore (1948, 1949) in the Cherryvale Formation (fig. 21A). The principal reference section in Kansas is along the north side of I–70, 0.7 mi (1.1 km) west of 18th Street (NW-SE-NW sec. 17, T. 11 S., R. 25 E.) in Wyandotte County. In this area, the lower part of the Westerville Limestone Member averages about 8 ft (2.4 m) of skeletal calcilutite, the middle is an oolite that ranges generally from a few inches (cm) to about 6 ft (1.8 m) thick, and the upper part of the Westerville is up to 10 ft (3 m) of locally shaly, barren laminated calcilutite. The Westerville Limestone Member thins southward to about 8 ft (2.4 m) along 119th St. at Mission Road (N line at NE corner sec. 21, T. 13 S, R. 25 E.) in Johnson County as the lower unit thins, the middle oolitic unit pinches out, and the upper unit thins and becomes shalier. The Westerville Limestone Member is not known to be exposed in Miami County or southward.

Drum Limestone Member (recorrelated and reclassified)

The Drum Limestone Member overlies the Wea Shale Member and the Middle Flaggy Limestone member and underlies the Nellie Bly Formation in southern Kansas (figs. 1, 21B). It was named by Adams (1903) from Drum Creek east of Independence in Montgomery County. Its principal reference section (fig. 23B) is at the Cherryvale Formation reference section south of Cherryvale (N line NE sec. 31, T. 32 S., R. 17 E. and just east of Drum Creek), where it consists of 2 ft (0.6 m) of skeletal calcilutite overlain by 4 ft (1.2 m) of oolite. Moore (1936, 1949) had correlated the Drum Limestone with both the Cement City Limestone of Missouri and the Dewey Limestone of Oklahoma (fig. 21A). He also subdivided it into two members: Dewey (or Cement City) Limestone Member below, overlain by Corbin City Limestone Member, the oolite facies. This correlation stood until A. P. Bennison found the true Cement City Limestone and the underlying Quivira Shale Member in a position 20 ft (6 m) above the Drum Limestone in its type region in a ravine on the west bluff of the Verdigris River on the northeastern outskirts of Independence (figs. 26, 27). Thus the Drum Limestone is not equivalent to the Cement City Limestone, but rather occupies the same stratigraphic position as the Westerville Limestone Member of the Cherryvale Formation in northeastern Kansas (fig. 21B). Therefore the Drum Limestone is now reduced in rank and classified in a similar fashion as the top member of the Cherryvale Formation in southern Kansas. The Quivira Shale Member has subsequently been found at the base of the Dewey Limestone in Oklahoma, and accordingly, the Cement City Limestone and Quivira Shale are reclassified as members of the Dewey Limestone (see later section).

The Drum Limestone Member is about 60 ft (18 m) of mainly oolite just east of Independence along the Verdigris River south of the US–160 bridge and in the cement plant quarries just to the south (north half of sec. 5, T. 33 S., R. 16 E.). It thins northeastward to just 1 ft (0.3 m) of skeletal calcarenite and calcilutite in a creek valley 2 mi (3 km) east of Morehead (NW-NW-SW sec. 32, T. 30 S., R. 18 E.) in southern Neosho County, currently the northernmost good exposure known. The Drum Limestone Member also thins southward from Independence to about 14 ft (4.2 m) at the bridge over Clear Creek (west line of NW-SW-SW sec. 28, T. 33 S., R. 16 E.). Here it is oolite that grades downward into thin wavy-bedded ledges of peloidal calcarenite, which overlie even-bedded shale-parted flags of the Middle Flaggy Limestone member. Although the basal contact of the Drum is placed at the base of the wavy-bedded limestone above a prominent shale parting here, a section about 1 mi (1.6 km) to the southeast (west line of NW-SW-NW sec. 34) shows a more gradational contact from thinner and more fine-grained oolite through peloidal calcarenite to typical middle Cherryvale flags. South-

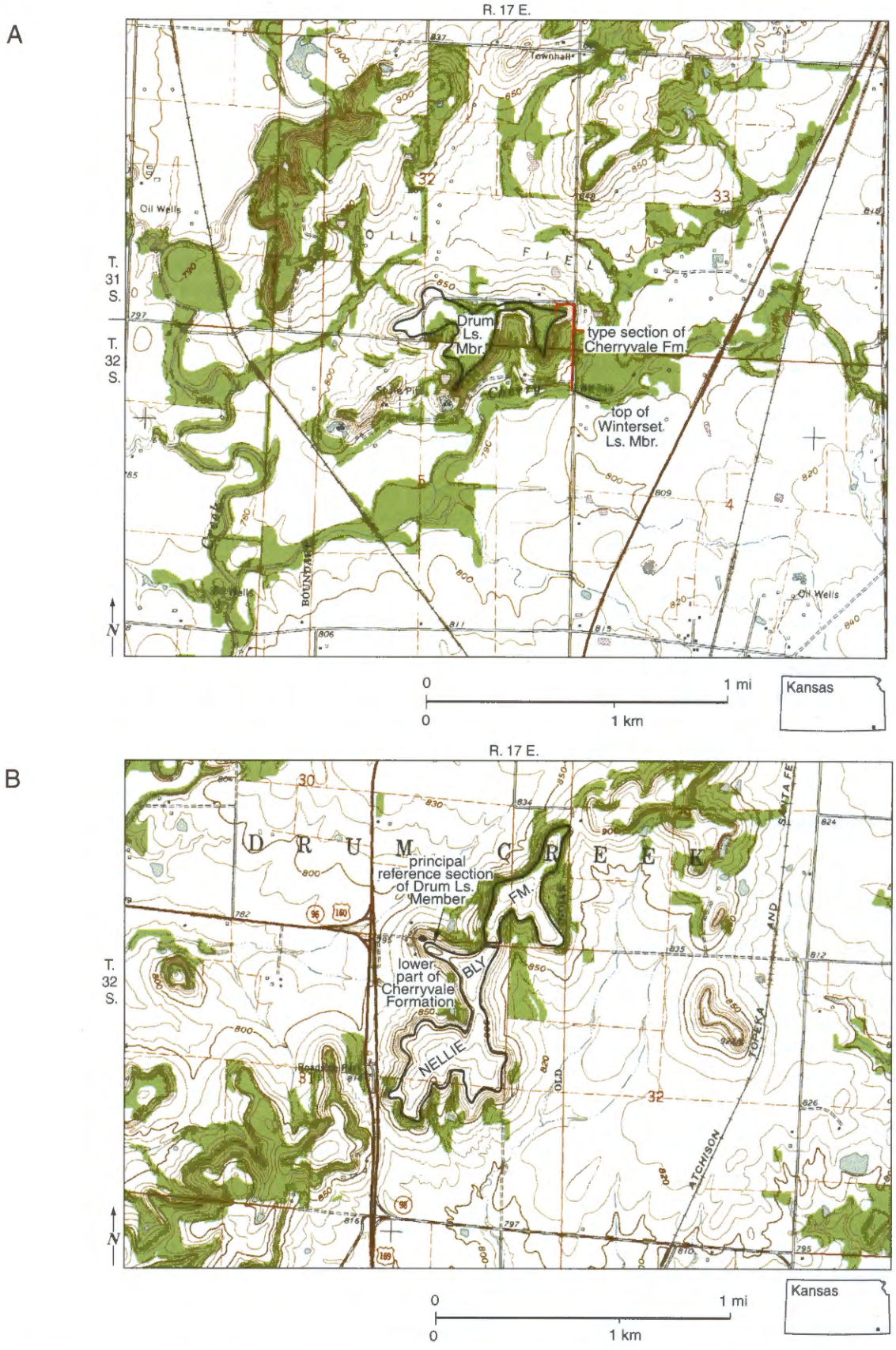


FIGURE 22—A) Map of part of 1962 (photoinspected 1977) Cherryvale, Kansas, 7 1/2-minute quadrangle, showing location of type section of Cherryvale Formation in hillslope and road ditch north of Cherryvale in Montgomery County. B) Map of part of 1962 (photoinspected 1977) Liberty, Kansas, 7 1/2-minute quadrangle, showing location of reference section of named members of Cherryvale Formation in southern Kansas and principal reference section of Drum Limestone Member in roadcuts along new east-west road (not shown on map) south of Cherryvale in Montgomery County.

ward toward Coffeyville, all the limestone in this interval is flaggy with shale partings, and some of the upper flags contain zones of peloidal calcarenite, suggesting that the southward-thinning Drum Limestone Member has graded into the top of the Middle Flaggy Limestone member north of Coffeyville (fig. 21B). This provides another reason to classify the Drum similarly as a member of the Cherryvale Formation. Reduction in rank of the Drum Limestone to a member reduces its previously named members to beds. Both names for the previous lower member (Dewey, Cement City) are now known to correctly apply only to an overlying limestone unit (see later section). Because the previous upper oolite member is even more local than the Drum Limestone Member and is adequately designated by its lithology alone, the name Corbin City Limestone is abandoned.

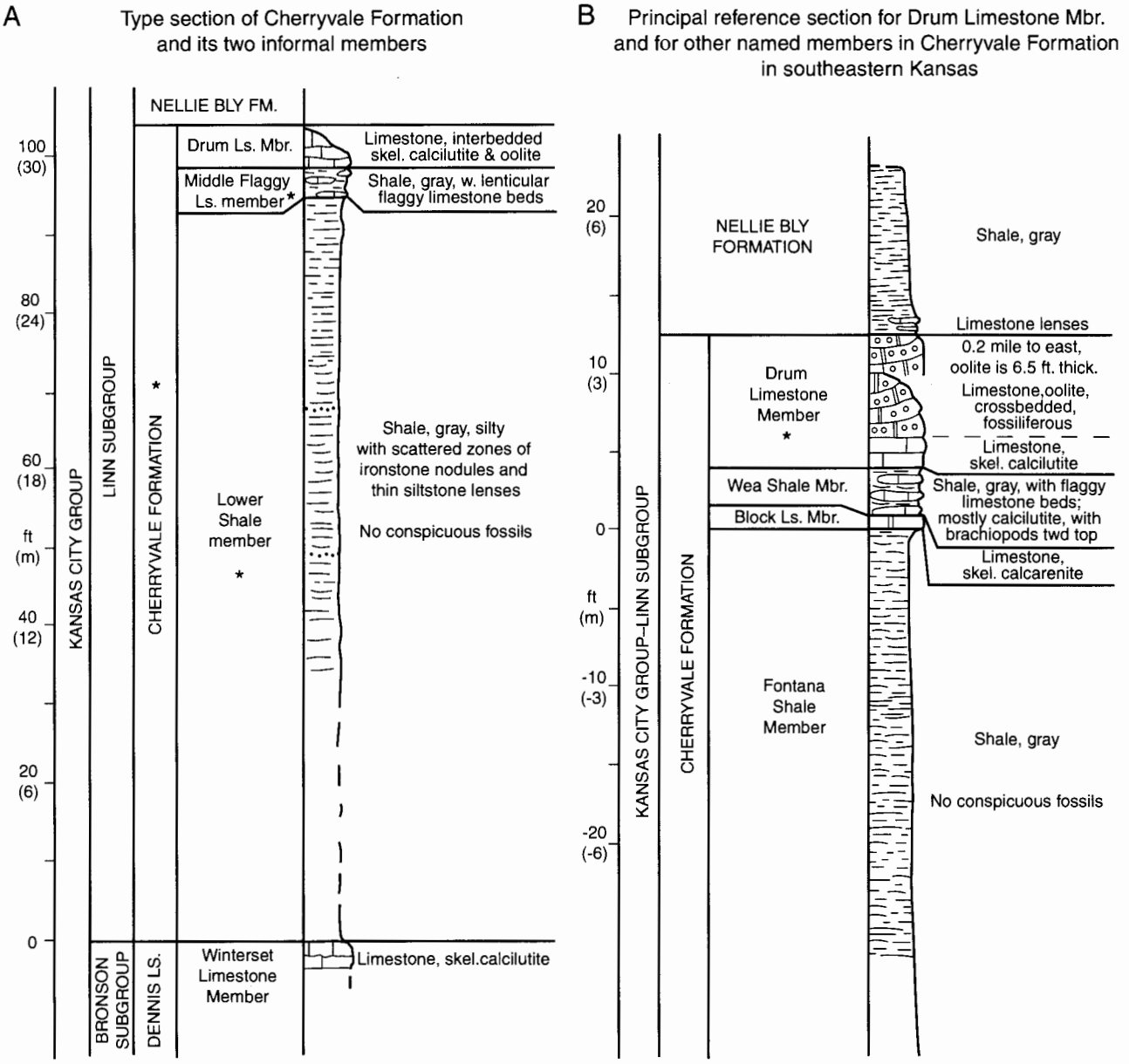


FIGURE 23—A) Measured section of Cherryvale Formation type section in hillslope south of road intersection and in road ditch along E line SE-SE-SE sec. 32, T. 31 S., R 17 E. (fig. 22A), 2 mi (3 km) north of Cherryvale, Kansas. This is also the principal reference section for the two informal members of the Cherryvale Formation (Lower Shale and Middle Flaggy Limestone), which are recognized where the Block Limestone Member cannot be identified. B) Measured section of upper part of Cherryvale Formation in roadcuts east of the US–160-169 junction along N line of NE sec. 31, T. 32 S., R 17 E. (fig. 22B), 3 mi (5 km) south of Cherryvale, Kansas. This is a reference section in southern Kansas for the more northerly named members (Fontana Shale, Block Limestone, Wea Shale) of the Cherryvale Formation, and the principal reference section for the Drum Limestone Member of the Cherryvale Formation, which is developed only in southern Kansas. Block Limestone Member lenses out toward north in this exposure.

Nellie Bly Formation (newly recognized in Kansas)

As now recognized, the Nellie Bly Formation overlies the Cherryvale Formation (including both the Drum and Westerville Limestone Members and the Wea Shale Member) and underlies tbe Dewey Limestone (Quivira Shale Member) in Kansas (figs. 1, 21B). The name was applied by Gould (1925, from an unpublished 1914 manuscript by Ohern) to shale and sandstone above the Hogshooter (Dennis) Limestone and below the Dewey Limestone in northern Oklahoma. The type area was designated by Oakes (1940) as exposures along Nellie Bly Creek in secs. 28, 29, 31, 32, T. 24 N., R. 13 E. southwest of Ramona, Washington County, Oklahoma. In this area the Nellie Bly ranges from 115 to 180 ft (35–54 m) of sandy shale to sandstone. The Nellie Bly Formation had been considered by Moore (1948, p. 2,031) to be the southern equivalent of the Cherryvale Formation of Kansas. It is now known, however, to overlie the Drum Limestone and Middle Flaggy Limestone members of the Cherryvale, both of which thin southward near the Kansas–Oklahoma border just above the Winterset Limestone Member (as on US–166 west of Coffeyville along N line at NW corner of sec. 5 and NE corner of sec. 6, T. 35 S., R. 16 E.). The southward shaly limestone equivalents of the Cherryvale have apparently been included in the top of the Hogshooter Limestone in Oklahoma (fig. 21B).

The principal reference section for the Nellie Bly Formation in Kansas is in a ravine on the west bluff of the Verdigris River (north of center S line, NE sec. 19, T. 32 S., R. 16 E.) on the north side of Independence (fig. 26), where A. P. Bennison discovered it separating the Drum and Dewey limestones. Here the Nellie Bly consists of 21 ft (6.3 m) of shale-parted sandstone above the Drum Limestone Member grading upward into sandy shale below the black Quivira Shale Member of the Dewey Limestone (fig. 27). The lower boundary of the Nellie Bly Formation is the basal contact of sandstone or sandy shale above the Drum Limestone Member in southern Kansas, but thin lenticular limestones are included in the lower Nellie Bly in places (fig. 23B). The upper boundary is the contact between sandstone, sandy shale, or mudstone of the Nellie Bly and the base of the overlying fissile black shale to fossiliferous gray shale (and locally to the north, a thin lenticular limestone bed) of the Quivira Shale Member of the Dewey Limestone. In places between Independence and the Oklahoma border, however, the Dewey Limestone had been eroded and the channels filled with sandstone from the overlying Chanute Shale. Because the type Dewey Limestone of Oklahoma was miscorrelated with the Drum Limestone Member of Kansas, the Nellie Bly of southern Kansas was readily (but erroneously) considered part of the Chanute. In these places, the upper contact of the Nellie Bly Formation is the base of the rubbly limestone beds containing eroded fragments of Dewey Limestone in the base of the Chanute, which erroneously had been considered to be the Corbin City Limestone Member (now abandoned) of the Drum Limestone, then ranked as a formation.

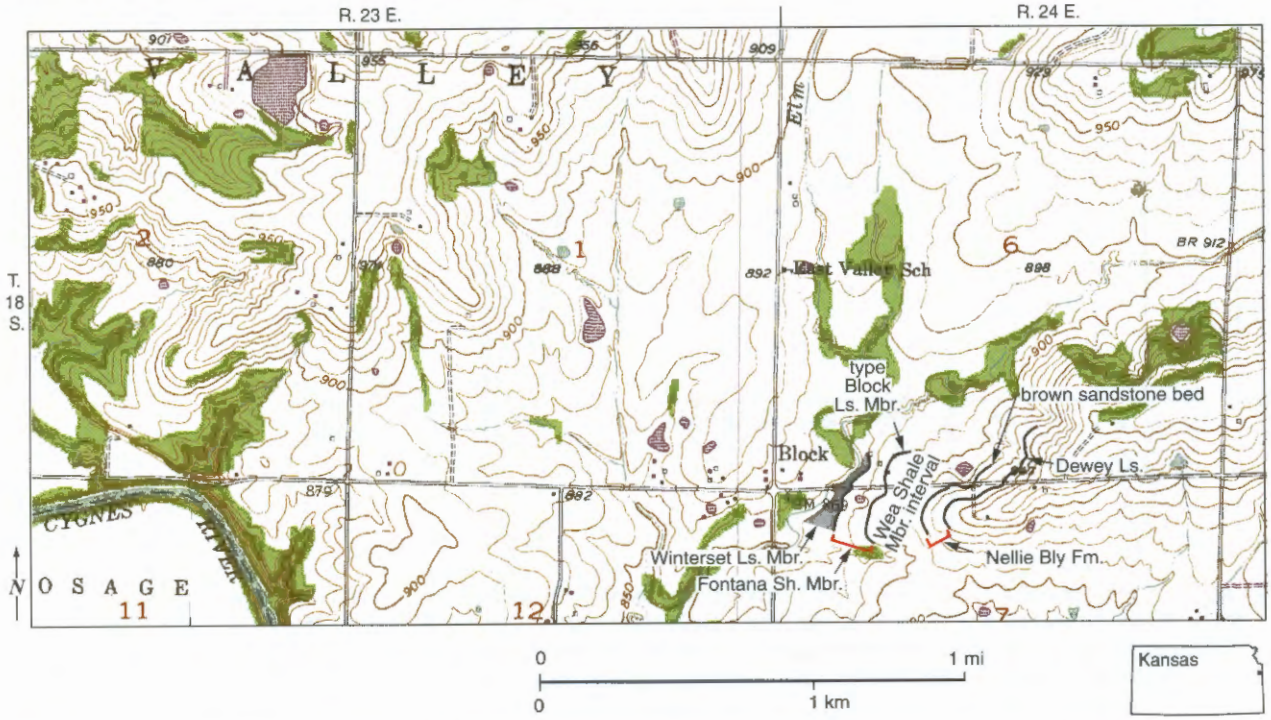


FIGURE 24—Map of part of 1956 (photorevised 1973) Paola East, Kansas, 7 1/2-minute quadrangle, showing location of neostratotype for interval of Wea Shale Member of Cherryvale Formation above type section of Block Limestone Member along road east of Block in Miami County. Brown sandstone bed is presumed to be at or near base of Nellie Bly Formation.

The Nellie Bly Formation is generally poorly exposed northward across eastern Kansas, where it was again easily confused with the younger Chanute Shale because the intervening Dewey Limestone is thin and rarely exposed. The Nellie Bly Formation includes the sandstones, sandy plant-bearing beds, thin coals, and gray to maroon mudstone observed below the Quivira Shale Member and originally included in the Wea Shale Member. The lower boundary of the Nellie Bly in this region is rarely exposed, but where seen (as at the neostratotype for the Wea Shale Member of the Cherryvale Formation east of Block in Miami County: fig. 25), it is the basal contact of sandstone, sandy shale, or mudstone above sparsely fossiliferous gray shale of the Wea. In the Kansas City area, the Nellie Bly Formation ranges from a few feet of gray blocky mudstone, typically with calcareous nodules and locally a thin coal at the top (all of which previously were included in the Quivira Shale Member), to absent in places where the fossiliferous Quivira Shale Member lies directly upon the Westerville Limestone Member. The Nellie Bly is 1.5 ft (0.45 m) of gray blocky mudstone with calcareous nodules and fractured limestone masses at a reference section at the entrance to the I–435 southbound onramp from K–32 (near center of SW sec. 30, T. 11 S., R. 24 E.) east of Edwardsville in Wyandotte County.

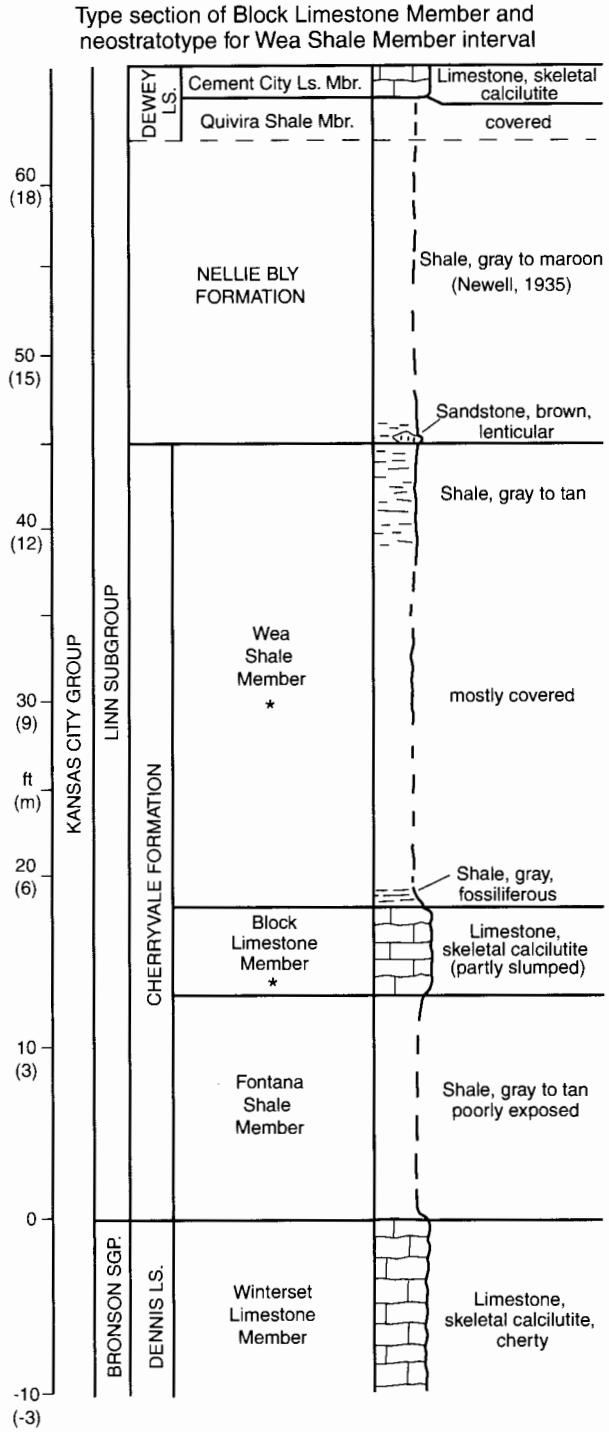


FIGURE 25—Measured section of neostratotype for Wea Shale Member interval, Block Limestone Member type section, and associated units along road along N line of NW sec. 7. T. 18 S., R. 24 E (fig. 24), 0.1–0.6 mi (0.2–1 km) east of Block, Miami County, Kansas, based partly on measurements by Newell (1935, p. 143–144, section 150).

Dewey Limestone (recorrelated, reclassified, and raised in rank in Kansas)

The Dewey Limestone is now recognized in Kansas to comprise, in ascending order, the Quivira Shale Member and the Cement City Limestone Member (figs. 1, 21B). It overlies the Nellie Bly Formation and underlies the Chanute Shale. The Dewey Limestone was named by Ohern (1910) from exposures in the old cement plant quarry in sec. 26, T. 27 N., R. 13 E., east of Dewey in Washington County, Oklahoma. Both the Dewey Limestone and Cement City Limestone (named from Missouri) had been incorrectly correlated with the Drum Limestone of southern Kansas, and both names had been applied to its lower member, the latter case causing the name Drum to be incorrectly applied to the next limestone above the Westerville Limestone Member in the Kansas City area (fig. 21A). When the miscorrelation was rectified by discovery of the Cement City Limestone Member and underlying Quivira Shale Member (which was regarded as the upper member of the Cherryvale Formation in the Kansas City area) above the Drum Limestone in its type area, the problem arose of how to reclassify the unit formerly called Drum in the Kansas City area. This was resolved after discovery of the Quivira Shale Member in the base of the type Dewey Limestone (which had always been considered a formation in Oklahoma), by inclusion of the Quivira as a member of the Dewey and by using the name Cement City (the next member above the Quivira in the Kansas City area) for the upper, limestone member of the Dewey. Thus the Dewey Limestone is a typical limestone formation of the Missourian succession of Kansas, lacking only a thin limestone member below the Quivira Shale Member (except for the local limestone bed in the Kansas City area), much like the older Dennis Limestone north of the pinchout of the basal Canville Limestone Member.

The principal reference section for the Dewey Limestone and its two members (fig. 27) in southeastern Kansas is just above that for the Nellie Bly Formation in the ravine along the west bluff of the Verdigris River, north of center S line NE sec. 19, T. 32 S., R. 16 E., on the northern edge of Independence in Montgomery County (fig. 26). Here, the formation is only 5 ft (1.5 m) thick, and it is generally poorly exposed northward as it thickens only gradually. Representative exposures are in the creek bed at US–59 (near NE corner of sec. 2, T. 24 S., R. 20 E.) west of Bayard in northern Allen County, in the roadcut 1 mi (1.6 km) east of Osawatomie (S line SW-SE-NE sec. 12, T. 18 S., R. 22 E.) in Miami County, and in the excellent long exposure along the north side of I–70 between 18th St. and Park/Kaw Drive exits (N half of sec. 17, T. 11 S., R 25 E.) in Wyandotte County, where it is 12 ft (3.6 m) thick. South of Independence, the Dewey Limestone had been removed by pre-Chanute erosion across much of southern Montgomery County (which contributed to its miscorrelation with the older Drum Limestone). Here conglomeratic limestones composed of Dewey Limestone rubble, which had been erroneously assigned to the Corbin City Limestone Member (now abandoned) of the Drum, more properly belong to the base of the overlying Chanute Shale and mark its contact with the underlying Nellie Bly Formation. Nevertheless, outliers of Dewey Limestone have been discovered in this area by A. P. Bennison, including a roadcut east of Montgomery County State Park (along S line of SE-SE-SW sec. 17, T. 33 S., R. 16 E.) where both members are exposed.

Quivira Shale Member (reclassified and redefined)

The Quivira Shale Member overlies the Nellie Bly Formation (and locally the Westerville Limestone Member of the Cherryvale Formation in the Kansas City area) and underlies the Cement City Limestone Member (figs. 1, 21B, 27). It was named by Moore (1932) and defined by Newell (1935) from exposures near Quivira Lake in Wyandotte County, and was considered to be the top member of the Cherryvale Formation by Moore (1948, 1949). Now that the Drum Limestone is considered equivalent to the Westerville Limestone Member, and the Nellie Bly Formation is known to separate both those limestones from the Quivira Shale Member, the Quivira Shale Member is removed from the Cherryvale Formation and placed with the Cement City Limestone Member in the Dewey Limestone. The Quivira Shale Member throughout Kansas is generally 2–5 ft (0.6–1.5 m) of moderately fossiliferous, gray to dark-gray to black shale with local phosphorite nodules and abundant conodonts, and it locally includes a thin limestone bed at the base. The underlying Nellie Bly Formation contains plant-bearing beds and unfossiliferous mudstones in addition to the sandstones and sandy shales. Therefore, it is the more appropriate unit to contain the gray to tan blocky mudstone and local capping thin coaly bed that overlie the Westerville Limestone Member in much of the Kansas City area and which had been included in the base of the Quivira Shale Member. Therefore, the Quivira Shale Member is redefined to exclude these beds, which are transferred to the Nellie Bly Formation. Thus the lower boundary of the Quivira Shale Member is

FIGURE 26—Map of part of 1959 (photorevised 1979) Independence, Kansas, 7 1/2-minute quadrangle, showing location of principal reference sections of Nellie Bly Formation and Dewey Limestone in Kansas, in ravine in bluff of Verdigris River on northeastern outskirts of Independence in Montgomery County, discovered by A. P. Bennison in 1986.

the contact of gray fossiliferous to black fissile shale or thin limestone, above gray to tan to maroon mudstone to sandy shale or sandstone of the Nellie Bly Formation. The principal reference section for the Quivira Shale Member lies on top of 0.1 ft (3 cm) of gray unfossiliferous Nellie Bly mudstone above the Westerville Limestone Member along Kaw Drive 0.6 mi (1 km) west of the I–635 overpass in Wyandotte County (center W half SE-SE sec. 12, T. 11 S., R. 24 E.). This locality is about 6 mi (10 km) northeast of Quivira Lake and is illustrated as Stop A4 by Heckel et al. (1999, p. 24).

Cement City Limestone Member (reclassified)

The Cement City Limestone Member overlies the Quivira Shale Member and underlies the Chanute Shale everywhere in Kansas (figs. 1, 21B, 27). It was named by Hinds and Greene (1915) from Cement City, northeast of Kansas City in Jackson County, Missouri. Previously classified as a member of the Drum Limestone, the Cement City Limestone Member is now recognized as the upper member of the Dewey Limestone, now that the miscorrelation of both units with the type Drum Limestone Member has been rectified. Good reference sections of the Cement City are located along Kaw Drive 0.6 mi (1 km) west of the I–635 overpass above the principal reference section for the Quivira Shale Member, and along the north side of I–70 (N half sec. 17, T. 11 S., R. 25 E.), 1 to 2 mi (1.6–3 km) to the east. The principal reference section in Kansas is designated along the westbound exit ramp from I–70 to Park Drive/Kaw Drive (E half of NE-NE sec. 18, T. 11 S., R. 25 E.), all in Wyandotte County. The Cement City Limestone Member ranges from 6 to 8 ft (1.8–2.4 m) of mainly wavy-bedded skeletal calcilutite in the Kansas City area, and locally has a bed of skeletal calcarenite up to 1 ft (0.3 m) thick at the top. The Cement City thins gradually southward across eastern Kansas to 2–4 ft (0.6–1.2 m) of brownish-weathering skeletal calcilutite with conspicuous white crinoid columnals. The best reference section in southern Kansas is in the ravine on the west side of the Verdigris River north of Independence at the principal reference section for the entire Dewey Limestone (figs. 26, 27).

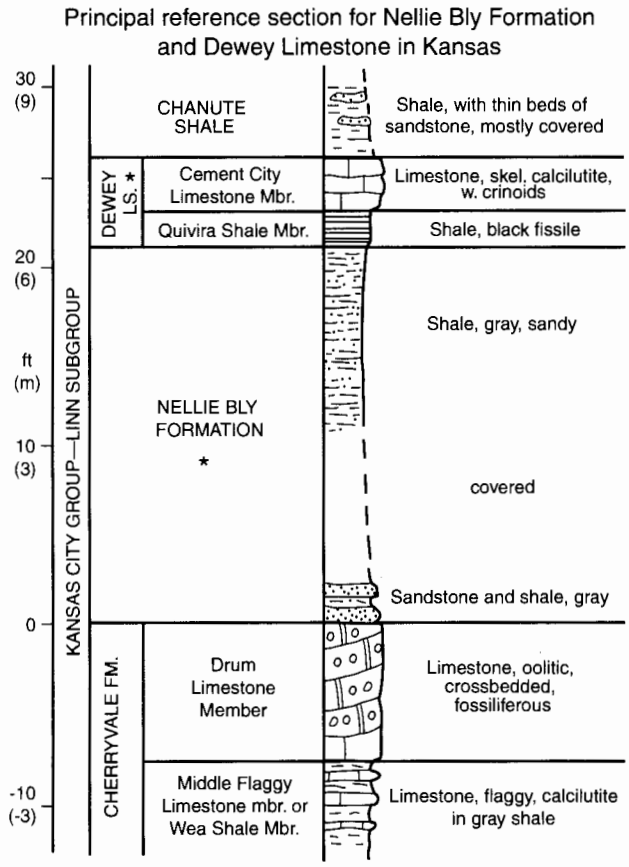


FIGURE 27—Measured section of principal reference sections of Nellie Bly Formation and Dewey Limestone in Kansas, in ravine in Verdigris River bluff just north of center of S line NE sec. 19, T. 32 S., R. 16 E. (fig. 26) on northeastern outskirts of Independence in Montgomery County. Thickness of Drum Limestone Member and underlying unit exposed in riverbank at low water is based on measurements by A. P. Bennison.

Chanute Shale (redefined)

The Chanute Shale is redefined as the unit that overlies the Dewey Limestone (Cement City Limestone Member) and underlies the Iola Limestone (Paola Limestone Member) (fig. 1). Named by Haworth and Kirk (1894) from exposures around Chanute in northwestern Neosho County, the name was stabilized by Moore (1936) to apply to the interval between the Drum Limestone and the Iola Limestone. The only precisely listed typical exposure given by Moore (1936, p. 109) "in SE sec. 33, T. 26 S., R. 18 E." has been rediscovered 1 mi to the east along the center S line SE-SE sec. 34, T. 26 S., R. 18 E., where the Chanute is about 20 ft (6 m) of shale and sandstone (now poorly exposed), but lying on what is now known to be the Cement City Limestone Member of the Dewey Limestone. Therefore, from here northward, where the true Drum Limestone Member is absent and the Cement City was misidentified as Drum, the name Chanute applies to the same interval as previously. In this region, the Chanute Shale averages about 40–50 ft (12–15 m) of dominantly sandstone and sandy shale, thinning northward to 6–15 ft (1.8–4.5 m) of sandy shale with sandstone toward the top in the Kansas City region. Southward from Chanute, the Chanute Shale thickens locally to over 200 ft (60 m) in southern Kansas, where it is dominated by sandstone. In this region, where the true Drum Limestone Member is thick and well exposed and the Dewey Limestone is thin and was generally overlooked, shale and sandstone of the underlying Nellie Bly Formation were included in the Chanute.

South of Independence where the Dewey Limestone was locally removed by pre-Chanute erosion, the basal

contact of the Chanute with the underlying Nellie Bly is marked in places by sandy, rubbly calcarenite, a lithic unit that had been misidentified as the Corbin City Limestone Member (now abandoned) of the Drum Limestone, but is now included in the basal Chanute. Representative exposures of this unit are along W line at SW corner SE sec. 5, T. 33 S., R. 16 E., southeast of Independence; near center of W line of SW-NW sec. 31, T. 34 S., R. 16 E., and near center of S line of SW-SW sec. 6, T. 35 S., R. 16 E., south of Dearing. In other places in this region, the base of the Chanute Shale is marked by a limestone conglomerate (e.g., near center of W line of SW-SW sec. 6, along the old highway at S line SW-NE-NE sec. 6, and along new US–166, near center of N line of NE-NE sec. 6, T. 35 S., R. 16 E., west of Coffeyville, and along the west side of an old quarry between Coffeyville and Independence in NE-NE-NW sec. 33, T. 33 S., R. 16 E.). Clasts in this conglomerate include fragments of marine fossils, skeletal calcilutite, oolite, dense barren calcilutite, shale, and occasional phosphate nodules and pieces of wood. These represent material derived from the Cement City Limestone and Quivira Shale Members of the Dewey Limestone, the Drum oolite, and possibly the middle Cherryvale flags, as well as debris from the old land surface.

Across most of eastern and southern Kansas, the Chanute Shale contains the **Thayer coal bed** (named from Thayer in southern Neosho County) in the middle. This coal bed is locally overlain by a thin dark limestone with scattered unidentified fossils in southern Miami County (US–169 roadcut north of bridge northeast of Osawatomie in SE-SW sec. 1, T. 18 S., R. 22 E.) and in northern Linn County (road ditch 2 mi [3 km] south of Beagle on W line at NW corner, sec. 23, T. 19 S., R. 22 E.). Below the Thayer coal bed, sandstones in the lower Chanute have been referred to the Noxie Sandstone Member (named from the settlement of Noxie in northern Nowata County, Oklahoma). This unit is reduced in rank to **Noxie sandstone bed** because of its lenticularity in most places and lack of lateral delineation of the type Noxie in southern Montgomery County and northern Oklahoma. Sandstones above the Thayer coal bed have been referred to the Cottage Grove Sandstone Member (named from Cottage Grove Township in southern Allen County), which is also reduced in rank to **Cottage Grove sandstone bed** because of lenticularity and lack of lateral delineation of the sandstone body in its type area.

ZARAH SUBGROUP (revised)

The Zarah Subgroup is revised to include the following formations in ascending order (fig. 1): Iola Limestone, Liberty Memorial Shale (reinstated and extended into Kansas from Missouri), Wyandotte Limestone (revised), and Lane Shale (revised). The Iola Limestone is now included in the Zarah Subgroup because the Wyandotte Limestone, which forms the majority of the lower Zarah in northeastern Kansas, rests with little lithic differentiation on top of the Iola Limestone where the intervening Liberty Memorial Shale has pinched out in east-central to southern Kansas. Correction of the long-standing miscorrelation between what is now termed Liberty Memorial Shale in the Kansas City area and the type Lane Shale of east-central Kansas also has necessitated the shifting of the two former upper members of the Wyandotte Limestone into the Lane Shale (figs. 1, 28).

Iola Limestone (upper boundary redefined)

The Iola Limestone overlies the Chanute Shale everywhere, and it underlies the Liberty Memorial Shale in northeastern Kansas and the Wyandotte Limestone in southeastern Kansas (fig. 1). The Iola had previously been considered to underlie the Lane Shale everywhere (fig. 28A), but it is now recognized that the Argentine Limestone Member of the Wyandotte Limestone descends over the southward pinchout of the shale previously called Lane at Kansas City to directly overlie the Iola below the type Lane Shale of western Miami County (fig. 28B). The shale between the Iola and Wyandotte limestones in the Kansas City area is now termed Liberty Memorial, a reinstated Missouri name (see below). The Iola Limestone was named by Haworth and Kirk (1894) for the prominent limestone underlying the town of Iola in Allen County. The type section listed by Moore (1936) is at the now-abandoned and partly water-filled cement plant quarry in Iola (NE sec. 2, T. 25 S., R. 18 E.), but it is now recognized that the interbedded shale and limestone beds above the main thick bed of quarried limestone belong to the overlying Liberty Memorial Shale and Wyandotte Limestone (fig. 28B, section 10). The Iola Limestone comprises three members in ascending order: Paola Limestone, Muncie Creek Shale, and Raytown Limestone.

Paola Limestone Member (unchanged)

The Paola Limestone Member overlies the Chanute Shale and underlies the Muncie Creek Shale Member (figs. 1, 28). It was named by Moore (1932) and defined by Newell (1935) from a composite section along the north edge of Paola in Miami County. The principal reference section is designated in a new roadcut east of the bridge over US–169 on the southeast side of Paola in NE-NW-NW sec. 22, T. 17 S., R. 23 E. (see Heckel et al., 1999, p. 66, Stop D4). Ranging from 1.5 to 2 ft (0.4–0.6 m) of skeletal calcilutite in its type area, the Paola thins northward to 1 ft (0.3 m) in the Kansas City area, thickens southward to 4 ft (1.2 m) in Anderson County, and then thins southward again to 1 ft (0.3 m) or less in southern Kansas.

Muncie Creek Shale Member (unchanged)

The Muncie Creek Shale Member overlies the Paola Limestone Member and underlies the Raytown Limestone

Member (figs. 1, 28). It was named by Moore (1932) and defined by Newell (1935) from exposures near Muncie Creek in Wyandotte County. The principal reference section of the Muncie Creek Shale Member is designated a short distance east of Muncie Creek along Kaw Drive 0.9 mile (1.4 km) west of the I–635 overpass, and 0.3 mile (0.5 km) west of the principal reference section for the Quivira Shale, in NE-SE-SW sec. 12, T. 11 S., R. 24 E. (illustrated by Heckel et al., 1999, p. 24, Stop A4). The Muncie Creek Shale is 2 to 3 ft (0.6–0.9 m) thick and consists of black phosphatic shale overlain and underlain by thinner beds of dark-gray shale in its type area. It thins southward to 0.2 to 0.5 ft (6–15 cm) of gray shale with abundant phosphorite nodules between southern Johnson County and northern Neosho County (as seen at the principal reference section for the Paola Limestone Member in Miami County). Farther southward, the Muncie Creek Shale Member thickens again to 1–3 ft (0.3–0.9 m) of gray and black phosphatic shale in southern Kansas.

Raytown Limestone Member (upper boundary redefined)

The Raytown Limestone Member overlies the Muncie Creek Shale Member, and it underlies the Liberty Memorial Shale in northeastern Kansas and the Wyandotte Limestone in parts of southern Kansas (figs. 1, 28B). Named by Hinds and Greene (1915) from Raytown in Jackson County, Missouri, the principal reference section for the Raytown Limestone Member in Kansas is designated in the roadcut on the southbound I–435 offramp to Holliday Road (NW-NE-NW sec. 6, T. 12 S., R. 24 E.) in northern Johnson County (figs. 29, 30). Another good reference section is above the principal reference section for the Muncie Creek Shale Member along Kaw Drive west of the I–635 overpass. The Raytown Limestone in the Kansas City area averages 7 ft (2.1 m) of mainly skeletal calcilutite. It contains a thin (up to 0.5 ft/15 cm) bed of crinoidal calcarenite at the base, separated by up to 0.5 ft (15 cm) of gray shale from the main mass of limestone and included previously by some in the Muncie Creek Shale Member. The Raytown thickens southward to about 40 ft (12 m) in Allen and northwestern Neosho counties where it forms a phylloid algal mound complex (Heckel and Cocke, 1969), south of which it thins to 5 ft (1.5 m) or less of non-algal sponge-rich calcilutite. Higher beds of limestone above shale now known to be the thinned southwestern extent of the Liberty Memorial Shale were once included in the Raytown Limestone Member in western Miami, Anderson, Allen, and Neosho counties (fig. 28A, sections 6, 9), but are now recognized as the southern facies of the Wyandotte Limestone (fig. 28B, sections 6, 10; see below).

Liberty Memorial Shale (reinstated)

The Liberty Memorial Shale overlies the Iola Limestone (Raytown Limestone Member) and underlies the Wyandotte Limestone (Frisbie Limestone Member and locally the Quindaro Shale Member) in northeastern Kansas (figs. 1, 28B). The name Liberty Memorial was originally applied by Clair (1943) to the shale above the Raytown Limestone and below the Frisbie Limestone Member in Jackson County, Missouri. This name was abandoned after Moore (1948) correlated this unit with the previously named Lane Shale of eastern Kansas. The name Liberty Memorial is now reinstated for exactly the same strata to which it was originally applied because recorrelation (fig. 28) shows that the type Lane Shale in Franklin County, Kansas, actually correlates with the shale interval above the Argentine Limestone Member of the Wyandotte Limestone in Kansas City. The type locality of the Liberty Memorial Shale proposed by Clair (1943) is in Kansas City, Missouri, presumably near a monument of that name in Penn Valley Park (SW sec. 8, T. 49 N., R. 33 W.). The principal reference section for the Liberty Memorial Shale in Kansas is designated along the I–435 southbound offramp to Holliday Road (W half of NE-NW sec. 6, T. 12 S., R. 24 E.) in northern Johnson County (fig. 29). The Liberty Memorial Shale here consists of 40 ft (12 m) of gray shale (fig. 30) with sparse fossils (mainly in the base), zones of ironstone nodules scattered throughout, and thin sandstone beds, particularly toward the top. Both lower and upper boundaries are abrupt contacts of gray, often sandy shale with the underlying and overlying limestone units. The Liberty Memorial Shale thins westward in 4 mi (7 km) to 25 ft (7.5 m) at the intersection of K–7 and K–32 on the east side of Bonner Springs (NW-SW sec. 28, T. 11 S., R. 23 E.). It also thins southward in northern Miami County to 28 ft (8.4 m) in the US–169/K–7 roadcut northeast of Paola (fig. 28B, section 4) just east of Lake Miola (from NE-SE-SW to W line of NW-SE sec. 11, T. 17 S., R. 23 E.). Here the overlying Frisbie Limestone Member has pinched out and the top of the silty, essentially unfossiliferous Liberty Memorial Shale lies in contact with the abundantly fossiliferous and darker Quindaro Shale Member of the Wyandotte Limestone. Westward, the Liberty Memorial thins further to a few feet (1–2 m) in quarries west of Paola (fig. 28B, section 6), where it was included in the upper Raytown Limestone Member (fig. 28A) by previous workers. It is absent in places nearby (K–68 roadcut west of Bull Creek: fig. 28B, section 5) and to the south, where the Wyandotte Limestone rests directly upon the Iola Limestone.

Wyandotte Limestone (revised)

The Wyandotte Limestone, as revised, overlies the Liberty Memorial Shale in northeastern Kansas and the

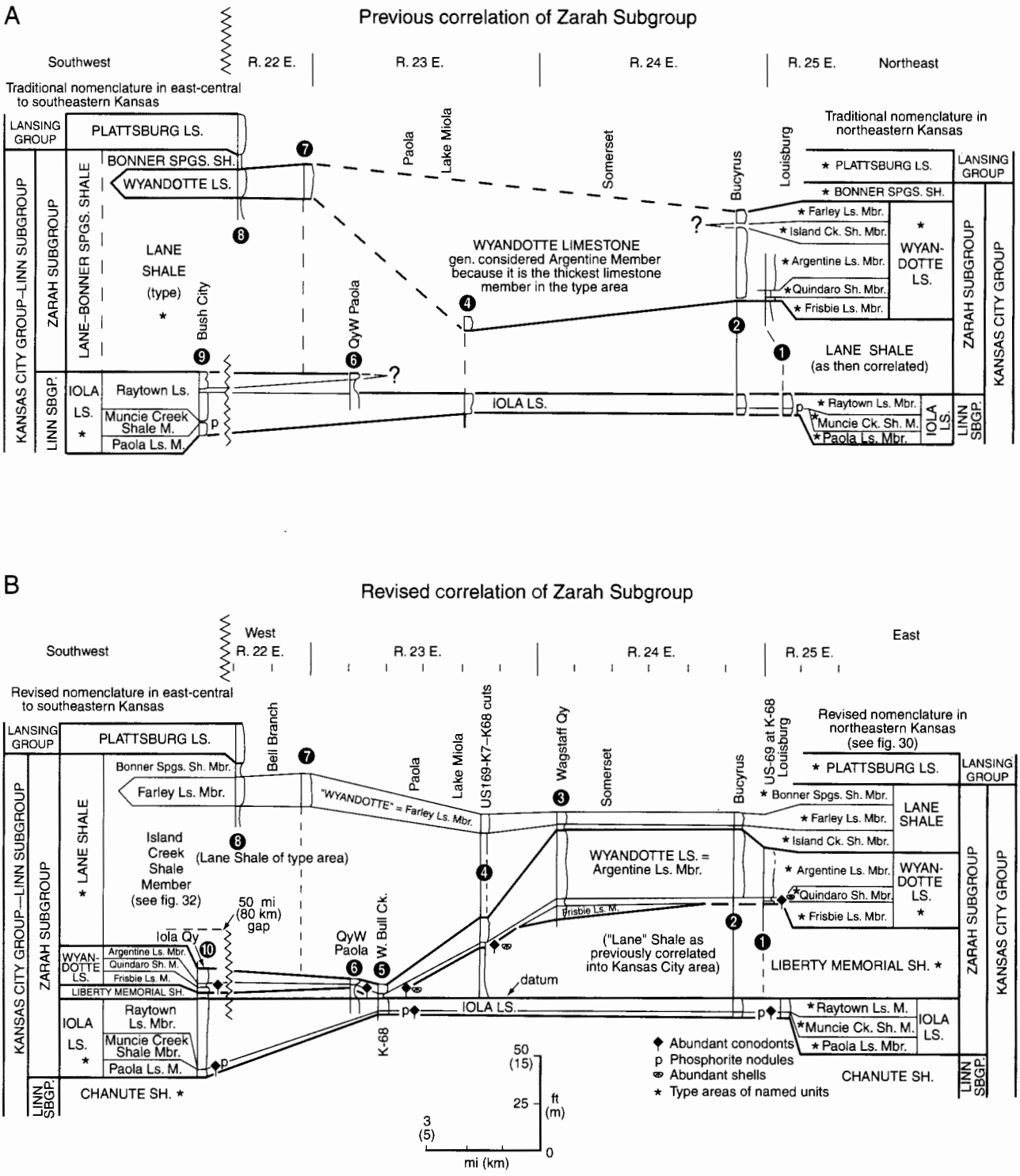


FIGURE 28—A) Previous correlation, nomenclature, and classification of upper middle Missourian (upper Kansas City Group, Zarah Subgroup) strata across Miami County, Kansas, between Kansas City area (where most units were named) and east-central to southeastern Kansas (where fewer units were recognized). B) Revised nomenclature and classification mandated by correction of miscorrelation of Farley Limestone Member in western Miami County with entire Frisbie–Argentine–Farley succession in northeastern Miami County (and northward), and concomitant miscorrelation of type Lane Shale of western Miami County with type Liberty Memorial Shale of Kansas City area. Where range numbers are shown across top, cross section extends along Route K–68 in southern part of T. 16 S., north of Paola in Miami County, Kansas. Datum is top of Raytown Limestone Member. Measured sections indicated by black circled numbers are located in Appendix.

Iola Limestone (Raytown Limestone Member) where the Liberty Memorial Shale is absent in parts of Miami County and southward. It underlies the Lane Shale (Island Creek Shale Member as reclassified) everywhere (figs. 1, 28B). The Wyandotte Limestone was named by Moore (1932) and defined by Newell (1935) from exposures in Wyandotte County, where it forms prominent bluffs along the Kansas River. Because of uncertain access to the typical exposures listed by Moore (1936) in cement plant quarries at the east edge of Bonner Springs (sec. 28, T. 11 S, R. 23 E.), the principal reference section for the Wyandotte Limestone and all its currently recognized members is designated 4 mi (6.4 km) eastward along the southbound offramp from I–435 to Holliday Road (NE-NW sec. 6, T. 12 S., R. 24 E.) in northernmost Johnson County (fig. 29). The Wyandotte Limestone is now revised to comprise only its former three lower members, in ascending order: Frisbie Limestone, Quindaro Shale, and Argentine Limestone Members (figs. 1, 28B, 30). This is because the previously included Island Creek Shale Member (fig. 28A), above the Argentine Limestone, is now known to correlate with the thick type Lane Shale in Miami County (fig. 28B). This recorrelation resulted from discovery that the Argentine Limestone Member thins dramatically in Miami County as it descends over the southwestward-thinning underlying Liberty Memorial Shale to overlie the Iola Limestone, with only the thin Quindaro Shale Member intervening, in the Lane Shale type area. The Island Creek Shale Member and the overlying Farley Limestone Member (formerly at the top of the Wyandotte and previously thought to constitute the entire formation in the Lane type area) are now included with the overlying Bonner Springs Shale Member as members of the revised Lane Shale (figs. 1, 28B, 30). The Wyandotte Limestone, as revised, averages 30–40 ft (9–12 m) thick in northeastern Kansas, thinning southward to an average of 5 ft (1.5 m) in southeastern Kansas.

Frisbie Limestone Member (unchanged)

The Frisbie Limestone Member is the basal member of the Wyandotte Limestone, lying above the Liberty Memorial Shale and below the Quindaro Shale Member (fig. 1). It was named by Moore (1932) and defined by Newell (1935) from a now poorly exposed outcrop east of the old railroad station of Frisbie in north-central Johnson County (center of N line sec. 17, T. 12 S., R. 23 E.). The principal reference section is designated 5 mi (8 km) to the east at the principal reference section for the entire Wyandotte Limestone along the southbound I–435 offramp to Holliday Road (figs. 29, 30). The Frisbie Limestone Member is generally a thin 1–5 ft (0.3–1.5 m)-thick dense skeletal calcilutite, which pinches out southwestward above the southwestward-thinning Liberty Memorial Shale in central Miami County.

Quindaro Shale Member (unchanged)

The Quindaro Shale Member overlies the Frisbie Limestone Member (or the Liberty Memorial Shale or Raytown Limestone Member southward) and underlies the Argentine Limestone Member of the Wyandotte Limestone (fig. 1). It was named by Moore (1932) and defined by Newell (1935) from exposures at Boyne's quarry (NW sec. 30, T. 10 S., R. 25 E.) in Quindaro Township in northeastern Wyandotte County. Because of uncertain access to this area, the principal reference section for the Quindaro Shale is designated 10 mi (16 km) to the southwest at the principal reference section for the entire revised Wyandotte Limestone at the entrance to the southbound offramp from I–435 to Holliday Road in northern Johnson County (figs. 29, 30). The Quindaro Shale Member is 0.4 ft (12 cm) of fossiliferous dark-gray shale at the reference section and ranges up to 1–3 ft (0.3–0.9 m) locally in northeastern Kansas as seen along US–69 just north of the K–68 overpass (SE corner sec. 25, T. 16 S., R. 24 E.) west of Louisburg (fig. 28B, section 1). Southwestward, the Quindaro averages about 1 ft (0.3 m) of conspicuously fossiliferous shale, lying upon the essentially unfossiliferous Liberty Memorial Shale in the US–169/K–7 roadcut east of Lake Miola (E line at NE corner of SW sec. 11, T. 17 S., R. 23 E.; fig. 28B, section 4) and upon the Raytown Limestone Member of the Iola Limestone in the K–68 roadcut west of Bull Creek (center of S line of SE sec. 29, T. 16 S., R. 23 E.) in Miami County (fig. 28B, section 5). The Quindaro Shale Member is often not differentiated from the argillaceous Argentine Limestone Member in southern Kansas, but can be identified in the quarry at Iola (fig. 28B, section 10).

Argentine Limestone Member (unchanged, but recorrelated southward)

The Argentine Limestone Member overlies the Quindaro Shale Member and underlies the Island Creek Shale Member of the Lane Shale as revised (figs. 1, 28B; see below). It was named by Moore (1932) and defined by Newell (1935) from an exposure (south of center N line sec. 29, T. 11 S., R. 25 E.) near Argentine Station on the south side of Kansas City in Wyandotte County. Because of current poor exposure there, the principal reference section is designated 7 mi (11 km) to the west at the principal reference section for the entire revised Wyandotte Limestone along the southbound offramp from I–435 to Holliday Road in northern Johnson County (figs. 29, 30). The Argentine ranges from 25 to 35 ft (7.5–10.5 m) of algal-rich skeletal calcilutite locally capped by abraded skeletal calcarenite from the Kansas City area to northern Miami County. It thins southward in central Miami County to 11 ft (3.3 m) of nonalgal skeletal calcilutite above the southward-thinning Liberty Memorial Shale at the US–169/K–7 roadcut east of Lake

Miola (E line NE-SW sec. 11, T. 17 S., R. 23 E.; fig. 28B, section 4). It thins westward to 4 ft (1.2 m) of similar rock in the K–68 roadcut (center S line SE sec. 29, T. 16 S., R. 23 E.) west of Bull Creek where it is separated from the top of the Iola Limestone by only the thin Quindaro Shale Member (fig. 28B, section 5). Farther southward, the Argentine Limestone Member averages about 5 ft (1.5 m) of argillaceous limestone with conspicuous crinoid and other skeletal debris resting on top of the Raytown Member of the Iola Limestone, as exposed along the US–169 roadcut at Chanute in Neosho County (E line NW sec. 19, T. 27 S., R. 18 E.).

Lane Shale (revised)

The Lane Shale now is recognized to overlie the Wyandotte Limestone (Argentine Limestone Member) and underlie the Plattsburg Limestone (Merriam Limestone Member) throughout Kansas (fig. 1). First used by Haworth and Kirk (1894) and stabilized by Moore (1936), the term Lane Shale (from the village of Lane in southeastern Franklin County) is revised to comprise in ascending order: Island Creek Shale Member, Farley Limestone Member, and Bonner Springs Shale Member. It has been determined that the type Lane Shale (fig. 28A) as recognized by Moore (1936) correlates with the Island Creek Shale Member between the Argentine and Farley Limestone Members (fig. 28B), all previously included in the Wyandotte Limestone. It also has been determined that the Farley Limestone Member is lenticular (extending only from northeastern Anderson County, Kansas, to the Missouri–Iowa border) within a much larger body of shale that extends along the entire outcrop belt. Therefore, it seems most appropriate to recognize the larger body of shale as a formation with more laterally continuous boundaries and to maintain the coherence of the Wyandotte Limestone as a dominantly limestone formation below, than to employ any other scheme of subdividing this part of the Zarah Subgroup. Therefore, the Island Creek Shale Member and Farley Limestone Member are removed from the Wyandotte Limestone and combined with the Bonner Springs Shale (which is reduced in rank to member) to constitute an expanded Lane Shale (fig. 28B). The lower boundary is the basal contact between gray shale and the underlying Argentine Limestone Member, and the upper boundary is the upper contact between shale, mudstone, or sandstone with the overlying Merriam Limestone Member.

Because complete exposures of the entire Lane Shale as revised are not available in the immediate type area, a neostratotype that encompasses the entire Lane interval is established in Miami County, 5 mi (8 km)

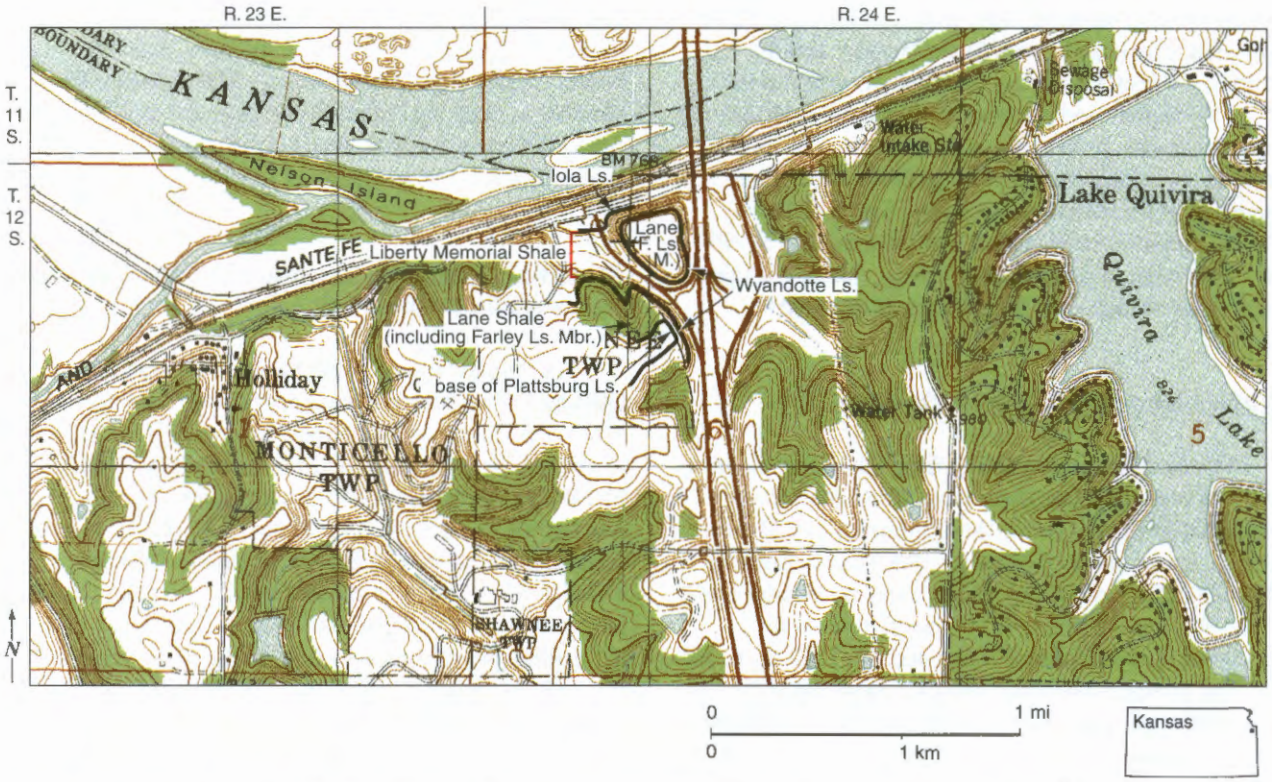


FIGURE 29—Map of part of 1991 Edwardsville, Kansas, 7 1/2-minute quadrangle, showing location of principal reference sections of Liberty Memorial Shale in Kansas, Wyandotte Limestone and its three members, and Island Creek Shale and Farley Limestone Members of Lane Shale, along ramps from I–435 to Holliday Road, east of Holliday in Johnson County. Lower formations are best exposed on east side of southbound offramp; higher units (upper part of Argentine Limestone Member and above) are easily accessible only above southbound onramp on southwest side. Farley Limestone Member (F.Ls.M.) of Lane Shale caps isolated hill on northeast side of offramp.

northeast of Lane, along the west line of sec. 28, T. 18 S., R. 22 E. (fig. 31). It extends from the top of the Wyandotte Limestone (center W line NW sec. 28, which rests on the Iola Limestone in a quarry in NW-SE sec. 20, T. 18 S., R. 22 E.) up to the base of the Plattsburg Limestone (N of SW corner sec. 28, T. 18 S., R. 22 E.). Here, the Lane interval is 135 ft (40.5 m) thick, and all three members are at least partially exposed (fig. 32). Southward the Farley Limestone Member disappears in northeastern Anderson County, and undivided Lane Shale (formerly termed Lane–Bonner Springs) extends through east-central and southeastern Kansas as 50 to 160 ft (15–48 m) of sandy shale in prominent bluffs held up by the overlying Plattsburg Limestone. It merges southward with the lower part of the Wann Formation in northern Oklahoma.

Island Creek Shale Member (recorrelated and reclassified)

The Island Creek Shale Member overlies the Argentine Limestone Member of the Wyandotte Limestone and underlies the Farley Limestone Member (figs. 1, 28B), as originally named by Moore (1932) and defined by Newell (1935) from an old quarry near Island Creek in northwestern Wyandotte County (at NW corner

Principal reference sections of Liberty Memorial Shale in Kansas, Wyandotte Limestone and its three members (Frisbie Limestone, Quindaro Shale, Argentine Limestone), Island Creek Shale and Farley Limestone Members of Lane Shale, and Raytown Limestone Member of Iola Limestone in Kansas

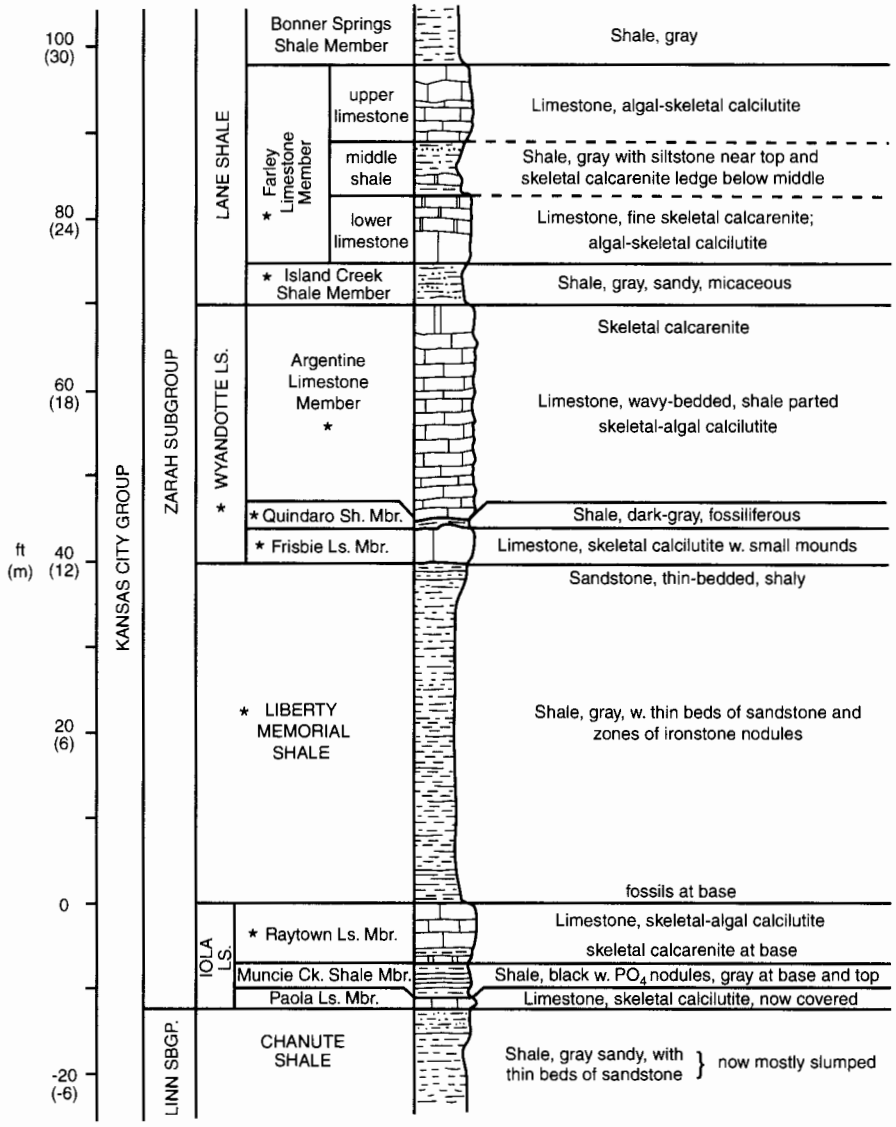


FIGURE 30—Measured section of principal reference sections of Liberty Memorial Shale, Wyandotte Limestone and its three members, and Island Creek Shale and Farley Limestone Members of Lane Shale and also of Raytown Limestone Member of Iola Limestone in Kansas, along southbound I–435 ramps to and from Holliday Road in NE-NW sec. 6, T. 12 S., R. 24 E. (fig. 29), 1 mi (1.6 km) east of Holliday, Johnson County, Kansas, slightly modified from Heckel (1988, p. 49). See also Heckel et al. (1999, p. 26, Stop A5) and cover photograph of this bulletin.

sec. 11, T. 10 S., R. 23 E.). Because the type locality now is poorly exposed, the principal reference section is selected 11 mi (18 km) southward, along the southbound onramp from Holliday Road to I–435 (NW sec. 6, T. 12 S., R. 24 E.) in northernmost Johnson County, where the Island Creek is 5 ft (1.5 m) of sandy shale (fig. 30). The Island Creek Shale Member thickens northward to a reported 40 ft (12 m) in its type area. It remains thin south of its principal reference section into northern Miami County, where it is 2 ft (0.6 m) thick in the quarry 2 mi (3 km) south of Wagstaff (SE-NW sec. 30, T. 16 S., R. 24 E.; fig. 28B, section 3). It then thickens abruptly southwestward to an interval about 45 ft (13.5 m) thick (fig. 28B, section 4) between the Farley Limestone exposed along K–68 (N line NW-NW-NE sec. 35, T. 16 S., R. 23 E.) and the descending top of the Argentine Limestone exposed just to the southwest along the northbound offramp of US–169/K–7 to K–68 (W line SW-NW-NE sec. 35). It thickens southwestward further to 70 to 110 ft (21–33 m) as the main part of the Lane Shale in its type area of western Miami and eastern Franklin County (figs. 28B, 32). There it consists mainly of gray micaceous silty shale with marine fossils toward the base and locally plant-bearing sandstone toward the top.

Farley Limestone Member (reclassified)

The Farley Limestone Member overlies the Island Creek Shale Member and underlies the Bonner Springs Shale Member in northeastern Kansas (fig. 1). It was named by Hinds and Greene (1915) from Farley in Platte County, Missouri, north of Kansas City, as the middle part of the Lane Shale as then understood in Missouri, but it was included as the top of the Wyandotte Limestone by Newell (1935). With the recent recorrelation of the Island Creek Shale Member (formerly in the Wyandotte Limestone) with the type Lane Shale in western Miami County, Kansas (see previous section), the Farley Limestone Member is removed from the top of the Wyandotte and placed back into the Lane Shale (fig. 28B). The principal reference section of the Farley Limestone Member in Kansas is along the southbound onramp from Holliday Road to I–435 (NW sec. 6, T. 12 S., R. 24 E.; fig. 29), where it comprises three units: lower Farley limestone, 8 ft (2.4 m) thick; middle Farley shale, 6 ft (1.8 m) thick; and upper Farley limestone, 9 ft (2.7 m) thick (fig. 30); these three units are differentiated with varying thicknesses northward into the type area. Southward, the middle shale disappears, and the undivided Farley Limestone Member

FIGURE 31—Map of part of 1963 Osawatomie, Kansas, 7 1/2-minute quadangle, showing location of neostratotype of Lane Shale along road 5 mi (8 km) northeast of Lane in Miami County. Vertical section of underlying Wyandotte and Iola Limestones is exposed in quarry to northwest, just off map in NW-SE sec. 20, T. 18 S., R. 22 E.

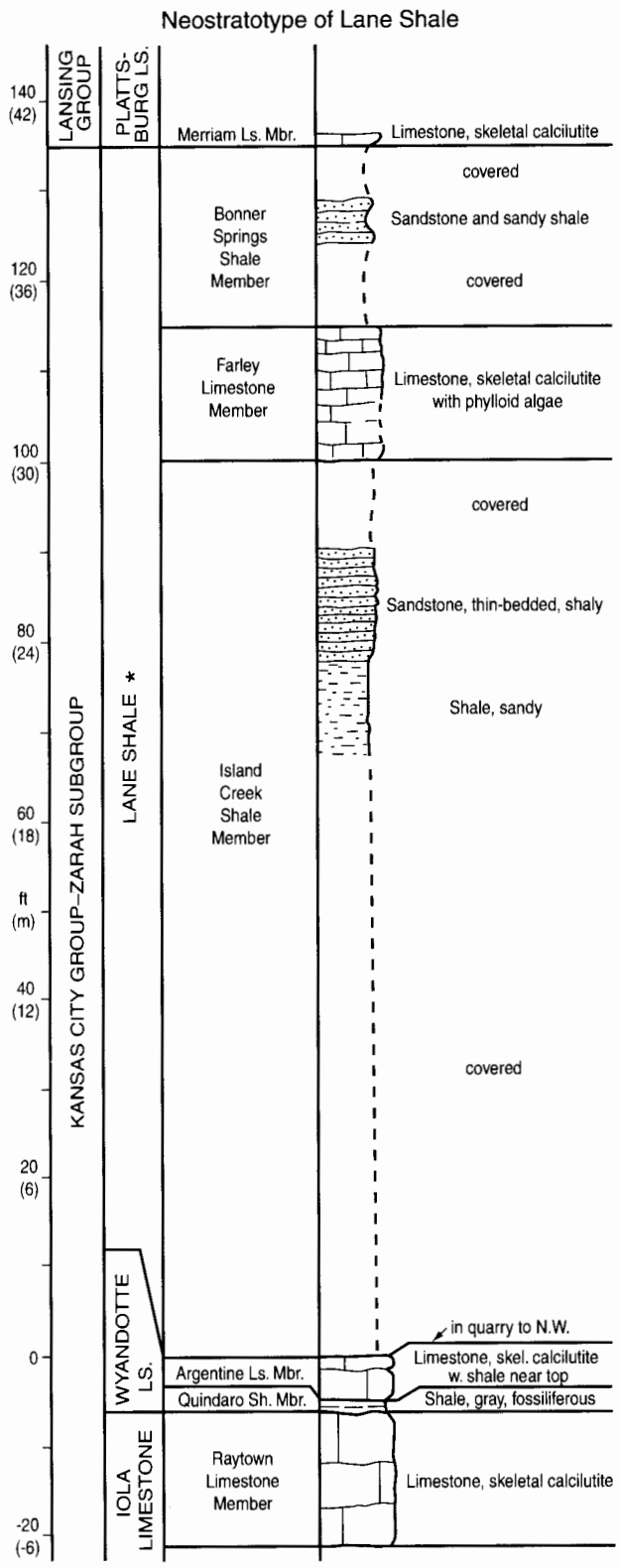


FIGURE 32—Measured section of Lane Shale neostratotype along N–S road north of US–169 between Lane and Osawatomie, along west line of sec. 28, T. 18 S., R. 22 E. (fig. 31), Miami County, Kansas, with Iola–Wyandotte succession projected in from quarry about 0.6 mi (1 km) to northwest, in NW-SE sec. 20 of this township.

is 16 ft (4.8m) thick along K–68 west of Paola, where it was once thought to represent the entire Wyandotte Limestone (fig. 28A, sections 7, 8). It attains 40 ft (12 m) as an algal mound complex in northwestern Linn County (NW-SW sec. 23, T. 19 S., R. 21 E.) before thinning and pinching out into the undivided Lane Shale near Greeley in Anderson County.

Bonner Springs Shale Member (reduced in rank and reclassified)

The Bonner Springs Shale Member overlies the Farley Limestone Member and underlies the Plattsburg Limestone in northeastern Kansas, and is now recognized as the upper member of the revised Lane Shale (figs. 1, 28B). It was named by Moore (1932) and defined as a formation by Newell (1935) from exposures northeast of Bonner Springs in western Wyandotte County. Because the Bonner Springs Shale Member can be differentiated from the shale beneath the Farley Limestone Member only where the Farley is present in northeastern Kansas, the Bonner Springs is reduced in rank to a member and included in the revised Lane Shale, which extends southward undivided far beyond the extent of the lenticular Farley Limestone Member. The principal reference section of the Bonner Springs Shale Member is in a roadcut on K–7 in SW-SE-NE sec. 29, T. 11 S., R. 23 E. on the northeast side of Bonner Springs, where it is 21 ft (6.3 m) of gray shale with shaly sandstone to sandy conglomeratic limestone in the top. The Bonner Springs Shale Member ranges from a few feet up to 25 ft (7.5 m) in thickness and includes lenticular reddish mudstones and fractured limestone masses as well as sandstone and conglomerate toward the top.

Lansing Group (redefined)

The Lansing Group overlies the Kansas City Group and underlies the Douglas Group. It comprises in ascending order, Plattsburg Limestone, Vilas Shale, Stanton Limestone, Rock Lake Shale, and South Bend Limestone (fig. 1). The latter two units are removed from the Stanton Limestone and raised in rank to formations, but are retained in the Lansing Group.

Plattsburg Limestone (unchanged)

The Plattsburg Limestone overlies the Lane Shale (Bonner Springs Shale Member) and underlies the Vilas Shale (fig. 1). It comprises, in ascending order, the Merriam Limestone Member, Hickory Creek Shale Member, and Spring Hill Limestone Member. Named from Plattsburg, Missouri, by Broadhead (1868), the principal reference section for the Plattsburg Limestone in Kansas is designated above that of the Bonner Springs Shale Member in the K–7 roadcut (SW-SE-NE sec. 29,

T. 11 S., R. 23 E.) on the northeast side of Bonner Springs in Wyandotte County (see Heckel et al., 1999, p. 26, Stop A6). A good reference section for southeastern Kansas is in the K–47 roadcut west of Altoona in Wilson County (NW corner sec. 17, T. 29 S., R. 16 E.; see Heckel, 1988, p. 53).

Merriam Limestone Member (unchanged)

The Merriam Limestone Member overlies the Bonner Springs Shale Member of the Lane Shale, and underlies the Hickory Creek Shale Member across eastern Kansas (fig. 1). Named from Merriam in Johnson County, Kansas, by Moore (1932) and defined by Newell (1935), its principal reference section is designated in the same place as that for the Plattsburg Limestone in the K–7 roadcut at Bonner Springs in Wyandotte County. The upper part of the Merriam Limestone Member is typically 1–2 ft (0.3–0.6 m) of laterally persistent skeletal calcilutite. The lower part is locally up to 9 ft (2.7 m) of lenticular skeletal to oolitic and conglomeratic calcarenite, developed at various places, mostly in northeastern Kansas.

Hickory Creek Shale Member (unchanged)

The Hickory Creek Shale Member overlies the Merriam Limestone Member and underlies the Spring Hill Limestone Member across eastern Kansas (fig. 1). Named by Moore (1932) and defined by Newell (1935) from exposures near Hickory Creek in eastern Franklin County, its principal reference section is designated on the south side of K–68 just east of the bridge over Hickory Creek (NE corner of NW sec. 32, T. 16 S., R. 21 E.). The Hickory Creek generally ranges from 0.5 to 2 ft (0.2–0.6 m) of fossiliferous gray to dark-gray shale in northeastern Kansas, thickening southward to 5 ft (1.5 m) at the Plattsburg Limestone reference section along K–47 in Wilson County and locally to 40 ft (12 m) in northern Montgomery County. Southward, the Hickory Creek Shale Member is identified near the middle of the Wann Formation of northern Oklahoma.

Spring Hill Limestone Member (unchanged)

The Spring Hill Limestone Member overlies the Hickory Creek Shale Member and underlies the Vilas Shale (fig. 1). Named from Spring Hill in southern Johnson County by Moore (1932) and defined by Newell (1935), its incomplete type section in a railroad cut (SE corner of sec. 14, T. 15 S., R. 23 E.) on the east side of town is supplemented by a principal reference section along the east side of US–169 (near center S line SE-SE sec. 10, T. 15 S., R. 23 E.) on the northwest side of town. The Spring Hill Limestone Member averages 15 ft (4.5 m) thick and consists generally of skeletal calcilutite overlain by skeletal to oolitic calcarenite in northeastern Kansas. It is developed southward largely as two distinct phylloid algal mound complexes up to 45 ft (13.5 m) thick in Anderson County and up to 70 ft (21 m) thick in southern Wilson County (Heckel and Cocke, 1969). It consists of thinner shalier calcilutite containing conspicuous calcisponges between the two mound complexes and southward toward the Oklahoma border.

Vilas Shale (unchanged)

The Vilas Shale overlies the Plattsburg Limestone (Spring Hill Limestone Member) and underlies the Stanton Limestone (Captain Creek Limestone Member) (fig. 1). It was named by Adams (1898) from Vilas in Wilson County, where it is about 100 ft (30 m) of gray micaceous sparsely fossiliferous shale. The principal reference section is designated about 6 mi (10 km) to the southwest along US–75 (west line SW sec. 22, T. 28 S., R. 16 E.), 4 mi (7 km) north of Altoona. A completely exposed reference section is along K–47 above that of the Plattsburg Limestone (near NE corner sec. 18, T. 29 S., R. 16 E.) just west of Altoona, where the Vilas Shale is only 25 ft (7.5 m) thick. It thins further to 1 ft (0.3 m) above the thickest parts of the underlying Spring Hill mound complexes in both Wilson and Anderson counties. It then thickens again southward and merges with the upper part of the Wann Formation in northern Oklahoma. The Vilas Shale ranges from 5 to 30 ft (1.5–9 m) thick in northeastern Kansas, where it contains mudstone, thin unfossiliferous earthy limestones, and local sandstone beds in gray sandy shale.

Stanton Limestone (revised)

The Stanton Limestone overlies the Vilas Shale and is now recognized to underlie the Rock Lake Shale across eastern Kansas (figs. 1, 33). The Rock Lake Shale and South Bend Limestone, once considered its upper two members, are now removed from the Stanton Limestone and raised in rank to separate formations. This is because the South Bend Limestone is now itself subdivided into members, and the Rock Lake Shale consists of deposits that represent widespread subaerial exposure, making the two units depositionally distinct from the remaining underlying members. The Stanton Limestone now comprises only three members, in ascending order, Captain Creek Limestone Member, Eudora Shale Member, and Stoner Limestone Member. The upper boundary of the Stanton Limestone is now the upper contact of the Stoner Limestone (or its equivalent named beds to the south), with mudstone, sandstone, or shale of the overlying Rock Lake Shale.

The Stanton Limestone was named by Swallow and Hawn (1865) from Stanton in western Miami County. Newell (1935) pragmatically resolved a problem of miscorrelation of the original type Stanton by retaining the name for the unit to which it had become commonly applied (see comment under the first guideline in the introduction). Shortly thereafter, Moore (1936) desig-

nated typical exposures in roadcuts near SE corner of sec. 3, T. 13 S., R 21 E. in eastern Douglas County about 25 mi (40 km) to the north. A better exposure (about 2.5 mi/4 km eastward) of the complete Stanton Limestone as now recognized is designated as its principal reference section, along the westbound onramp from Edgerton Road to K–10 in westernmost Johnson County (NE-SE-SE sec. 36, T. 12 S., R. 21 E.). The Stanton Limestone averages between 25 and 35 ft (7.5–10.5 m) in thickness in its type region of northeastern Kansas. It thickens steadily southward across southeastern Kansas to 95 ft (28.5 m) at a nearly completely exposed reference section in the roadcut west of the Elk City Dam (from W half of NE to SE-NW sec. 7, T. 32 S., R. 15 E.) in central Montgomery County. Here most of the thickening occurs as phylloid algal mound facies in both limestone members (Heckel and Cocke, 1969). From here it thins southward to about 20 ft (6 m) of mainly shale with thin siltstone and limestone beds (Heckel, 1975a) in southern Montgomery County. The Stanton Limestone is equivalent to part of the Barnsdall Formation of northern Oklahoma (see fig. 33).

Captain Creek Limestone Member (new beds recognized)

The Captain Creek Limestone Member overlies the Vilas Shale and underlies the Eudora Shale Member across eastern Kansas (fig. 1). Named by Newell (1935) from Captain Creek east of Eudora in eastern Douglas County, with a type locality designated by Moore (1936), its principal reference section is designated nearby, along a gravel road just north of K–10 (SE-SE-SW sec. 3, T. 13 S., R. 21 E.) about 2.5 mi (4 km) southwest of that for the Stanton Limestone. The Captain Creek is about 5–8 ft (1.5–2.4 m) of skeletal calcilutite in northeastern Kansas, thickening steadily southward to 50 ft (15 m) of largely phylloid algal mound facies in central Montgomery County (Heckel and Cocke, 1969). Southward it thins to 1–2 ft (0.3–0.6 m) of yellow-weathering sponge-rich skeletal calcilutite (Heckel, 1975a).

The **Benedict limestone bed** is a distinctive bed at the base of the Captain Creek in Wilson, Woodson, and Allen counties, named by Heckel (1975b) from Benedict in central Wilson County. It is 4 ft (1.2 m) of dense fossiliferous oolitic calcarenite overlain by 2 ft (0.6 m) of shale at its type section along the road northeast of town (SE-NE-NE-NE sec. 10, T. 28 S., R. 15 E.). It contains large stromatolite heads and lenses of brachiopod-bearing calcarenite to the northeast, and red-algal-dominated calcilutite beds southward. These latter beds are well exposed above greatly thinned Vilas Shale (above the thick Spring Hill algal-mound complex in the Plattsburg Limestone) along the K–96 roadcut west of Neodesha (SE-SW sec. 23, T. 30 S., R. 15 E.).

The **Tyro oolite bed** forms the south end of the Captain Creek Limestone Member below the southward-thinning sponge-rich calcilutite facies in southern Montgomery County. Named by Heckel (1975a), it is at least 15 ft (4.5 m) of oolite at its type section in an old quarry (NW-SW-SE sec. 30, T. 34 S., R. 15 E.), 1 mi (1.6 km) northeast of Tyro. From here it thins both northward across T. 34 S., and southward into Oklahoma.

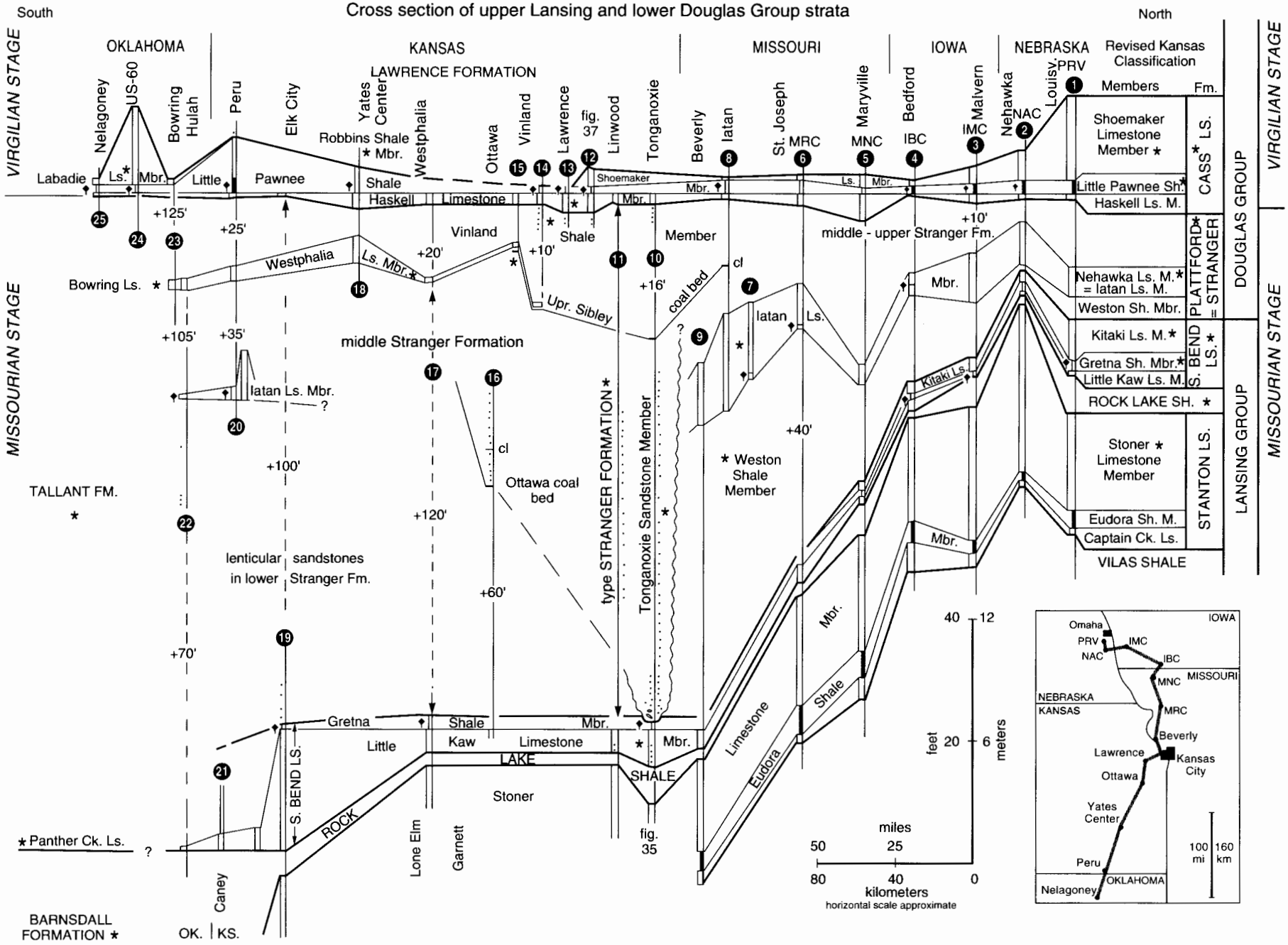
Eudora Shale Member (unchanged)

The Eudora Shale Member overlies the Captain Creek Limestone Member and underlies the Stoner Limestone Member (figs. 1, 33). Named by Condra (1930) from Eudora in eastern Douglas County, the principal reference section is just above that of the Captain Creek Limestone Member along the gravel road north of K–10 (SE-SE-SW sec. 3, T. 13 S., R. 21 E.), just east of Eudora. The Eudora is 5–8 ft (1.5–2.4 m) of gray shale with black phosphatic shale in the middle in northeastern Kansas, thinning to less than a foot of gray phosphatic shale in east-central Kansas. It thickens to up to 50 ft (15 m) of fossiliferous shale with the thin black phosphatic facies at the base in central Montgomery County, just south of the Captain Creek algal-mound complex. In this area, its upper boundary is the upper contact of shale with siltstone or limestone beds classified with the overlying Stoner Limestone Member. The Eudora Shale Member then thins generally to about 20 ft (6 m) in southern Montgomery County, and locally to 1 ft (0.3 m) above the type Tyro oolite bed in the Tyro quarry, where it is abruptly overlain by conglomeratic sandstone at the base of the Rock Lake Shale.

Stoner Limestone Member (new beds recognized)

The Stoner Limestone Member overlies the Eudora Shale Member and underlies the Rock Lake Shale, now recognized as a separate formation (figs. 1, 33). The Stoner Limestone Member was named by Condra (1930) from the Stoner farm near South Bend, in Cass County, Nebraska. Its principal reference section in Kansas is the same as that for the entire Stanton Limestone along the westbound onramp from Edgerton Road to K–10 (NE-SE-SE sec. 36, T. 12 S., R. 21 E.) in western Johnson County. The Stoner Limestone ranges from 12 to 18 ft (3.6–5.4 m), mainly of skeletal calcilutite locally overlain by skeletal calcarenite and rubbly calcilutite in northeastern Kansas. Southward it reaches as much as 40 ft (12 m) in thickness, including phylloid algal facies, in northern Montgomery County before grading southward into a succession of marine shale, siltstone, and limestone, in which several named beds are recognized.

The **Timber Hill siltstone bed**, 2–4 ft (0.6–1.2 m) thick, overlies the Eudora Shale Member and underlies the Rock Lake Shale (and the Rutland limestone bed southward) in west-central Montgomery County. It was named by Heckel (1975a) from a roadcut (near center W line NW sec. 25, T. 32 S., R. 14 E.) on the east side of


Cross section of upper Lansing and lower Douglas Group strata
South
North
OKLAHOMA
KANSAS
MISSOURI
IOWA
NEBRASKA
LAWRENCE FORMATION
Revised Kansas Classification
Members
Fm.
VIRGILIAN STAGE
MISSOURIAN STAGE
DOUGLAS GROUP
LANSING GROUP
Shoemaker Limestone Member *
Little Pawnee Sh.*
Haskell Ls. M.
CASS * LS.
PLATTFORD * = STRANGER
Nehawka Ls. M.* = Iatan Ls. M.
Weston Sh. Mbr.
Kitaki Ls. M.*
Gretna Sh. Mbr.*
Little Kaw Ls. M.
S. BEND LS. *
ROCK LAKE SH. *
Stoner * Limestone Member
Eudora Sh. M.
Captain Ck. Ls.
STANTON LS.
VILAS SHALE
middle - upper Stranger Fm.
middle Stranger Formation
type STRANGER FORMATION *
Tonganoxie Sandstone Member
* Weston Shale Member
Ottawa coal bed
lenticular sandstones in lower Stranger Fm.
TALLANT FM. *
BARNSDALL FORMATION *
* Panther Ck. Ls.
OK. | KS.
Caney
Lone Elm
Garnett
fig. 35
Labadie
Nelagoney
Bowring
Hulah
Peru
Elk City
Yates Center
Robbins Shale * Mbr.
Westphalia
Ottawa
Vinland
Lawrence
fig. 37
Linwood
Tonganoxie
Beverly
Iatan
St. Joseph
Maryville
Bedford
Malvern
Nehawka
Louisv.
NAC
PRV
MRC
MNC
IBC
IMC
Ls.
Mbr.
Shale
Limestone
Haskell
Shoemaker
Little
Pawnee
Bowring Ls. *
Westphalia Ls. Mbr. *
Vinland Shale
Upr. Sibley
coal bed
cl
Iatan Ls.
Iatan Ls. Mbr.
Kitaki Ls.
Gretna Shale Mbr.
Little Kaw Limestone Mbr.
LAKE SHALE
Stoner
ROCK
S. BEND LS.
Limestone
Shale
Eudora
Mbr.
+125'
+25'
+20'
+10'
+16'
+40'
+105'
+35'
+100'
+120'
+60'
+70'
feet
meters
40
20
12
6
miles
50
25
80
40
0
kilometers
horizontal scale approximate
IOWA
Omaha
PRV
NAC
IMC
IBC
MNC
MISSOURI
NEBRASKA
KANSAS
MRC
Beverly
Lawrence
Kansas City
Ottawa
Yates Center
Peru
Nelagoney
OKLAHOMA
100 mi
160 km

Timber Hill, where it is hard calcareous siltstone. From here it extends southward to cap Walker Mound in NE sec. 5, T. 33 S., R. 15 E., where it contains sparse brachiopods.

The **Rutland limestone bed** overlies the Timber Hill siltstone bed, and underlies the Rock Lake Shale in west-central Montgomery County. It was named by Heckel (1975a) from a quarry in Rutland Township (NE corner sec. 2, T. 33 S., R. 14 E.), where it is up to 8 ft (2.4 m) of orange-brown-weathering, abraded-grain skeletal calcarenite (mostly grainstone), which appears to be equivalent to the top of the Stoner Limestone Member. The Rutland bed thins and extends southward to sec. 12, T. 33 S., R. 14 E.

The **Bolton limestone bed** overlies the Eudora Shale Member and underlies the Rock Lake Shale in southern T. 33 S. and northern T. 34 S. in southern Montgomery County. Named by Heckel (1975a) from a railroad cut (center S half NW-NW sec. 36, T. 33 S., R. 14 E.) southwest of Bolton, it is 1–4 ft (0.3–1.2 m) of argillaceous skeletal calcarenite (mostly packstone), which appears to be equivalent to the lower part of the Stoner Limestone Member.

Rock Lake Shale (raised in rank)

The Rock Lake Shale overlies the revised Stanton Limestone (Stoner Limestone Member) and underlies the revised South Bend Limestone (Little Kaw Limestone Member) across eastern Kansas (figs. 1, 33). It is removed from the Stanton Limestone and elevated to the rank of formation because it comprises mainly terrestrial deposits that represent widespread exposure and disconformity after the close of a major cycle of marine deposition, like many of the shale formations (e.g., Vilas, Chanute, Nellie Bly, Galesburg) lower in the succession. Named from Rock Lake in Sarpy County, Nebraska, by Condra (1927), its principal reference section in Kansas is a roadcut on the northeast side of K–7 (center west line NW sec. 8, T. 11 S., R. 23 E.) just south of US–40 (fig. 34) and about 3 mi (5 km) north of Bonner Springs in western Wyandotte County. Here it is 6 ft (1.8 m) of gray mudstone to micaceous shale with thin sandstone beds (fig. 35). The Rock Lake Shale ranges from 1 to 3 ft (0.3–0.9 m) of gray mudstone up to 15 and locally 50 ft (4.5–15 m) of sandstone-dominated interval across most of eastern Kansas. Sandstones in the Rock Lake generally are friable, noncalcareous, often reddish-colored, and unfossiliferous, which distinguishes them from the hard calcareous, fossiliferous, grayer, and locally conglomeratic sandstones that occur at places in the base of the overlying South Bend Limestone. The Rock Lake Shale thickens southward to perhaps 150 ft (45 m) of sandstone and sandy shale, with local thin oolitic sandy limestone zones, in southern Montgomery County above the named beds at the south end of the Stoner Limestone Member. One of the sandstones is traceable enough from southern T. 32 S. across T. 33 S. to be termed informally the **Onion Creek sandstone body** by Heckel (1975a) after exposures along Onion Creek, particularly along the road between sections 14 and 15 and 22 and 23, T. 33 S., R. 14 E.

South Bend Limestone (raised in rank, revised, and subdivided)

The South Bend Limestone overlies the Rock Lake Shale and underlies the Stranger Formation across eastern Kansas (figs. 1, 33). It is removed from the Stanton Limestone and raised in rank to formation because it is now subdivided into members representing a distinctly later cycle of marine deposition that is separated from the Stanton Limestone by the terrestrial deposits of the Rock Lake Shale. The South Bend Limestone has been subdivided by Pabian and Strimple (1993) into three named units in its type area in Nebraska, in ascending order, Little Kaw Limestone, Gretna Shale, and Kitaki Limestone (figs. 1, 33), homologous to those of other marine limestone formations in Kansas. The Little Kaw Limestone and Gretna Shale are exposed and recognized as members in Kansas (fig. 35), but the Kitaki Limestone is not known south of core MNC in northern Missouri (fig. 33). Named from South Bend in Cass County, Nebraska, by Condra and Bengston (1915), the principal reference section of the South Bend Limestone in Kansas is a roadcut along the southwest side of K–7 (NW-SW-NW sec. 8, T. 11 S., R. 23 E.) essentially across the highway from that of the Rock Lake Shale just south of US–40, about 3 mi (5 km) north of Bonner Springs in Wyandotte County (figs. 34 and 33, section 10). An excellent reference section for the South Bend Limestone in southeastern Kansas is exposed at the top

FIGURE 33 (left)—Correlation cross section of upper Missourian and lower Virgilian strata (upper Lansing and lower Douglas Groups) across eastern Kansas from Nebraska, Iowa, and Missouri to northern Oklahoma, showing classification of members of South Bend Limestone and Cass Limestone in Nebraska (as recently emended by R. R. Burchett of Nebraska Geological Survey, personal communication, 1996), and their recognition and correlation into Kansas. Names Nehawka and Plattford are Nebraska names that are not used in Kansas because they are exactly equivalent to names Iatan and Stranger, respectively. Datum is top of Haskell Limstone Member; secondary datum is top of Little Kaw Limestone Member, with thickness between datums based on that in section 11. Symbols are same as on fig. 2, with abundant conodonts represented by tailed diamond symbols and fossil-rich shales represented by narrow vertical lines. Numbers preceded by + on vertical section represent footage omitted from diagram because of space considerations. Missourian–Virgilian Stage boundary is shown above base of Haskell Limestone Member, the most appropriate position based on current conodont biostratigraphic information (Boardman et al., 1989; Barrick et al., 1995; Heckel et al., 1999, p. 63; Heckel, 2002). Locations of measured sections indicated by numbers are given in Appendix.

of the roadcut west of Elk City Dam (SW-SE-NW sec. 7, T. 32 S., R.15 E.), northwest of Independence in Montgomery County (fig. 33, section 19). The boundaries of this formation are described under its component members.

Little Kaw Limestone Member (reinstated)

The Little Kaw Limestone Member overlies the Rock Lake Shale and underlies the Gretna Shale Member across eastern Kansas (figs. 1, 33). The name Little Kaw was derived by Newell (1935) from Little Kaw Creek, 2 mi (3 km) southwest of Bonner Springs in southern Leavenworth County, and applied to the unit believed for most of the time since then to represent the entire South Bend Limestone of Nebraska. The name was abandoned by Moore (1949) when he accepted its equivalence to the earlier named South Bend Limestone. Because the type South Bend in Nebraska is now known to include two younger units as well (fig. 33), the name Little Kaw is reinstated to apply to only the basal limestone unit of the South Bend, comprising exactly the same strata to which it was originally applied. The type section of the Little Kaw Limestone Member is designated near the "typical exposures" given in Moore (1936), at the much better exposed principal reference section for the entire South Bend Limestone in Kansas (fig. 33, section 10) in the roadcut at the intersection on the west side of K–7 (NW-SW-NW sec. 8, T. 11 S., R. 23 E.), just south of US–40 (fig. 34) and 3 mi (5 km) north of Bonner Springs. Here the Little Kaw is 6 ft (1.8 m) thick, comprising 3 ft (0.9 m) of skeletal calcilutite above 3 ft (0.9 m) of sandy limestone to fossiliferous calcareous sandstone (fig. 35). The Little Kaw Limestone Member is generally 2–4 ft (0.6–1.2 m) of skeletal calcilutite with various amounts of fossiliferous to conglomeratic sandstone at the base across most of Kansas. Locally, it contains a conspicuous biota dominated by derbyiid and meekellid brachiopods or myalinid clams. Its lower boundary is typically sharp above the mudstone and shale of the underlying Rock

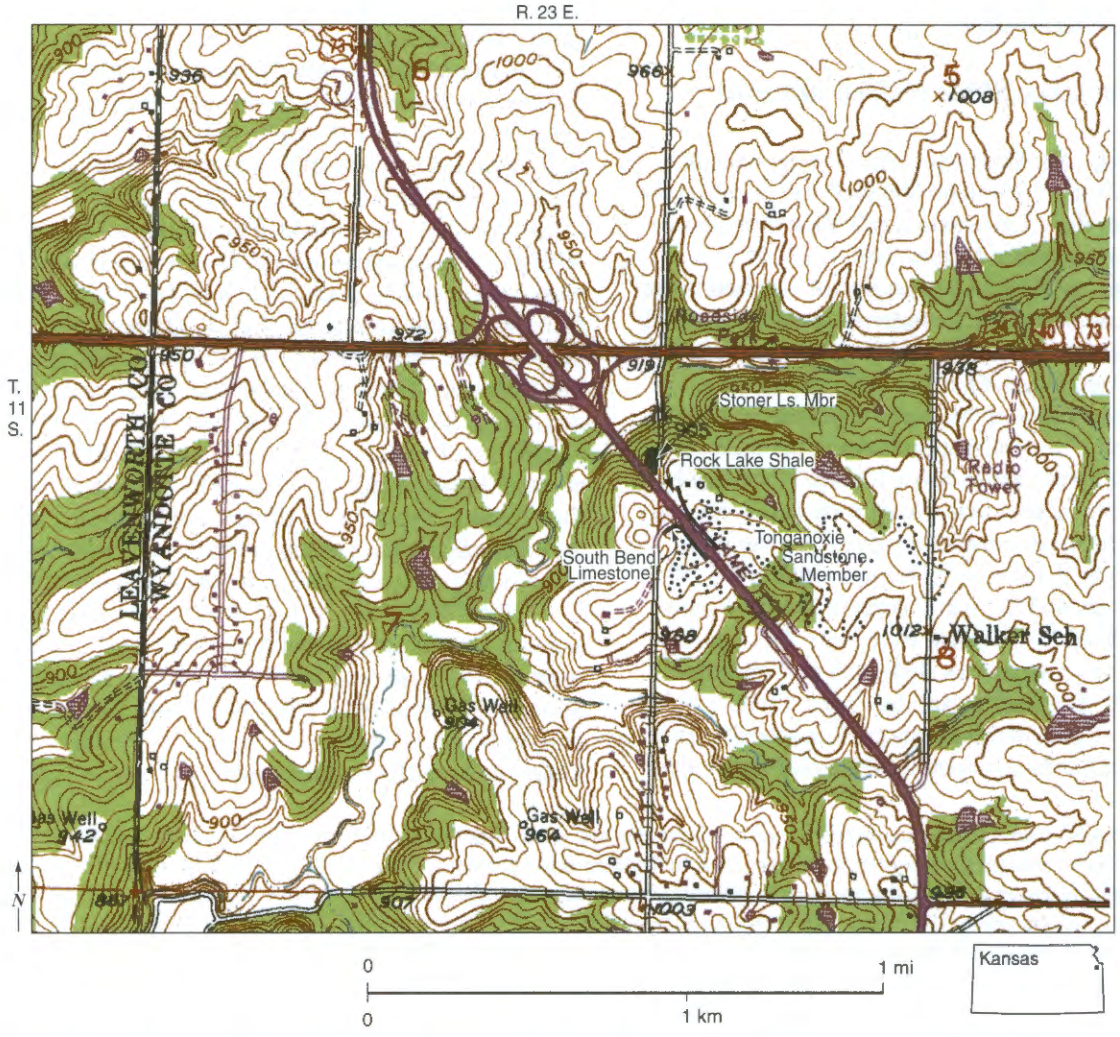


FIGURE 34—Map of part of 1950 (photorevised 1975) Bonner Springs, Kansas, 7 1/2-minute quadrangle, showing locations of principal reference sections of Rock Lake Shale and South Bend Limestone and its component Gretna Shale Member in Kansas, and type section of its component Little Kaw Limestone Member, in roadcuts along K–7 just south of US–40 in Wyandotte County.

Lake Shale, but locally appears more diffuse above sandstone in the Rock Lake. Here, however, closer inspection allows the hard calcareous fossiliferous sandstone of the basal Little Kaw to be distinguished from the more friable unfossiliferous sandstones of the Rock Lake. The upper boundary with the overlying Gretna Shale Member is sharp. The Little Kaw Limestone Member thickens to 20 ft (6 m) at the reference section west of Elk City Dam (fig. 33, section 19), and includes phylloid algal facies up to 25 ft (7.5 m) nearby in central Montgomery County (Heckel and Cocke, 1969). Southward, it thins to 4–5 ft (1.2–1.5 m) of yellowish-weathering skeletal calcilutite with conspicuous calcisponges in southwestern Montgomery County (Heckel, 1975a).

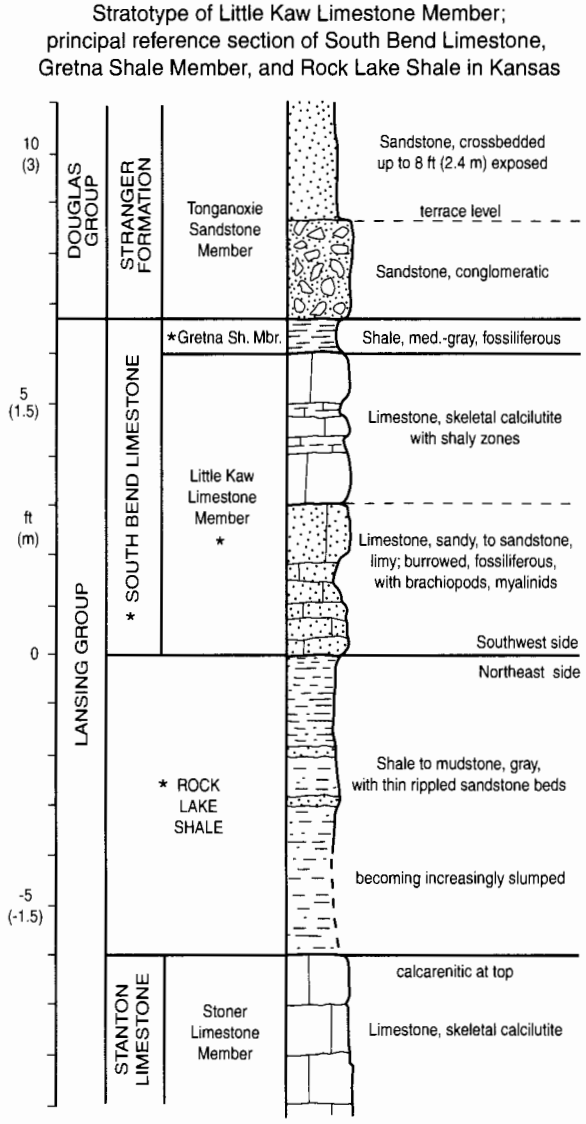


FIGURE 35—Measured section of Little Kaw Limestone Member stratotype, and principal reference section of South Bend Limestone and Gretna Shale Member in Kansas, in roadcut on southwest side of K–7 just south of US–40, in NW-SW-NW sec. 8, T. 11 S, R. 23 E. (fig. 34), and of Rock Lake Shale in Kansas, in roadcut on northeast side of K–7 just to north (near center W line NW sec. 8, same township), Wyandotte County, Kansas.

Gretna Shale Member (now recognized in Kansas)

The Gretna Shale Member overlies the Little Kaw Limestone Member and underlies the Stranger Formation across eastern Kansas (fig. 1). The name Gretna Shale was applied by Pabian and Strimple (1993) from Gretna in Sarpy County, Nebraska, to the middle shale unit of the South Bend Limestone in its type area. Its fossiliferous, conodont-rich nature and its consistent position above the Little Kaw Limestone Member makes it easy to trace into Kansas (fig. 33). Its principal reference section in Kansas is the same as that for the entire South Bend and the type section of the Little Kaw Limestone Member in the K–7 roadcut just south of US–40 (figs. 34 and 33, section 10). The Gretna Shale is generally about 1 ft (0.3 m) of fossiliferous shale with crinoids, brachiopods, bryozoans, and conodonts in the few places where it is exposed across eastern Kansas. Its upper boundary is sharp where it is overlain by limestone (as in Nebraska) or by sandstone (as at the principal reference section, fig. 35), but is more diffuse where overlain by sandy shale or siltstone of the Stranger Formation. Although it would be reasonably mapped with the Stranger in those places, its thinness would render it merely the line between the South Bend and Stranger formations on any map. The Gretna Shale Member is partly exposed above the Little Kaw Limestone Member in a US–59 roadcut 5 mi (8 km) north of Lone Elm (E line, north of SE corner of sec. 6, T. 22 S., R. 20 E.) in Anderson County (fig. 33, section 17). It is well exposed as 0.3 ft (10 cm) of fossiliferous shale between the top of the Little Kaw Limestone and thin argillaceous sandstone beds at the base of the Stranger Formation in the reference roadcut west of Elk City Dam (SW-SE-NW sec. 7, T. 32 S., R. 15 E.) in northwestern Montgomery County (fig. 33, section 19). Southward the Gretna thickens above the thinning Little Kaw Limestone Member to several feet of fossiliferous shale in southwestern Montgomery and extreme southeastern Chautauqua County (fig. 33, section 21).

Douglas Group (redefined)

The Douglas Group overlies the Lansing Group and underlies the Shawnee Group. It is now recognized to comprise three formations in Kansas, in ascending order, Stranger Formation, Cass Limestone (newly extended into Kansas from Nebraska), and Lawrence Formation (figs. 1, 33).

Stranger Formation (redefined)

The Stranger Formation overlies the South Bend Limestone (Gretna Shale Member) and underlies the

newly recognized Cass Limestone (Haskell Limestone Member) across eastern Kansas (figs. 1, 33). The Stranger Formation consists mainly of shale to sandy shale with a large number of lenticular sandstone bodies, and it contains somewhat discontinuous thin limestone units and coal beds. The entire Stranger ranges from about 100 ft (30 m) thick in northeastern Kansas to at least 200 ft (60 m) thick southward. Previously subdivided completely into five named members, the Stranger Formation is now recognized to comprise the same five formal members, but with a large amount of unsubdivided strata, particularly in east-central and southeastern Kansas (fig. 33). The members are, in ascending order: Weston Shale Member, Iatan Limestone Member, both recognized only in northeasternmost (Leavenworth County) and southernmost (Chautauqua County) Kansas; Tonganoxie Sandstone Member, recognized only in northeastern Kansas (Wyandotte and Leavenworth to Franklin counties) and capped by the Upper Sibley coal bed; Westphalia Limestone Member and Vinland Shale Member, both recognized across most of Kansas. Because the Tonganoxie Sandstone Member is now stratigraphically well enough delineated (Feldman et al., 1995) to be readily identified and constrained in its type area in northeastern Kansas, it excludes the multitudes of lenticular sandstones southward, some of which are now known to lie below the position of the Iatan Limestone Member. It also excludes the mudstone northward between the Iatan Limestone Member and Upper Sibley coal bed. The Stranger Formation was named by Moore (1932) and defined by Newell (1935) from exposures along Stranger Creek in southern Leavenworth County. Its principal reference section, essentially the original type section (fig. 33, section 11), extends from exposures of the South Bend Limestone (E line NE-SE-SE sec. 3, T. 12 S., R. 21 E.) up to the base of the Haskell Limestone Member (center S line sec. 3) about 2 mi (3 km) northwest of Linwood.

Weston Shale Member (revised)

The Weston Shale Member overlies the South Bend Limestone (Gretna Shale Member) and underlies the Iatan Limestone Member in northern Leavenworth and Atchison counties, Kansas, and northward (figs. 1, 33). Named by Keyes (1899) from Weston in Platte County, Missouri, its type section (fig. 33, section 9) was designated by Ball (1964) in the bluffs above Beverly, Missouri (SW-SE-NE sec. 31, T. 53 N., R. 35 W.), 4 mi (7 km) northeast of Leavenworth, Kansas. The Weston Shale Member is about 50–60 ft (15–18 m) of gray poorly fossiliferous silty shale with ironstone nodules at its type section, thinning southward and becoming poorly exposed in Kansas. It is recognized in Kansas only where the overlying Iatan Limestone Member is present, because some of the thick lower Stranger shales previously mapped as Weston in east-central Kansas where the Iatan is not yet identified could possibly be younger than the Iatan. The Weston interval is delimited beneath the lens of Iatan Limestone Member in eastern Chautauqua County, however, where it may be as much as 200 ft (60 m) of gray silty shale containing a considerable amount of sandstone that previously would have been called Tonganoxie. The thin fossiliferous Gretna Shale Member of the South Bend Limestone has been removed from the base of the Weston Shale Member (see above).

Iatan Limestone Member (now recognized in southern Kansas)

The Iatan Limestone Member overlies the Weston Shale Member and underlies the middle to upper part of the Stranger Formation in Leavenworth and Chautauqua counties in Kansas (figs. 1, 33). Named by Keyes (1899) from Iatan in Platte County, Missouri, exposures extend southeastward in the eastern bluffs of the Missouri River, where it is up to 18 ft (5.4 m) of skeletal calcilutite with phylloid algae. A reference exposure to the east along I–29 yielded critical conodonts (fig. 33, section 7). The Iatan Limestone Member is poorly exposed on the Kansas side of the Missouri River and is not known in the poorly exposed lower part of the Stranger Formation across most of eastern Kansas. The Iatan Limestone Member reappears around Peru in eastern Chautauqua County, where it consists of 1–2 ft (0.3–0.6 m) of shaly crinoidal limestone, exposed in the road ditch along US–166 (NE- SE-SW sec. 23, T. 34 S., R. 12 E.) 3 mi (5 km) west of Niotaze (fig. 33, section 20, and illustrated in Heckel et al., 1999, p. 48, Stop C1). Locally it is up to 12 ft (3.6 m) of phylloid algae-dominated calcilutite, which is exposed in the old quarry 1 mi (1.6 km) northeast of Peru (SW-SE-SE sec. 10, T. 34 S., R. 12 E.). Both facies are exposed in the east bank of the creek south of old US–166, just west of Peru (near center of E line of SW-SW sec. 16, T. 34 S., R. 12 E.), where the thinned algal facies overlies fossiliferous shale and crinoidal limestone facies. This unit was mapped as Haskell Limestone Member by Ball (1964), but its conodont fauna is that of the type Iatan (Heckel, 2002) rather than that of the Haskell and overlying shale, which are now known to be exposed in higher strata along new US–166 around Peru (fig. 33, section 20; Heckel et al., 1999, p. 48, 50).

Tonganoxie Sandstone Member (restricted geographically)

The Tonganoxie Sandstone Member occurs in the middle of the Stranger Formation in northeastern Kansas above the stratigraphic position of the Iatan Limestone and below the Upper Sibley coal bed (figs. 1, 33). Named by Moore (1936) from Tonganoxie in Leavenworth County, its principal reference section (fig. 33, section 10) comprises a series of exposures along US-

24–40 (from S line SW-SE sec. 2, T. 11 S., R. 21 E., to center S line SE sec. 6, T. 11 S., R. 22 E.), 2 to 4 mi (3.2–6.4 km) east of Tonganoxie. The base is well exposed along K–7 (in SW-NW sec. 8, T. 11 S., R. 23 E.) above the principal reference section for the South Bend Limestone (fig. 35), 10 mi (16 km) east of Tonganoxie and 3 mi (5 km) north of Bonner Springs. The Tonganoxie Sandstone Member contains thick-bedded conglomeratic sandstone overlain by conspicuously crossbedded sandstone at the base (fig. 35) grading upward to thinner bedded and shaly sandstone. It totals perhaps up to 150 ft (45 m) in thickness in a 20-mi (33-km)-wide erosional paleovalley that was eroded through the Iatan Limestone Member, and in places through the South Bend Limestone and into the Rock Lake Shale (see Feldman et al., 1995). Although the notorious lenticularity of sandstone bodies at different horizons in thick shale-dominated formations such as the older Galesburg and Chanute caused the sandstone members in them to be reduced in rank to informal beds, the Tonganoxie Sandstone has been sufficiently well delineated by Feldman et al. (1995) to be retained as a formal member. However, it is recognized only in its type area from Wyandotte and Leavenworth, through Douglas to Franklin counties (figs. 1, 33). It contains the **Ottawa coal bed** at its base southwest of Ottawa in Franklin County (fig. 33, section 16). This geographic restriction of the name eliminates the problem of calling older sandstones southward "Tonganoxie" when they are known to lie below the Iatan Limestone Member, as is the case in eastern Chautauqua County.

Upper Sibley coal bed (unchanged)

The Upper Sibley coal bed overlies the Tonganoxie Sandstone Member (or the undivided main part of the Stranger Formation beyond the limits of the Tonganoxie), and underlies the Westphalia Limestone Member where it is present (figs. 1, 33). Named by Moore (1936) as the Sibley coal from Sibley (now Sibleyville) in Douglas County, it was referred to by Moore (1949) as the upper Sibley coal bed because by that time a lower coal bed was called the lower Sibley coal. The Upper Sibley coal bed is the most laterally continuous of all the coal beds in the Stranger Formation, as it extends from southern Douglas County through Leavenworth County, where it becomes 1.5 ft (0.5 m) thick east of Tonganoxie, and into Platte County, Missouri. Its principal reference section (fig. 33, section 15) is along a roadcut (east of center S line SE sec. 12, T. 14 S., R. 20 E.) 2.5 mi (4 km) east of Vinland (and 4 mi [7 km] southeast of Sibleyville) where it is 0.2 ft (6 cm) thick just below the Westphalia Limestone Member.

Westphalia Limestone Member (unchanged)

The Westphalia Limestone Member overlies the Upper Sibley coal bed in northeastern Kansas and the undivided main part of the Stranger Formation southward, and it underlies the Vinland Shale Member throughout Kansas (figs. 1, 33). Named by Moore (1936) from Westphalia in western Anderson County, the currently best exposure near his "typical" outcrops serves as its principal reference section (fig. 33, section 17: center E line NE sec. 20, T. 21 S., R. 18 E.). The Westphalia Limestone Member is generally fusulinid-rich skeletal calcarenite (packstone) from its type area southward, where it attains 4 ft (1.2 m) in thickness in a good exposure below the spillway of Woodson County State Lake (fig. 33, section 18: SE-SW-NE sec. 14, T. 26 S., R. 14 E., illustrated in Heckel et al., 1999, p. 62, Stop D1). It can be traced southward to an exposure in a roadcut (center of W line SW sec. 23, T. 34 S., R. 12 E., illustrated in Heckel et al., 1999, p. 48, Stop C2) south of US–166, where it is stratigraphically between the Iatan Limestone Member and the Haskell Limestone Member (fig. 33, section 20). In Oklahoma, it is known as the Bowring Limestone (fig. 33, sections 22–23). The Westphalia Limestone Member in northeastern Kansas is up to 1.5 ft (0.5 m) of ostracode-rich calcilutite, which is well exposed above the Upper Sibley coal bed in its principal reference section 2.5 mi (4 km) east of Vinland (fig. 33, section 15).

Vinland Shale Member (unchanged)

The Vinland Shale Member overlies the Westphalia Limestone Member and underlies the Haskell Limestone Member of the Cass Limestone across eastern Kansas (figs. 1, 33). Named by Newell (1935) from Vinland in eastern Douglas County, its type section was delineated by Ball (1964) in a roadcut (E line SE-SE sec. 2, T. 14 S., R. 20 E.) 2 mi (3 km) northeast of Vinland, where it is 26 ft (8 m) of gray shale capped by sandstone (fig. 33, section 14). The Vinland Shale Member ranges from 4 to 40 ft (1.2–12 m) of sparsely to locally abundantly fossiliferous shale with lenticular sandstones. It is well exposed as nearly 5 ft (1.5 m) of fossiliferous myalinid-bearing shale overlying blocky mudstone between the Westphalia and Haskell Limestone Members below the spillway to Woodson County State Lake (fig. 33, section 18; see Heckel et al., 1999, p. 62, Stop D1).

Cass Limestone (now recognized in Kansas)

The Cass Limestone is now recognized as a formation in Kansas by transferral to it of the basal beds of the Lawrence Formation. The Cass overlies the Stranger Formation and underlies the revised Lawrence Formation (fig. 1). It comprises three members in ascending order: Haskell Limestone Member, Little Pawnee Shale Member, and Shoemaker Limestone Member (fig. 33). The Cass Limestone was named from Cass County, Nebraska, by Condra (1927), who later (1949) subdivided it into three members in ascending order: Shoe-

maker Limestone (as then revised), Little Pawnee Shale, and Haskell Limestone (as then erroneously correlated from Kansas). Because the thin, dark Little Pawnee Shale Member contains phosphate nodules and an abundant, distinctive conodont fauna that are found also in shale above the Haskell Limestone Member in its type region and throughout Kansas, the Haskell Limestone Member correlates with the basal rather than the upper member of the Cass Limestone in Nebraska (fig. 33). This displaces the name Shoemaker, which becomes available for the upper limestone member. The principal reference section for the Cass Limestone in Kansas is the roadcut along the north side of K–32 (center S line SW sec. 13, T. 12 S., R. 20 E.) in southwestern Leavenworth County (fig. 36), nearly 6 mi (10 km) west of Linwood, where all three members are present (figs. 37 and 33, section 12). Elsewhere in Kansas, only the Haskell Limestone and Little Pawnee Shale Members are currently known to be exposed.

Haskell Limestone Member (reclassified)

The Haskell Limestone Member is removed from the Lawrence Formation and is now classified as the basal member of the Cass Limestone in Kansas (figs. 1, 33). It overlies the Vinland Shale Member of the Stranger Formation and underlies the Little Pawnee Shale Member of the Cass. Named by Moore (1932) from the Haskell Indian Institute (now Haskell Indian Nations University) in Lawrence, its type section (fig. 33, section 13) was designated by Moore (1936; see Ball, 1964) along 15th Street (center N line NE sec. 5, T. 12 S., R. 20 E.) on the east side of town. The Haskell Limestone Member generally ranges from 1 to 4 ft (0.3–1.2 m) mainly of skeletal calcilutite throughout Kansas. Oolite occurs locally at the base in its type region. Good reference sections for southeastern Kansas include the base of the spillway to Woodson County State Lake (fig. 33, section 18: SE-SW-NE sec. 14, T. 26 S., R. 14 E.; see Heckel et al., 1999, p. 62, Stop D1) and the new US–166 roadcuts east and west of Peru in Chautauqua County (fig. 33, section 20), where it has thinned to 0.3 ft (0.1 m).

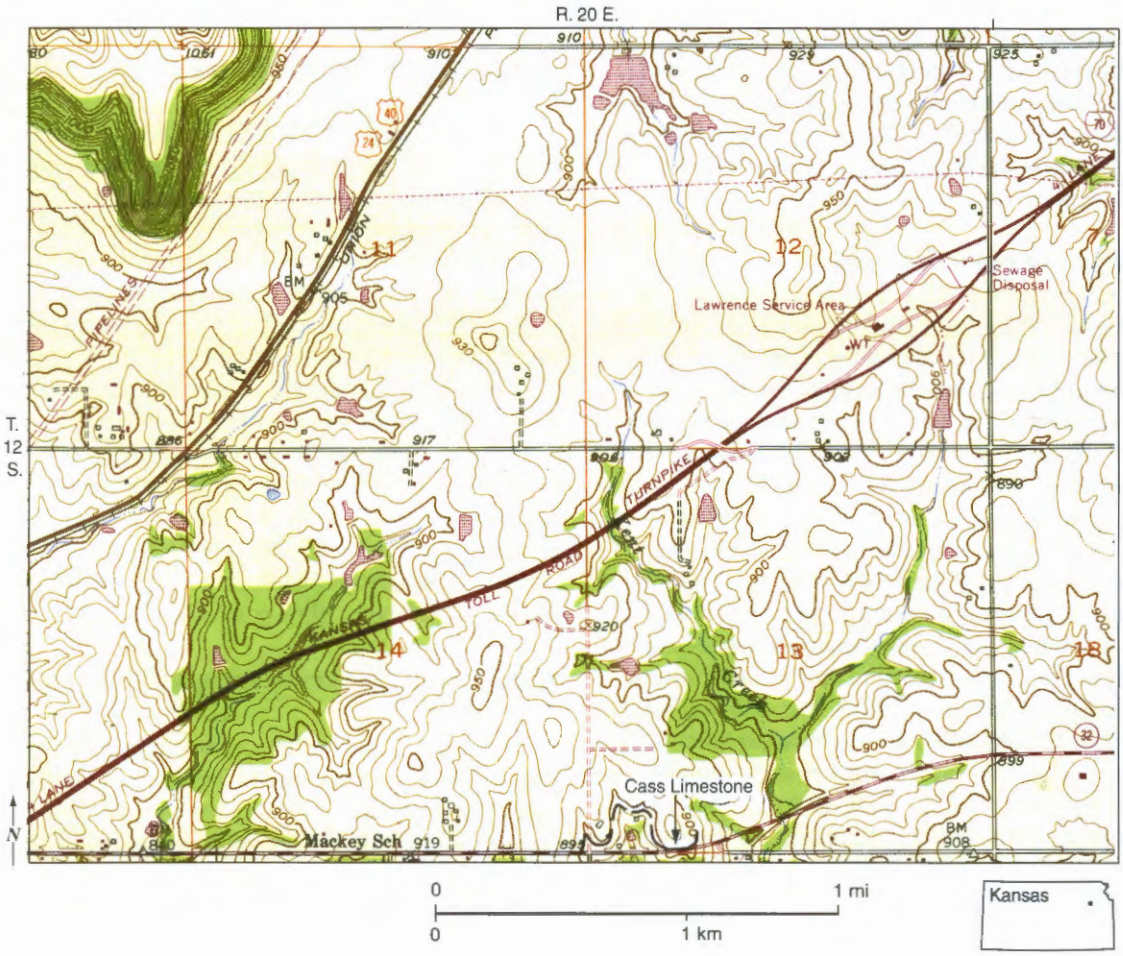


FIGURE 36—Map of part of 1950 (photorevised 1978) Midland, Kansas, 7 1/2-minute quadrangle, showing location of principal reference section of Cass Limestone, Little Pawnee Shale Member, and Shoemaker Limestone Member in Kansas, in roadcut on K–32, east of junction with US–40-24, and west of Linwood in Leavenworth County.

Little Pawnee Shale Member (newly recognized in Kansas)

The Little Pawnee Shale Member is now recognized in Kansas in what had been considered the basal beds of the Robbins Shale Member of the Lawrence Formation (fig. 1). It overlies the Haskell Limestone Member everywhere in Kansas, and it underlies the Shoemaker Limestone Member of the Cass Limestone at its principal reference section on K–32 west of Linwood (figs. 37 and 33, section 12). Elsewhere, the Little Pawnee Shale Member underlies the Robbins Shale Member of the Lawrence Formation (the two latter units slightly revised by the removal from them of the Little Pawnee Shale Member and the Cass Limestone, respectively). The Little Pawnee Shale Member was named by Condra (1949) from Little Pawnee Creek in Saunders County, Nebraska, as the middle member of the Cass Limestone. Its principal reference section in Kansas is the same as that of the Cass Limestone on K–32, 6 mi (10 km) west of Linwood (fig. 36), where it is 0.6 ft (20 cm) of fossiliferous gray shale between the two limestone members (fig. 37), with sharp lower and upper contacts. Elsewhere in Kansas, the Little Pawnee Shale Member averages generally 1 ft (0.3 m) of gray to dark-gray fossiliferous phosphatic shale, locally with a thin bed of ironstone at the top. Where the overlying Shoemaker Limestone Member is absent, the upper boundary of the Little Pawnee Shale Member is more diffuse with the base of the thick, more silty, and much less fossiliferous gray Robbins Shale Member. Locally, the contact is sharper at the base of a siltstone or sandstone bed in the base of the Robbins Shale Member. Although it would be reasonably mapped with the Lawrence Formation in those places, its thinness would render it merely the line between the Cass and Lawrence formations on any map. Reference sections for the Little Pawnee Shale Member (along with the Haskell Limestone Member) include the spillway at Woodson County State Lake (fig. 33, section 18; Heckel et al., 1999, p. 62, Stop D1), and the US–166 roadcuts both east (center sec. 22, T. 34 S., R. 12 E.) and west (NE-NE sec. 20) of Peru in Chautauqua County. Along US–166, it is darker in color and greater in thickness (9–11 ft [2.7–3.3 m]) than it is elsewhere. In the eastern roadcut, it is overlain by a thin bed of sandstone (fig. 33, section 20; Heckel et al., 1999, p. 48), and in the western roadcut, it has thin lenses of shelly limestone at the top (Heckel et al., 1999, p. 50, Stop C3).

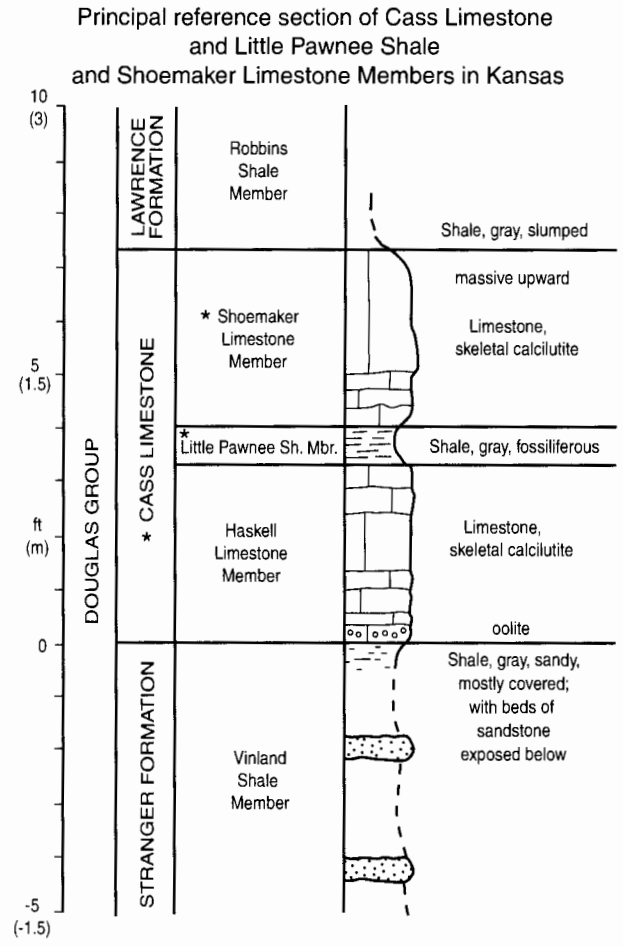


FIGURE 37—Measured section of principal reference section of Cass Limestone, Little Pawnee Shale Member, and Shoemaker Limestone Member in Kansas in roadcut on north side of K–32 at center of S line of SW sec. 13, T. 12 S., R. 20 E. (fig. 36), 6 mi (10 km) west of Linwood and 2.5 mi (4 km) east of junction with US–40, Leavenworth County, Kansas.

Shoemaker Limestone Member (newly recognized in Kansas)

The Shoemaker Limestone Member of the Cass Limestone overlies the Little Pawnee Shale Member and underlies the Robbins Shale Member of the Lawrence Formation (figs. 1, 33). This relationship is shown at the K–32 cut (fig. 36), 6 mi (10 km) west of Linwood in southern Leavenworth County (center S line SW sec. 13, T. 12 S., R. 20 E.), which serves as its principal reference section in Kansas (along with that of the Cass Limestone and Little Pawnee Shale Member). Here the Shoemaker Limestone Member is 3.3 ft (1 m) of skeletal calcilutite, with sharp contacts (figs. 37 and 33, section 12). The name Shoemaker (Condra, 1927) was originally applied to the entire Cass Limestone in Nebraska, but was later restricted to the lower limestone member there (Condra, 1949), when the upper limestone member was miscorrelated with the Haskell Limestone Member of Kansas. Recognizing both this miscorrelation and the result that the upper limestone member no longer had a name, R. R. Burchett of the Nebraska Geological Survey agreed that the displaced name Shoemaker can be applied to the upper limestone member there, a procedure that is accepted in Kansas. The Shoemaker Limestone Member is absent across most of eastern Kansas, but its position correlates with that of the Labadie Limestone of northern Oklahoma, which overlies the Little Pawnee Shale Member in central Osage County (fig. 33, sections 23–25).

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Appendix

Locations and sources of all numbered measured sections used for cross sections in figs. 2, 28, and 33. Sections are based on measurements by P. H. Heckel unless otherwise noted, either in text below, or in references cited below or in figure captions.

Figure 2:

1. Type section of Shale Hill Formation with parts of adjacent formations at Shale Hill just northwest of Utica, 5 mi (8 km) southwest of Chillicothe, Livingston County Missouri [Sampsel quadrangle], located and illustrated in figs. 5–6. Upper part is roadcuts that expose Hertha Limestone [S line SW-NE sec. 23, T. 57 N., R. 26 W.], and Swope and Dennis Limestones [S line SE-NE sec. 21, T. 57 N., R. 26 W.; both Flat Creek quadrangle] along US–36, Caldwell County, Missouri, between 8 and 11 mi (13 and 18 km) west of Utica.

2. Richmond railroad cut along southeast side of railroad near center of E half NW-SW sec. 24, T. 52 N., R. 28 W. [Richmond quadrangle], just northwest of Richmond, Ray County, Missouri. Section from Heckel (1991, Outcrop 6, p. 36–37).

3. Odessa: Cut hillside along westbound offramp from I–70 to M–131 and roadcut above, in SE-SE-NE sec. 35, T. 49 N., R. 28 W. [Odessa North quadrangle], on northwest side of Odessa, Lafayette County Missouri. Section slightly modified from Howe (1982, Stratigraphic section 8).

4. Creek bed along 63rd St. and roadcut along southbound onramp to I–435 in SW-NW sec. 6, T. 48 N., R. 32 W., in east side of Kansas City, Jackson County, Missouri [Independence quadrangle]. Section illustrated as Stop A2 in Heckel et al. (1999, p. 18).

5. Harrisonville: Section from Howe (1982, Stratigraphic Section 4) exposed in and around shale pit in SE-SE sec. 5, T. 44 N., R. 31 W., on southwest side of Harrisonville, Cass County, Missouri [Harrisonville quadrangle].

6. Type section of Elm Branch Shale, in roadcut located and illustrated in figs. 17–18, 1 mi (1.6 km) southwest of Fontana, Miami County, Kansas [Fontana quadrangle].

7. Walley Mound: Section from creek bed south of bridge up road to west, along center N line NW sec. 15, T. 41 N., R. 33 W., 1.5 mi (2.4 km) northeast of Amsterdam, Bates County, Missouri [Amoret quadrangle]; from Heckel (1991, Outcrop 10, p. 38–39).

8. US–69 roadcuts east of LaCygne: Lower and middle parts are roadcuts along US–69 in NW-NW-SE sec. 31 and near center N half sec. 31, T. 19 S., R. 25 E., illustrated as Stops 2A and 2B in Heckel (1978, p. 24–25). Upper part is roadcut along center E line SE-SE sec. 36, T. 19 S., R. 24 E. [which includes type section of Middle Creek Limestone Member along S line just west of section corner], all 3 to 4 mi (5–6.4 km) east of LaCygne, Linn County, Kansas [Boicourt quadrangle].

9. Trading Post: in northeast bank of Marais des Cygnes River above and below US–69 bridge, near center of sec. 5, T. 21 S., R. 25 E., at Trading Post, Linn County, Kansas [Pleasanton quadrangle]. Section from Heckel (1991, Outcrop 11, p. 39).

10. Roadcut west of Pleasanton in NE-NW-NW sec. 34, T. 21 S., R. 24 E., 3 mi (5 km) west of north side of Pleasanton, Linn County, Kansas [Mound City quadrangle].

11. US–69 roadcuts northwest of Prescott and vicinity: Lower part comprises roadcuts along US–69, 4 to 5 mi (6.4–8 km) south of Pleasanton, Linn County, Kansas, located and illustrated in figs. 7–8 and including stratotype of Mantey Shale Member. Upper part from base of Bethany

Falls Limestone Member through base of Stark Shale Member exposed in quarry 1 mi (1.6 km) to west, in NW-NW sec. 25, T. 22 S., R 24 E., Linn County, Kansas [Prescott quadrangle].

12. Xenia NW: Lower part is roadcut along center of S line SE sec. 20, and upper part is on north side of quarry north of Boulware Cemetery in SW-SW-NW sec. 20, T. 23 S., R. 22 E., 4–4.5 mi (6.4–7.2 km) south of Blue Mound and 2 to 3 mi (3–5 km) northwest of Xenia, Bourbon County, Kansas [Blue Mound quadrangle]. Roadcut exposure below Sniabar Limestone Member resembles that of measured section 10, which is along depositional strike to northeast.

13. Type section of Guthrie Mountain Shale Member, along north side of roadcut 1.5 mi (2.4 km) southwest of Guthrie Mountain, located and illustrated in figs. 11–12 [Xenia quadrangle].

14. Principal reference section for Exline Limestone Member in Kansas, in ditch and cuts along north side of road ~1 mi (1.6 km) east of Turkey Creek and 3 mi (5 km) north of Uniontown, located and illustrated in figs. 9–10 [Xenia quadrangle].

15. Schubert Creek quarry and vicinity: Lower part is exposures of Swope Limestone with oomoldic oolite facies at top, overlain by well-preserved Mound Valley oolite and lower Galesburg Shale in quarry [augmented by nearby roadcut] in NW-NE sec. 24, T. 25 S., R. 21 E., just west of Schubert Creek. Upper part is exposures of complete Galesburg Shale and lower members of Dennis Limestone reported in SW-NW sec. 24 by J. M. Jewett in 1931 KGS files, both ~3 mi (5 km) southeast of Bronson, Bourbon County, Kansas [Moran SE quadrangle].

16. Uniontown East roadcut along S line SE-SE-SW sec. 23, T. 25 S., R. 22 E., nearly 1 mi (1.6 km) east of Uniontown, Bourbon County, Kansas, from Heckel (1991, Outcrop 14, p. 40) [Uniontown quadrangle].

17. Uniontown K–3 roadcut: Main part exposing upper Hepler Formation through lower Bethany Falls Limestone Member is roadcut and adjacent gully along K–3 in E half NW and along E line NE–SW sec. 34, T. 25 S., R. 22 E., 1 mi (1.6 km) south of Uniontown, Bourbon County, Kansas [Uniontown quadrangle], illustrated as Stop B1 in Heckel et al. (1999, p. 32). Lowest part exposing Lost Branch and lower Hepler Formations is in ravines west of K–3 in SW-NE-NW sec. 34, described as Outcrop 15 in Heckel (1991, p. 40–41). Upper part comprises exposure of Bethany Falls Limestone Member in quarry in NW-NE-SE sec. 8, T. 26 S., R. 22 E., 2.5 mi (4 km) east of Bourbon County State Lake dam, and exposure in road ditch along N line NE-NW-NE sec. 4, T. 26 S., R. 21 E., from top of non-oolitic facies in Bethany Falls Limestone Member in creek bed across covered interval that apparently includes Ladore Shale, to exposed section from well-preserved oolite of Mound Valley Limestone to lower Winterset Limestone Member, 3 mi (5 km) northwest of Bourbon County State Lake dam and 2.5 mi (4 km) northeast of Elsmore, Allen County, Kansas [Moran SE quadrangle].

18. Prong Creek Core (KPC) containing neostratotype of Hepler Formation, located and illustrated in figs. 3–4 [Porterville and Hepler quadrangles], and described with comments on correlation by Heckel (1991, p. 41–43); correlation of original type section of Hepler Sandstone is now uncertain but is likely above Perry Farm Shale Member.

19. Prong Creek southwest: Lower part extends along S line SW-SW sec. 9, from black shale bed at base of Mound City Shale Member in SE-SW-SW sec. 9, to exposure of Sniabar Limestone Member just west of NE corner sec. 17. Upper part extends along W line sec. 9 and E line sec. 8 from top of Sniabar Limestone Member in stream bed in SW-NW-SW sec. 9 to top of Bethany Falls Limestone Member near center E line NE sec. 8, all T. 27 S., R. 22 E., 3 mi (5 km) east of Porterville and ~1 mi (1.6 km) south of Prong Creek Core, Bourbon County, Kansas [Porterville quadrangle]; see also fig. 3.

20. Exposure in bank of Canville Creek at US–59 bridge just south of NE corner sec. 22 and adjacent roadcut along N line NW-NW sec. 23, T. 27 S., R. 20 E., Neosho County, Kansas [Stark quadrangle], containing principal reference section for Galesburg Shale; illustrated and

described as Stop 4 by Heckel et al. (1979, p. 26–27). Principal reference sections for Canville Limestone and Stark Shale Members of Dennis Limestone are in roadcut along north side of US–59 [S line SW-SE-SW sec. 13, T. 27 S., R. 20 E.], 1.3 mi (2 km) east of bridge.

21. Kimball East: Lower part exposes strata from upper Hepler through Sniabar Limestone Member in creek bank and up hill north of road in SW-SW-SE-SW sec. 27, T. 27 S., R. 21 E., Neosho County, Kansas [Porterville quadrangle]. Section continues 1.3 mi (2 km) to west, from top of Sniabar exposed in roadbed just south of NW corner sec. 33, westward to Middle Creek Limestone Member in pasture just west of SE corner SW sec. 29, Bethany Falls Limestone Member along N line NW-NE-NW sec. 32, Mound Valley Limestone along NE-NW-NE-NE sec. 31, and to blocks of Canville Limestone Member along N line NW-NE-NW-NE sec. 31, T. 27 S., R. 21 E., 0.7 mi (1 km) east of Kimball [Stark quadrangle].

22. Page's pasture: Exposures from fossiliferous sandstone in Elm Branch Shale in east-facing hill in NW-SE-NW sec. 6, up to black Hushpuckney Shale and Bethany Falls Limestone Members at top of hill, northward along outcrop trace to gully at center W line NE-NW sec. 6, up gully through Ladore Shale to Mound Valley Limestone in NE-NW-NW sec. 6, T. 28 S., then up through Galesburg Shale to Canville Limestone Member and basal Stark Shale Member on west side of pond in SW-SE-SW-SW sec. 31, T. 27 S., R. 21 E., back of residence of Marion Page, 1 mi (1.6 km) south of Kimball, Neosho County, Kansas [Stark quadrangle]. Permission must be obtained before visiting this locality.

23. Erie north roadcut: Exposures along both sides of US–59, 2 mi (3.2 km) north of Erie, Neosho County, Kansas, located and illustrated in figs. 19B and 20B as principal reference section for Mound Valley Limestone [Shaw quadrangle].

24. Erie southwest: Lower part is exposure of Mound Valley Limestone along road just west of US–59 at NW corner sec. 7, T. 29 S., R. 20 E., with interval westward to lower part of Winterset Limestone Member along N line NE-NW-NE sec. 12, T. 29 S., R. 19 E., 2 mi (3.2 km) southwest of Erie. Upper part comprises 1931 and 1936 measurements by J. M. Jewett in KGS files of complete exposures of upper Galesburg through Canville Limestone, Stark Shale and lower Winterset Limestone Members along S line from SE-SE-SW to SE-SW-SE sec. 33, T. 28 S., R. 19 E., 3 mi (5 km) to WNW, ~5 mi (8 km) west of Erie, Neosho County, Kansas [Shaw quadrangle].

25. Middle part is Hertha Limestone neostratotype located and illustrated in figs. 15–16. Lower part is exposures of upper Lenapah Limestone, Memorial Shale, and lower Lost Branch Formation along western tributary to Bachelor Creek in SE-SW sec. 28, southwestward along tributary to exposures of middle Hepler Formation in NW-NW sec. 33, T. 29 S., R. 20 E., described as Outcrop 17 by Heckel (1991, p. 44). Upper part is interval of Ladore Shale southwest of Hertha neostratotype to Mound Valley Limestone at top of hill in SE-NW sec. 32, T. 29 S., R. 20 E., Neosho County, Kansas [South Mound quadrangle].

26. Lower part is principal reference section for South Mound Shale Member along N line NE-NE-NE-NW sec. 15, described as Outcrop 18 in Heckel (1991, p. 44–45). Upper part is partial exposure from sandstone bed at top of South Mound Shale Member upward through Exline fossiliferous shale and Tacket Formation to Bethany Falls Limestone Member in road ditch along W line SW-SW-SW-NW sec. 10, T. 30 S., R. 20 E., 1 mi (1.6 km) northeast of South Mound, Neosho County, Kansas [South Mound quadrangle].

27. Principal reference section for Ladore Shale along outlet of Lake Parsons in NW-NW-NE sec. 33, plus thick Mound Valley Limestone in roadcut just to south in SW-NW-NE sec. 33, T. 30 S., R. 19 E., Neosho County, Kansas [Galesburg quadrangle].

28. Principal reference section for Dennis Limestone in roadcut south of US–160, along center E line NE sec. 21, T. 31 S., R. 18 E., illustrated and described as Stop 7 by Heckel et al. (1979, p. 34), supplemented by better exposure of Stark and Canville Members and top of Galesburg

Shale in ravine along west side of road in NE-SE-NE-NE sec. 20, 1 mi (1.6 km) to west, 1 to 2 mi (1.6–3.2 km) southwest of Dennis. Section continues down to Mound Valley Limestone [misidentified as Bethany Falls/ Swope] as reported by J. M. Jewett in 1935 and W. L. Jungman in 1959 in KGS files, along road down bluff along Big Hill Creek near N line NE-NW sec. 32, T. 31 S., R. 18 E., 3 mi (5 km) southwest of Dennis, Labette County, Kansas [Dennis quadrangle].

29. Middle part is neostratotype of Tacket Formation, located and illustrated in figs. 13–14. Lower part is exposure of limestone [lower bed of Checkerboard Limestone Member] at base of South Mound Shale Member north of road and west of creek in SE-SW-SE sec. 7, and exposure of 'Hepler' coal [discovered by A. P. Bennison] in creek bank south of road near center of N half NW-NE sec. 18, T. 32 S., R. 19 E., 0.6 mi (1 km) south of Tacket Formation neostratotype [Parsons West quadrangle]. Top is approximate interval between top of Bethany Falls Limestone Member at neostratotype and Mound Valley Limestone at top of Tackett Mound just to southwest, with measured section that includes Cedar Bluff coal projected in from Big Hill Lake spillway in SE-NE-SW sec. 7, above Mound Valley Limestone in quarry in NE-SE-NE sec. 18, T. 32 S., R. 18 E., about 6 mi (10 km) to west [Dennis quadrangle], all in Labette County, Kansas.

30. Type Mound Valley Limestone, just northwest of Mound Valley, Labette County, Kansas [Mound Valley quadrangle], located and illustrated in figs. 19A, 20A.

31. Stratotype of Lost Branch Formation and reference section for South Mound Shale Member, on Lost Branch and Pumpkin Creek from NE-NE-NE to SW-SW-NE sec. 10, T. 33 S., R. 18 E., just southwest of Mound Valley, Labette County, Kansas [Mound Valley quadrangle], described as Outcrop 19 and illustrated in fig. 6 of Heckel (1991, p. 14, 45–46).

32. Type Perry Farm Shale Member [of Lenapah Limestone] in bank south of road at driveway east of bridge over Pumpkin Creek near center N line NW-NE sec. 7, T, 34 S., R. 18 E., 1.5 mi (2.4 km) west of Angola, Labette County, Kansas [Valeda quadrangle], described as Outcrop 21 by Heckel (1991, p. 46–47).

33. South Coffeyville Core [OSC] drilled by Oklahoma Geological Survey as C–CN–3, in SW-SW-SW-NW-SW sec. 28, T. 29 N., R. 15 E., 4 mi (6.4 km) WSW of South Coffeyville, Nowata County, Oklahoma [Elliott quadrangle], described by L. A. Hemish, summarized and classified by P. H. Heckel.

34. Type Lenapah Limestone: Lower part is in roadcut along both sides of US–169 near W line NW-SW sec. 20, T. 28 N., R. 16 E. Upper part is in old quarry west of old US–169 in NW-NE sec. 30, augmented by newer quarry in SE-NE and NE-SE sec. 30, T. 28 N., R. 16 E., 2 to 3 mi (3–5 km) north of Lenapah, Nowata County, Oklahoma [Elliott quadrangle].

35. Little California Creek: Lower part is in banks along south side of creek in west half of SE sec. 10, T. 27 N., R. 15 E., 3 mi (5 km) WSW of Lenapah, Nowata County, Oklahoma [Delaware quadrangle], illustrated as Stop B8 in Heckel et al. (1999, p. 44). Because this is on private property, permission must be obtained through the Oklahoma Geological Survey, Norman, Oklahoma, some time in advance of a visit. Upper part is in creek bank in NE-SE-NW sec. 10, 0.5 mi (0.8 km) to north.

Figure 28:

1. Louisburg area and south:
In A, lower Wyandotte section is Locality 35 of Miller (1966, p. 59), measured along old US–69, W line SW sec. 5, T. 17 S., R. 25 E., ~1.5 mi (2.4 km) south of Louisburg; Iola section is Section 162 of Newell (1935, p. 149) on old US–69 at SE corner sec. 6, T. 18 S., R. 25 E., ~7.5 mi (12 km) south of Louisburg.

In B, lower Wyandotte was measured along southbound offramp from new US–69 to K–68, near SE corner sec. 25, T. 16 S, R. 24 E., on west side of Louisburg; Iola section was measured on east side of new US–69 in E half of NW sec. 7, T. 18 S., R. 25 E, 8 mi (13 km) south of Wyandotte section, all in Miami County, Kansas [all in Louisburg quadrangle].

2. South of Bucyrus to southwest of Louisburg: Farley–Island Creek–Argentine section was mentioned by Miller (1966, p. 17) as being in SW-SW sec. 1, T. 16 S., R. 24 E., and upper part was measured just south of road along North Wea Creek in NE-NW-NW sec. 12, T. 16 S., R. 24 E., 3 mi (5 km) south of Bucyrus [Bucyrus quadrangle]. Iola–Liberty Memorial [formerly Lane] section is Locality 31 of Miller (1966, p. 58) in NW sec. 1, T. 17 S., R. 24 E., ~2 mi (3 km) southwest of Louisburg [Louisburg quadrangle].

3. Quarry south of Wagstaff, showing Argentine and Farley Limestone Members separated by Island Creek Shale Member in SE-NW sec. 30, T. 16 S., R. 24 E., 2 mi (3 km) south of Wagstaff, Miami County, Kansas [Spring Hill quadrangle]. This quarry was expanded since publication of section in Miller (1966, Locality 17).

4. US–169-K–7 roadcuts northeast of Paola; from top of Raytown Limestone Member in west road ditch in NE-SE-SW sec. 11 through Liberty Memorial Shale to Quindaro Shale and Argentine Limestone Members on west side just south of bridge at NE corner of SW sec. 11, T. 17 S., R. 23 E., just east of Lake Miola; continuing 2.3 mi (3.7 km) northward from top of Argentine Limestone Member on west side of northbound offramp to K–68 in SW-NW-NE sec. 35, T. 16 S., R. 23 E. up through largely covered, thickened Island Creek Shale Member interval to Farley Limestone Member on south side of K–68 just east of intersection [Paola East quadrangle]. Separation of Farley and Argentine Limestone Members was not recognized in previous work, as shown in cross section A.

5. K–68 roadcut west of Bull Creek, with Raytown Limestone, Quindaro Shale, and Argentine Limestone Members on north side at center south line of SE sec. 29, T. 16 S., R. 23 E., 3 mi (5 km) north of Paola, Miami County, Kansas [Paola West quadrangle]. Muncie Creek Shale Member and top of Paola Limestone Member are barely exposed below Raytown on south side of roadcut.

6. Quarry west of Paola in SE sec. 18, T. 17 S., R. 23 E., where Raytown Limestone Member is overlain by several feet of shale followed by limestone, all classified by Mitchell (1981) following Miller (1966, fig. 8, p. 16) as part of Raytown Limestone Member. Section taken from Mitchell (1981, p. 304) who showed abundant conodonts in top of shale and base of overlying limestone, indicating that they are Quindaro Shale and Argentine Limestone Members of Wyandotte Limestone as in K–68 roadcut (Section 5, above), 4 mi (6.4 km) to north [Paola West quadrangle].

7. K–68 roadcut east of Bell Branch, exposing Farley Limestone Member along south line SE sec. 25, T. 16 S., R. 22 E., above 1,040-ft (315-m) elevation, 130 ft (39 m) above top of Argentine Limestone Member, now identified at ~910-ft (276-m) elevation in Section 5 [above] just 2 mi (3 km) to east [Paola West quadrangle]. Farley exposure just to west [Section 8 below] was once thought to represent entire Wyandotte Limestone here and southwestward above original type Lane Shale, now known to be thickened facies of Island Creek Shale Member.

8. K–68 roadcut west of Bell Branch, along south line SW-SW sec. 26 and SE-SE sec. 27, T. 16 S., R. 22 E., exposing Farley Limestone Member, Bonner Springs Shale Member, and all three members of Plattsburg Limestone [Paola West quadrangle]. This is Locality 10 of Miller (1966, p. 55) who classified Farley as Frisbie and Argentine Limestone Members with no intervening Quindaro Shale Member, following earlier authors.

9. Quarry south of Bush City, in NE-NE sec. 31, T. 21 S., R. 21 E., 2 mi (3 km) SSE of Bush City, Anderson County, Kansas [Bush City quadrangle]. Mitchell (1981, p. 249–250, 312) included all strata in Raytown Limestone Member following previous practice, but termed

interbedded shale and limestone toward top 'Bush City bed' (p. 249) because of difference from typical upper Raytown. This upper unit is now known to represent Wyandotte Limestone because of conodont-rich lower shale (Quindaro).

10. Quarry on south side of Iola, in NE sec. 2, T. 25 S., R. 18 E., Allen County, Kansas [Iola quadrangle]. All limestone in quarry above Paola Limestone and Muncie Creek Shale was traditionally classified as Raytown Limestone Member, although Mitchell (1981, p. 259) termed upper interbedded shales and limestones as 'Bassett beds' and 'Owl Creek beds' because of lithic differences from typical massive Raytown in this area. Interpreting conodont-rich shale in middle of succession on diagram in Mitchell (1981, p. 320) as Quindaro Shale Member, overlying limestone-rich unit can be recognized as Argentine Limestone Member, and underlying limestone-rich unit as Frisbie Limestone Member, all together constituting Wyandotte Limestone in region where it had never before been recognized. Frisbie Limestone Member is separated from top of Raytown by conodont-poor shale that represents featheredge of Liberty Memorial Shale.

Figure 33:

1. Platte River Valley section [PRV], with Cass Limestone and upper Plattford from localities in Cass County, Nebraska (from Burchett and Reed, 1967, p. 38); Nehawka through Stanton Limestone from Ash Grove quarry in sec. 13, T. 12 N., R. 11 E., northeast of Louisville, Cass County, Nebraska (from Heckel et al., 1979, p. 56).

2. [NAC] Amerada Core [Schroeder #1], drilled in NE-SE sec. 26, T. 11 N., R. 12 E., 4 mi (6.4 km) NNW of Nehawka, Cass County, Nebraska, reposited at Nebraska Geological Survey, Lincoln. Described by Condra (1939), with section from top of Stoner Limestone Member through top of Cass Limestone redescribed by P. H. Heckel in 1988.

3. [IMC] Malvern Core, drilled by Kaser Construction Company in sec. 5, T. 71 N., R. 41 W., south of Malvern, Mills County, Iowa, reposited at Iowa Geological Survey [DNR], Iowa City. Described by P. H. Heckel.

4. [IBC] Bedford Core, drilled in SE sec. 4, T. 67 N., R. 34 W., south of Bedford, Taylor County, Iowa, reposited at Iowa Geological Survey [DNR], Iowa City. Described by P. H. Heckel.

5. [MNC] Nodaway County Core [WM-5], drilled in SE-NW sec. 10, T. 65 N., R. 36 W., 7 mi (11 km) NNW of Maryville, Nodaway County, Missouri, reposited at Missouri DNR Division of Geology and Land Survey, Rolla. Description by K. Deason provided by W. B. Howe.

6. [MRC] Rochester Core [WM-10], drilled in SE-SE sec. 4, T. 59 N., R. 34 W., 3 mi (5 km) north of Rochester, Andrew County, Missouri, reposited at Missouri DNR Division of Geology and Land Survey, Rolla. Description by B. Netzler and K. Deason provided by W. B. Howe. Abundant conodonts in thin shale in lower Iatan Limestone Member reported by Goebel (1985, p. 94).

7. I–29 roadcut exposing Iatan Limestone Member on east side of I–29, in SW-NW sec. 25, T. 54 N., R. 35 W., ~1 mi (1.6 km) north of entrance from County Highway E, west of Camden Point, Platte County, Missouri [Tracy quadrangle].

8. Quarry NW of Sadler, in bluff along Missouri River near NW corner sec. 33, T. 54 N., R. 36 W., ~2 mi (3 km) southeast of Iatan, Platte County, Missouri [Weston quadrangle]. Iatan Limestone Member now covered by fill.

9. Beverly roadcut on south side of Route 92, with section continuing up bluff, near center of north half of NE sec. 31, T. 53 N, R. 35 W., at Beverly, Platte County, Missouri [Platte City quadrangle].

10. Lower part is type section of Little Kaw Limestone Member in roadcut along K–7 just south of US–40, located in figs. 34–35 [Bonner Springs quadrangle]. Upper part is most of type section of Tonganoxie Sandstone Member in series of roadcuts along US–40 for 3 mi (5 km) from center S line SE sec. 6, T. 11 S., R. 22 E., to exposure of Haskell Limestone Member near center N line NE sec. 10, T. 11 S., R. 21 E., 1 to 4 mi (1.6–6.4 km) east of Tonganoxie, Leavenworth County, Kansas [Tonganoxie quadrangle]. Upper Sibley coal level and total thickness of Tonganoxie Sandstone Member based on subsurface information published in Feldman et al. (1995, p. 1,023–1,024, 1,036).

11. Type Stranger Formation interval estimated from exposures of lower and upper Little Kaw Limestone Member along road ditch on E line NE-SE-SE sec. 3, T. 12 S., R. 21 E., southward then westward to exposure of Haskell Limestone Member in roadcut just east of center S line sec. 3, ~2 mi (3 km) NNW of Linwood, Leavenworth County, Kansas [Tonganoxie quadrangle]. Thickness estimated from elevations of base and top, modified by regional dip of 30 ft per mile; this thickness is used to tie two datums [top of Haskell Limestone Member and top of Little Kaw Limestone Member] together for cross section.

12. Principal reference section for Cass Limestone and Little Pawnee Shale and Shoemaker Limestone Members in Kansas, in roadcut along north side of K–32, 6 mi (9.6 km) west of Linwood, Leavenworth County, Kansas, located and illustrated in figs. 36–37 [Midland quadrangle].

13. Type section of Haskell Limestone Member in roadcut along south side of 15th Street at center N line NE sec. 5, T. 13 S., R. 20 E., on east side of Lawrence, Douglas County, Kansas [Lawrence East quadrangle].

14. Type section of Vinland Shale Member, in roadcut on west side of road along E line SE-SE sec. 2, T. 14 S., R. 20 E., ~2 mi (3 km) northeast of Vinland, Douglas County, Kansas [Baldwin City quadrangle]. Total thickness of Vinland Shale Member [26 ft: 7.8 m] and presence of Westphalia Limestone Member at base reported by Ball (1964).

15. Principal reference section for Upper Sibley coal bed, in roadcut on north side of road just east of center S line SE sec. 12, T. 14 S., R. 20 E., 2.5 mi (4 km) east of Vinland, Douglas County, Kansas [Baldwin City quadrangle].

16. Quarry [Buildex] that includes type section of Ottawa coal bed in NW-NW sec. 23, T. 17 S., R. 19 E., south of Ottawa, Franklin County, Kansas [Ottawa South quadrangle]. Thicknesses based on section in Feldman et al. (1995, p. 1,024).

17. Lower part is Lone Elm roadcut exposing Little Kaw Limestone and Gretna Shale Members along US–59, along E line north of SE corner sec. 6, T. 22 S., R. 20 E., ~5 mi (8 km) north of Lone Elm, Anderson County, Kansas [Bush City quadrangle]. Upper middle part is principal reference section for Westphalia Limestone Member in road ditch near center E line NE sec. 20, T. 21 S., R. 18 E., 3 mi (5 km) ENE of Westphalia, Anderson County, Kansas [Westphalia quadrangle]. Thickness of interval from lower part estimated from elevations of Little Kaw and Westphalia Limestone Members, assuming regional dip of 30 ft per mile, over distance of 11 mi (17.6 km). Upper part is roadcut exposing Haskell Limestone Member and upper Vinland Shale Member near center S line SW-SE sec. 13, T. 21 S., R. 17 E., 2 mi (3 km) north of Westphalia [same quadrangle], with interval estimated from elevations and assumed regional dip.

18. Exposure in spillway of Woodson County State Lake, in SE-SW-NE sec. 14, T. 26 S., R. 14 E., 6 mi (9.6 km) east of Toronto, Woodson County, Kansas [Toronto SE quadrangle]. Illustrated as Stop D1 in Heckel et al. (1999, p. 62). This is type section for Robbins Shale Member of Lawrence Formation, which now overlies Cass Limestone, the latter comprising Haskell Limestone Member, Little Pawnee Shale Member, and Shoemaker Limestone Member [where present].

19. Lower part is roadcut west of Elk City Dam in SW-SE-NW sec. 7, T. 32 S., R. 15 E., ~5 mi (8 km) east of Elk City, Montgomery County, Kansas [Table Mound quadrangle]. Illustrated as Stop 8 in Heckel (1978, p. 40). Top is exposure of Haskell Limestone Member in road near center W line NW-SW sec. 23, T. 32 S., R. 13 E., ~4 mi (6.4 km) southwest of Elk City [Caney NW quadrangle]. Thickness of interval from lower part estimated from elevation of top of Little Kaw Limestone Member south of old bridge in NW-SW-NE sec. 18, T. 32 S., R. 14 E., 1.5 mi (2.4 km) south of Elk City [Elk City quadrangle] and that of Haskell Limestone Member at above locality, assuming regional dip of 30 ft per mile. Little Kaw Limestone Member is known to thin abruptly southward to 4 ft (1.2 m) in exposures along US–160 in SW-SE sec. 28, T. 32 S., R. 14 E. [Caney NW quadrangle], 3 mi (5 km) southeast of bridge locality. Because thinning is from top, datum for cross section is shifted to base of Little Kaw Limestone Member from here southward.

20. US–166 roadcuts around Peru: Lower part is Iatan Limestone Member in road ditch along north side of US–166 in NE-SE-SW sec. 23, T. 34 S., R. 12 E., 3 mi (5 km) west of Niotaze, Chautauqua County, Kansas [Peru quadrangle], illustrated as Stop C1 in Heckel et al. (1999, p. 48). Middle part is roadcut just to west near center W line SW sec. 23, illustrated as Stop C2 in Heckel et al. (1999, p. 48). Upper part combines roadcuts along US–166 near center sec. 22, and in NE-NE sec. 20, T. 34 S., R. 12 E., east and west of Peru, respectively, illustrated above Stop C2 and as Stop C3 in Heckel et al. (1999, p. 48, 50). Iatan Limestone thickens locally to 12 ft (3.6 m) in old quarry in SW-SE-SE sec. 10, ~2 mi (3 km) NNW of its exposure in US–166 roadcut.

21. Caney area: Driveway exposes top of Little Kaw Limestone Member, and cuts in bank just to south expose fossiliferous Gretna Shale Member in NW-SW-NW sec. 6, T. 35 S., R. 14 E., on east side of US–75, 1 mi (1.6 km) north of Caney, Montgomery County, Kansas [Caney quadrangle]. Also, 2 mi (3 km) west of Caney, road ditch and adjacent excavation expose Gretna Shale Member on southwest side of road near center SE-SW sec. 10, T. 35 S., R. 13 E., in Chautauqua County, and 3-ft (0.9-m) exposure of sandy Little Kaw Limestone Member is present above road level on bluff west of Little Caney River in NW-NE-NW sec. 13, T. 29 N., R. 12 E., Washington County, Oklahoma [Copan quadrangle], just south of Kansas border, and 1 mi (1.6 km) southeast of Gretna Shale Member exposure.

22. Hulah area: Lower part is Little Kaw Limestone Member exposed in road ditch along north side of OK–10 in SE-SE-SE sec. 4, T. 28 N., R. 12 E., and Gretna Shale Member exposed in bank along south side of OK–10, in SE-SW-SW sec. 4, east of Hulah, Osage County, Oklahoma [Bowring quadrangle]. Middle part is exposure of Iatan Limestone Member and adjacent strata above low water level of Hulah Reservoir north of OK–10 just west of dam and bridge over Caney River in SE-SE-SW sec. 2, T. 28 N., R. 11 E., Osage County, Oklahoma, with interval estimated from elevations of Little Kaw and Iatan Limestone Members assuming 30-ft-per-mile regional dip. Upper part is exposure of Bowring [Westphalia] Limestone at top of hill in NE-NE sec. 10, 0.6 mi (1 km) WSW of Iatan Limestone Member exposure, with thickness of interval estimated from elevations and regional dip.

23. Bowring area: Road ditch along north side of OK–10 exposes type Bowring Limestone [=Westphalia Limestone Member] in SW-NE-NW-SW sec. 28, T. 28 N., R. 11 E., ~0.5 mi (0.8 km) southwest of Bowring [Herd quadrangle]. Interval extends westward nearly 3 mi (5 km) along OK–10 to Labadie Limestone Member exposure in SW SE SW sec. 25, T. 28 N., R. 10 E., with thickness estimated from elevations and regional dip of 30 ft per mile.

24. Dry Hollow: Roadcuts along US–60 both east and west of Dry Hollow in NE-NW-SW sec. 2 and center of NW-SE sec. 3, T. 26 N., R. 10 E., Osage County, Oklahoma [Herd quadrangle], expose thick Labadie Limestone Member [in its type area] and underlying Little Pawnee Shale Member, about 12 mi (19 km) west of Washington–Osage County line.

25. Nelagoney area: Road ditch on west side of bend in road, near center E line sec. 32, T. 25 N., R. 10 E., exposes all three members of Cass Limestone, 0.5 mi (0.8 km) north of junction with OK–11 and nearly 2 mi (3 km) south of Nelagoney, Osage County, Oklahoma [Barnsdall quadrangle].

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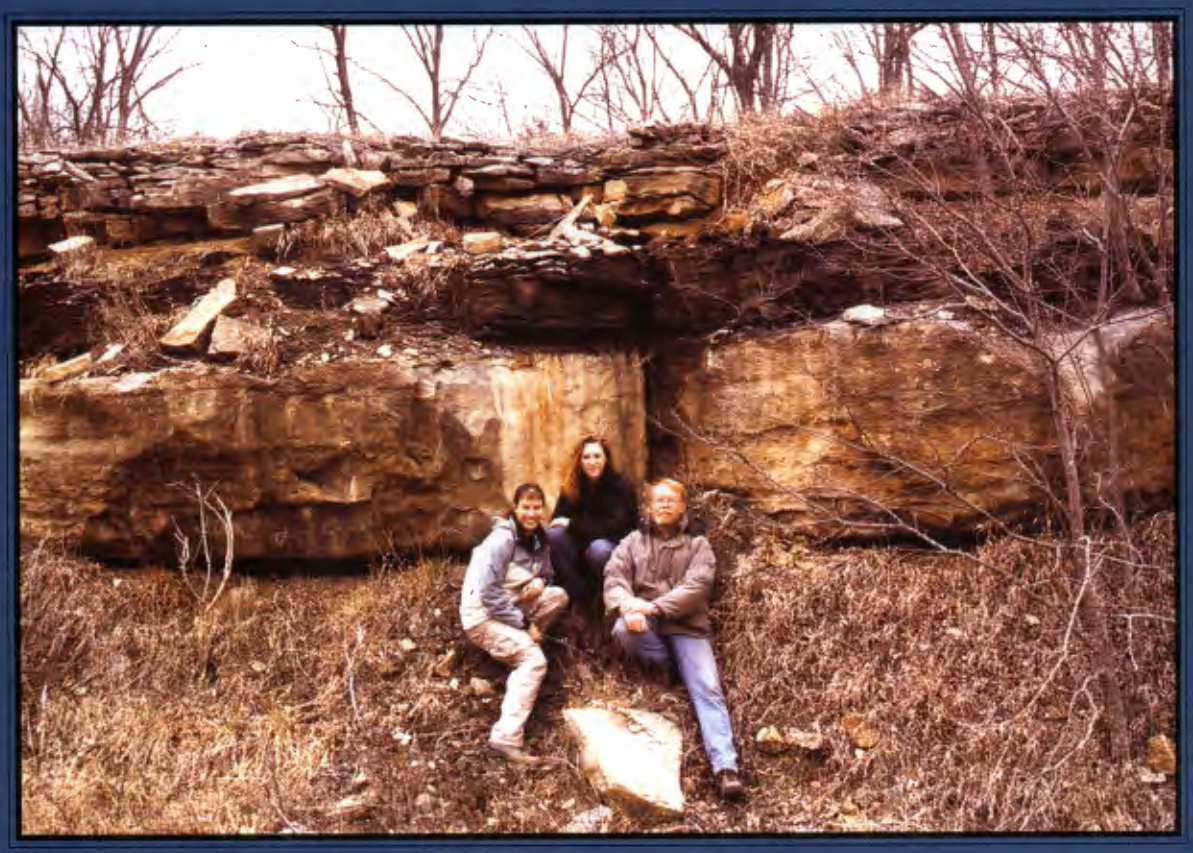
Index



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