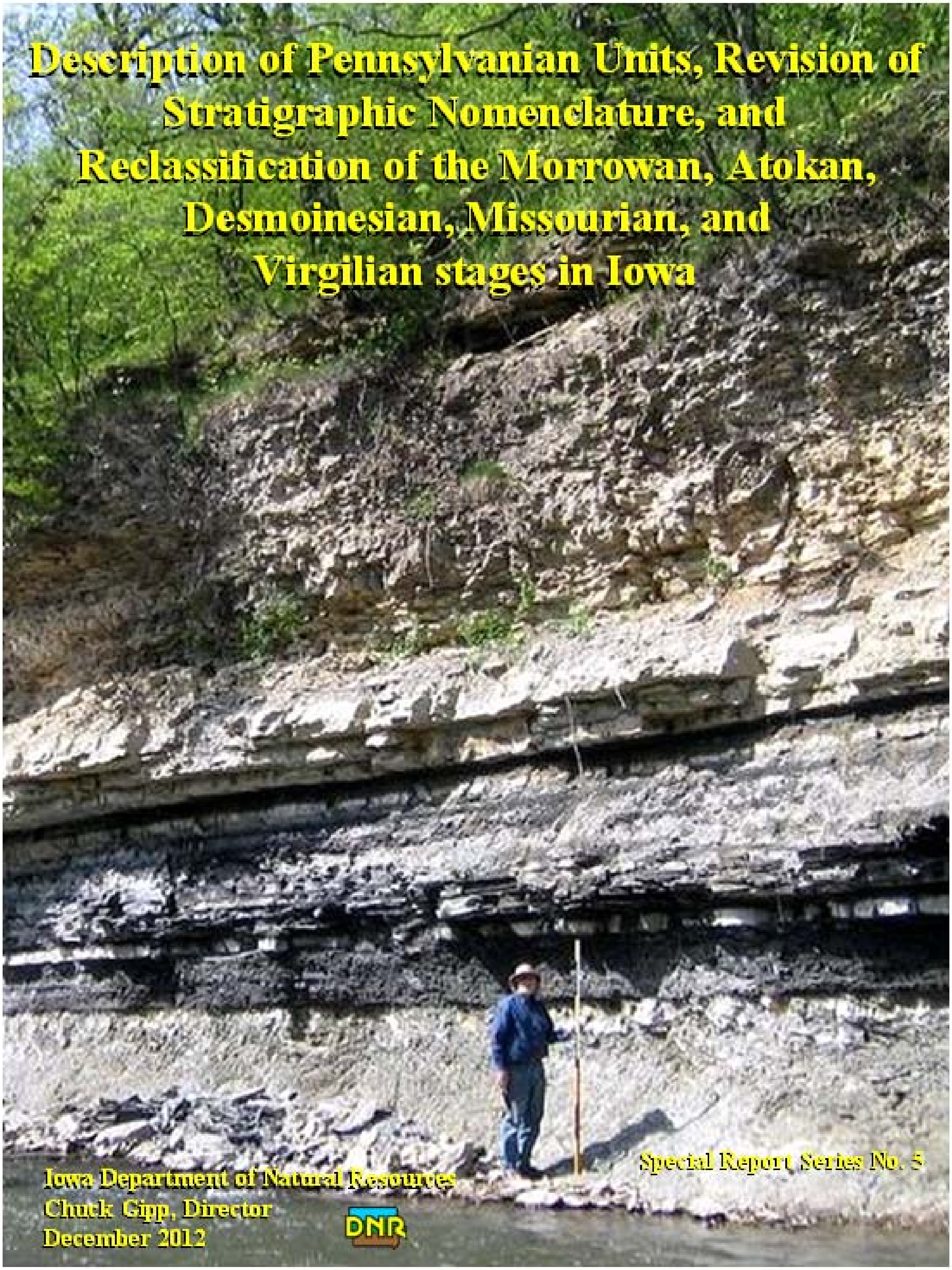
Description of Pennsylvanian Units, Revision of Stratigraphic Nomenclature, and Reclassification of the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian stages in Iowa



Special Report Series No. 5

Iowa Department of Natural Resources
Chuck Gipp, Director
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DNR

Front Cover: Photograph of reference section for upper Chanute Shale and Paola Limestone Member, Muncie Creek Shale Member, Raytown Limestone Member of the Iola Limestone. Author John Pope holding staff that is 6.5 feet (2.0 m) long, with the top near the base of Paola Limestone. The outcrop is at an exposure in a south-facing cutbank of North River in the SE SW NE NW section 11, T. 76 N., R. 29 W., Madison County, Iowa, about 300 feet (91 m) east of the Elmwood Avenue bridge. Photo by Diana Pope, May 2008.

Description of Pennsylvanian Units, Revision of Stratigraphic Nomenclature, and Reclassification of the Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian stages in Iowa

Special Report Series No. 5

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ABSTRACT

A revision of Pennsylvanian stratigraphic nomenclature in Iowa has been necessated for a number of reasons: 1) the correction of several long-standing miscorrelations within the Missourian succession from Iowa to Kansas, Missouri, and Nebraska; 2) the recent naming of several new units in Iowa (e. g., Pammel Park Limestone, East Peru Limestone, Clanton Creek Limestone); 3) the recent recognition of units in Iowa that were previously known only in other states; 4) the lack of documented, relatively well-exposed and easily accessible type and reference outcrops and cores in Iowa; 5) the beginning of reorganization and recorrelation of the Iowa Cherokee Group using a conodont biostratigraphic framework; 6) recent stratigraphic revisions in neighboring states of Missouri, Illinois, Kansas, and Oklahoma; 7) and the recent ratification of global upper Carboniferous System, Pennsylvanian Subsystem, subdivision classification and nomenclature.

In the Wabaunsee Group, subgroups are removed with new formations and members recognized. This brings Iowa nomenclature, with minor exceptions, into agreement with Kansas nomenclature. The Shawnee Group remains virtually unchanged. Revision of the Douglas Group includes names extended from adjacent states for newly recognized formations, members and beds in Iowa. As in Kansas, the provisional Missourian-Virgilian stage boundary is now recognized near the top of the Haskell Limestone Member of the Cass Limestone. The Lansing Group has been substantially revised with several new formations, members and beds recognized. Most names are extended from Kansas, but the Arbor Hill Coal bed in the Rock Lake Shale is named in this report. Subgroups have been removed from the Kansas City Group along with other substantial revisions of formations and members. The Harmon Tunnel Coal bed in the Nellie Bly Shale is newly named in this report. In the Bronson Group, the name Ladore Shale has been replaced by the Elm Branch Shale and several new members have been recognized. The Desmoinesian-Missourian stage boundary is placed at the base of the Exline Limestone Member in the Pleasanton Formation.

In the Marmaton Group several new formations, members and beds have been recognized. Many of the changes are due to the extension of names from surrounding states. The McBride Coal bed of the Bandera Shale and the Imes Coal bed in the Mine Creek Shale Member of the Pawnee Formation are newly named in this report. The Cherokee Group has also been substantially revised with one new formation, and several new members and beds recognized. The Red Haw Limestone Member of the Swede Hollow Formation is newly named in this report. The newly recognized Verdigris Formation was erected by removing the Ardmore Limestone and Oakley Shale members from the Swede Hollow Formation. The Whitebreast Coal bed was also removed from the Swede Hollow Formation and placed in the Floris Formation, below the newly named Wiscotta Shale Member. Several other new members and beds have been recognized in the Floris Formation, with the Elliot Ford Limestone, Olmitz Limestone and Belinda Shale being named as new members. The Thousand Acre Coal bed is also newly named. The lower part of the Cherokee Group, below the Belinda Shale Member, has not been revised pending further study of marine units above coal beds. The Atokan-Desmoinesian boundary is placed at the base of the Cliffland Coal, Kalo Formation, based on conodonts.

Since Pennsylvanian units in southeast Iowa, in Scott and Muscatine counties, have been recognized as being in a structural extension of the Illinois Basin, I have followed the most recent revisions of nomenclature in the Illinois Basin of Illinois, Indiana and Kentucky for this part of Iowa. This now includes strata of the Caseyville Formation of the Raccoon Creek Group, which replaces the older McCormick Group and lower Kewanee Group. The upper part of the abandoned Kewanee Group is unnamed at this time. The upper Raccoon Creek Group now includes the abandoned Abbott Formation and the lower part of the abandoned Spoon Formation.

INTRODUCTION

A revision of Pennsylvanian stratigraphic nomenclature in Iowa, since the most recent revision by Ravn and others (1984), has been necessated for a number of reasons: 1) the correction of several long-standing miscorrelations within the Missourian succession from Iowa to Kansas, Missouri, and Nebraska; 2) the recent naming of several new units in Iowa (e. g., Pammel Park Limestone, East Peru Limestone, Clanton Creek Limestone); 3) the recent recognition of units in Iowa that were previously known only in other states; 4) the lack of documented, relatively well-exposed and easily accessible type and reference outcrops and cores in Iowa; 5) the beginning of reorganization and recorrelation of the Iowa Cherokee Group using a conodont biostratigraphic framework; 6) and recent stratigraphic revisions in neighboring states of Missouri, Illinois, Kansas, and Oklahoma.

With the current understanding of the cyclic deposition of most Pennsylvanian units (see section on cyclothems below) and ongoing correlation of units on a worldwide basis, a genetic (allostratigraphic) classification system should be established in conjunction with the traditional lithostratigraphic classification system. The current lithostratigraphic classification system cannot be used for this purpose, because current lithostratigraphic formational boundaries do not always allow easy correlation or interpretation of the cyclic nature and genesis of rock units (e.g., Oread, Lecompton, Topeka formations), but a complete revision of the lithostratigraphy would be unnecessarily burdensome due to the over 150 years that it has been used in geologic literature, with only relatively minor revisions in the last fifty years. In order to establish a formal allostratigraphic classification system, a full understanding of the lithostratigraphic classification system of the rock units must be in place. This report is a step toward more fully understanding the chronologic succession, geographic distribution and classification of Pennsylvanian strata in Iowa, and how they relate to strata in adjacent states in the Midcontinent.

Included in this report is information on original authors and locations of type and reference sections in Iowa, and in other states where units were named. An attempt has been made to provide a basic history of nomenclatural changes of selected units using charts comparing old and current classification systems, but not all early changes and details of nomenclatural history are included. These changes often reflect corrections made after recognition of previous miscorrelation of units, especially across the Kansas, Missouri and Nebraska outcrop belt, which affected Iowa nomenclature and correlations. It is hoped that the basic history will familiarize readers as to how the current nomenclature relates to the older nomenclatural literature.

This report also includes descriptions of stratigraphic units at type sections located in Iowa, and basic descriptions of selected outcrops and cores that illustrate lateral changes of units. In addition to published reports from Iowa, published reports from the surrounding and nearby states of Illinois, Missouri, Kansas, Nebraska and Oklahoma were used, because many names used in Iowa were first proposed in these states, and because most of Oklahoma, Kansas, Missouri, Nebraska, and Iowa lie within the same depositional basin (Midcontinent Basin). Many type sections, stratigraphic names, and nomenclatural histories are from Wilmarth (1938), Keroher (1966), Keroher (1970), Swanson and others (1981), Luttrel and others (1986), Luttrel and others (1991), and the USGS National Geologic Map Database, Geologic Names Lexicon (GEOLEX).

Some of the outcrop sections and cores used in this report have been used in previous publications (GSI/GSA guidebooks, Iowa DOT reports, IGS Annual and coal reports, etc.), but many are from unpublished M.S. and Ph. D. theses, and unpublished notes of the author and others.

Type and reference sections for Iowa outcrops are for the most part established in roadcut backslopes, lake shorelines and streamcuts. These outcrops are relatively stable over long periods of time, compared to quarry sections that are now often filled shortly after quarry operations cease. If no adequately exposed sections are available or complete sections are lacking in a single outcrop (e.g., Shawnee Group) a section of a long core is used as a reference section. These cores include: the Riverton core (W-27556) in Fremont County; the Bedford core (W-30816) in Taylor County; the Malvern core (W-28868) in Mills County; and the Logan core (W-26516) in Harrison County. Iowa Geological Survey (IGS) Coal Project cores (e.g., CP-37, CP-78) are used as reference sections for selected Desmoinesian and Atokan strata. All cores are reposited in the Iowa Geological Survey's Oakdale facility, and are listed with the exact location at the end of this volume. They are directly identified by and the striplog can be accessed via the W (well-log) number following the name, in GEOSAM on the Iowa Geological Survey website. It should be noted that the names of certain units and their horizons (mainly below the Oakley Shale) in many of the Iowa Geological Survey (IGS) Coal Project cores and other cores are uncertain, pending study of marine units and their associated conodont faunas. Most of these early stratigraphic "picks" were based on palynology and counting of coal beds above or below relatively recognizable units. In many cases the palynology did not give enough resolution and the lenticular nature of units made counting coal beds uncertain.

For some strata, several outcrops are used to provide adequate exposure in case of slumping or vegetation overgrowth (e.g., Myrick Station Limestone Member), and several cores or outcrops are used for some strata to illustrate the lateral variation in sediments (e.g., Swede Hollow Formation). Quarry sections will still be used to illustrate some sections, but they may not be accessible in the future.

Comments in parentheses (e.g., new name in Iowa; new beds recognized) below the unit names, refers to changes since the last revision of the Pennsylvanian in Iowa by Ravn and others in 1984.

Early Studies of the Pennsylvanian (Carboniferous) in Iowa

After the early exploration of eastern Iowa along the Mississippi River by French explorers, and along the Missouri River by the Lewis and Clark expedition, one of the first surveys of Iowa in the Pennsylvanian outcrop area along the Des Moines River was carried out by Nathan Boone and Albert Lea in the 1830s. The first recorded coal mining in Iowa was done in 1840 in Scott and Van Buren counties by early settlers (Lees, 1909). The Carboniferous strata in the Iowa part of the northern Midcontinent, were first recognized and investigated by D.D. Owen in 1839, and his observations were published in 1840 and revised in 1844. D.D. Owen (1852) also published on the regional geology of Iowa, Minnesota and Nebraska.

Several geologists and paleontologists were quite active in the 1850s and 1860s, publishing much new information on Iowa. James Hall (1858) published investigations of the coal fields of Iowa and Worthen (1858) reported on the geology of the Des Moines River Valley. White (1867, 1868a, 1868b) published on important aspects of Pennsylvanian stratigraphy, and also in 1868, St. John published his *Surface Geology of the Raccoon River Region*. Some other workers in the late 19th century and early 20th century include: M.F. Arey, H.F. Bain, S. Calvin, L.M. Cline, C.H. Gordon, H. Hinds, C.R. Keyes, J.H. Lees, A.G. Leonard, E.H. Lonsdale, A.L. Lugn, W.H. Norton, G.L. Smith, J.L. Tilton, J.A. Udden, and L.W. Wood.

Iowa Structural Basins

Early geologists (e.g., Keyes, 1894) called the area between the Appalachian Mountains and the Rocky Mountains, the Interior Basin. This was then subdivided into the Appalachian Coal Basin, and two basins adjacent to the Mississippi River. The area east of the Mississippi River was called the Eastern Interior Coal Basin or Eastern Interior Basin (now known as the Illinois Basin) and the area west of the Mississippi River was called the Western Interior Coal Basin or Western Interior Basin (now known as the Midcontinent Basin). Figure 1 shows the Pennsylvanian outcrop area and major structural features of the Interior region. Some of these structural features were pre-Pennsylvanian in origin or were active during the Pennsylvanian and affected Pennsylvanian sedimentation; others may be post-Pennsylvanian.

Pennsylvanian units in southeast Iowa, in Scott and Muscatine counties, have been recognized as being in a structural extension of the Illinois Basin (Fitzgerald, 1977; Ravn et al., 1984). The Illinois Basin lies mainly in the southern two-thirds of Illinois, southwestern Indiana, and western Kentucky. There are a few outliers in St. Louis, Lincoln and St. Charles counties near St. Louis, in east-central Missouri and in Scott and Muscatine counties in southeastern Iowa. The Illinois Basin is separated from the Midcontinent Basin by the Lincoln Arch, 'Mississippi River Arch' and the Ozark Dome. Since Scott and Muscatine counties in Iowa are structurally part of the Illinois Basin, The author agrees with Fitzgerald (1977), Ravn and Fitzgerald (1982), Ravn and others (1984) and Ravn (1986), that Illinois Basin stratigraphic nomenclature should be used in this part of Iowa. However, the author will follow the most recent revisions of Greb and others (1992), the Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin (2001), and Jacobson (2002) for stratigraphic nomenclature in this part of the Iowa Pennsylvanian. This now includes strata of the Caseyville Formation of the Raccoon Creek Group, which replaces the older McCormick Group and lower Kewanee Group. The upper part of the abandoned Kewanee Group is unnamed at this time. The upper Raccoon Creek Group now includes the abandoned Abbott Formation and the lower part of the abandoned Spoon Formation.

Most of the rest of the Pennsylvanian of Iowa (approximately the southwestern one third of the state) occurs in the Midcontinent Basin. The relatively shallower central and northern part of the basin is referred to as the Northern Midcontinent Shelf. Most of the Midcontinent Basin lies within southwest Iowa, northwest Missouri, southeast Nebraska, eastern Kansas, and northeast Oklahoma. The Forest City Basin (Lee, 1946; Jewett, 1951; Anderson and Wells, 1968), a sub-basin of the Midcontinent Basin, lies in southwest Iowa, northwest Missouri, east of the Nemaha Ridge in Kansas and Nebraska, and north of the Bourbon Arch in east-central Kansas. The author will use 'Midcontinent' stratigraphic nomenclature for areas outside of Scott and Muscatine counties of Iowa. Pennsylvanian chronostratigraphic units within the Forest City Basin include in ascending order: possible Morrowan, and definite Atokan, Desmoinesian, Missourian, and Virgilian stages (Burchett, 1979; Peppers and Brady, 2007).
The recently completed STATEMAP Project mapped Pennsylvanian strata in 67 of the 99 counties in Iowa (Witzke, et al., 1997; Witzke, et al., 1998; Witzke, et al., 2001; Pope, et al., 2002; Witzke, et al., 2003a, 2003b, 2003c; Witzke, et al., 2004, Witzke, Anderson and Pope, 2010). A few isolated outliers of terrestrial origin, in the eastern and southeastern part of the state have not been assigned to any specific basin.

Midcontinent Rift System

The Midcontinent Rift System (Figure 1) that was principally active about 1.2-1.0 billion years ago, extends from northeast Kansas thru Iowa, Minnesota, and Wisconsin to Michigan (Anderson, 1992). The Iowa segment of the rift extends from southeastern Nebraska to southern Minnesota and is separated from segments to the northwest and southeast by transform faults. The Midcontinent Rift System is characterized by a central horst, called the Iowa Horst, in the Iowa segment of the rift system. The Iowa Horst is dominated by Keweenawan mafic volcanic and plutonic rocks (reaching thicknesses of up to 30,000 feet – 9,200 m) and is locally capped by Keweenawan clastic rocks in several discrete basins. The horst is separated from flanking clastic-filled basins by high-angle reverse faults with total modeled displacements in excess of 30,000 feet (9,200 m), with most movement occurring in the Precambrian. The Thurman-Redfield Fault Zone is the southeastern bounding fault of the Iowa Horst; the Northern Boundary Fault Zone is the northwestern bounding fault. For a more complete discussion of the Thurman-Redfield Fault Zone, see Pope and others (2002) and Witzke and others (2003b).

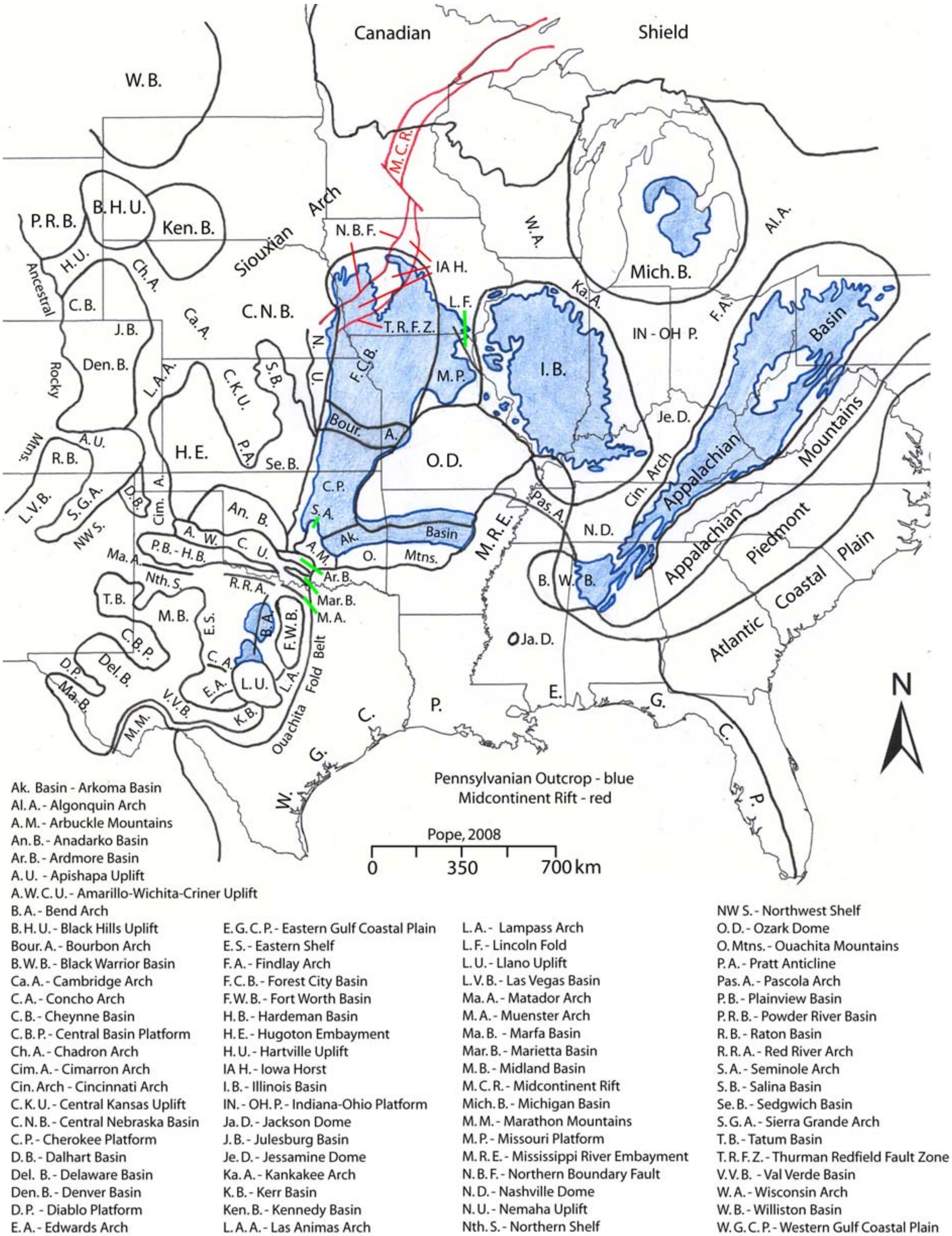

Figure 1. Pennsylvanian outcrop and tectonic map of interior United States. Modified from Jewett, 1951; Anderson and Wells, 1968; Rascoe and Adler, 1983; Greb et al., 1992; Rice, 1994; Muehlberger, 1997.

Cyclothems

It is now recognized that most lithologic units in the Pennsylvanian of the Midcontinent Basin were deposited in various environments that resulted from glacial-eustatic rise and fall of sea-level brought about by waxing and waning of Gondwanan glaciers (Wanless and Shepard, 1936; Heckel, 1977, 1980, 1994, 2007, 2008). Termed cyclothems by Wanless and Weller (1932), these cycles of transgression and regression were recognized by Heckel (1986, 1988, 1990, 1994, 2002b, 2007, 2008) as marine transgressive-regressive sequences, centered on thin, nonsandy, black, phosphatic 'core' shales (Figure 2).

Cyclothems are allostratigraphic units ('stratigraphic sequences' of sequence stratigraphy), which are partially defined on the basis of bounding discontinuities. In south-central Iowa these discontinuities are often paleosols, developed during times of subaerial exposure.

On the Northern Midcontinent Shelf, cyclothems are classified informally into three scale-based groups identified by the extent of marine transgressive and highstand units (Heckel, 1999). Major marine cycles are characterized by a widespread, conodont-rich gray to black shale, located between the transgressive and regressive limestones that extend across the entire shelf. Intermediate cycles are characterized by a conodont-rich gray shale or limestone, and are distributed with limited extent toward the northern part of the shelf. Minor cycles typically extend only a short distance northward from the Oklahoma basinal region, or represent minor reversals of sea-level within more major cyclothems.

Most major Midcontinent cyclothems, and some intermediate ones, display a distinctive vertical sequence of lithic members (Heckel, 1977). Each lithic member represents a particular phase of deposition during a single phase of glacial-eustatic sea-level change (transgression-regression). In south-central

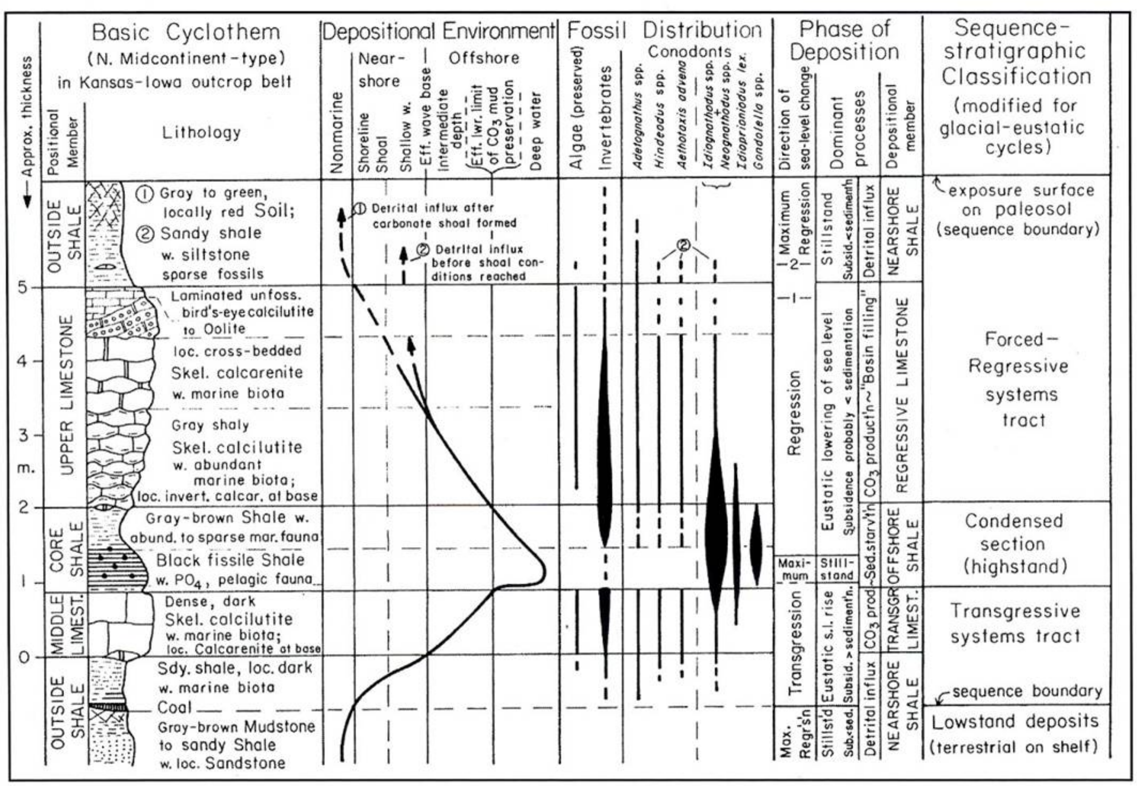

Figure 2. Typical marine cyclothem of Northern Midcontinent Shelf (from Heckel, 1994).

Iowa, most cyclothems overlie a basal mudstone (lowstand systems tract of sequence stratigraphic terminology). Pope (1999) and Heckel (2002b) recognized that coal beds often overlie these basal mudstones (underclays), which are now recognized as paleosols that can be identified and traced beyond the limits of a local coal bed (Joeckel, 1995). They regarded the top of the paleosol, near or at the base of a coal (when present), to be the most widespread disconformity and the boundary between cyclothems. Heckel (1995), Pope (1999) and Heckel (2002b) considered the coal to be more temporally and genetically related to the overlying marine units, because it formed by the ponding of fresh water on a coastal plain of low relief at the leading edge of the transgression.

Above this is typically a thin transgressive limestone (transgressive systems tract) representing a deepening-upward sequence that was deposited in a marine environment. Overlying the transgressive limestone is the offshore ‘core’ shale (highstand systems tract) interpreted as deep-water high-stand deposits that represent a condensed interval deposited under conditions of sediment starvation at maximum marine transgression (Heckel, 1977, 1994). This was in water deep enough to inhibit benthic carbonate-producing algal growth or preservation of carbonate mud. Above the highstand deposits is typically a thick regressive limestone (‘regressive systems tract’) deposited as sea level lowered to the point that benthic algal production of carbonate mud resumed, and this mud was preserved. These limestones often shallow upward into shoal-water and tidal-flat deposits. Shale is often found above the regressive limestone along with local sandstones, deposited during final regression or lowstand. These shales are often capped by gray to red blocky mudstones identified as paleosols. Such deposits represent the lowstand systems tract where soil formation and erosion, including the formation of paleovalleys (Pope and Goettemoeller, 2002), occurred. The paleosol marks the top of the underlying cyclothem beneath the base of the overlying cyclothem. For a more comprehensive discussion of cyclothems see Heckel (1977, 1980, 1994, 2007). Heckel and Baesemann (1975) related conodont distribution in cyclothems to the different depositional environments. For a brief history of Midcontinent cyclothems see Marshall (2009).

Part I: MIDCONTINENT (FOREST CITY) BASIN STRATIGRAPHY

Carboniferous System

The Coal Measures was the original name for the coal deposits of England, and similar deposits were known in the rest of Europe. In 1822, Conybeare (*in* Conybeare and Phillips) used the name Carboniferous (from the Latin words for coal-bearing) for the Coal Measures and three underlying units: Millstone Grit, Mountain Limestone, and Old Red Sandstone. This included strata from what is now the Devonian up through the Pennsylvanian. Murchison placed the Old Red Sandstone in the Devonian (on a map drawn in 1836) and in 1840, Sedgwick and Murchison officially removed the Old Red Sandstone from the Carboniferous and placed it in the Devonian.

After the Old Red Sandstone was placed in the Devonian, European geologists realized the Carboniferous consisted of a lower sequence (Lower Carboniferous) comprising the Mountain Limestone and Millstone Grit, and an upper sequence (Upper Carboniferous) comprising the Coal Measures. The Coal Measures were also recognized in North America, especially in Pennsylvania (Rogers, 1836), and a carbonate sequence underlying the Coal Measures was recognized in the Mississippi River Valley. Winchell (1870, p. 136) first mentioned the name Mississippian, which he proposed to apply to the lower carbonate sequence in North America, for exposures near St. Louis, Missouri. Williams (1891) also recognized the Mississippian, and correlated it with the Lower Carboniferous of Europe, thus leaving the Upper Carboniferous of North America as essentially equivalent to the Upper Carboniferous of Europe. Later in 1891, Williams used the name Pennsylvanian for exposures of Upper Carboniferous (Coal Measures) strata in North America, with the state of Pennsylvania as the type area. Interestingly, the name Pennsylvanian was first used by Williams (*in* Simonds, 1891) in a report on Washington County, Arkansas. The U.S. Geological Survey did not officially adopt the names Mississippian and Pennsylvanian until 1953.

Western and eastern European geologists did not use the North American terminology and American geologists did not use western and eastern European terminology. In the latter part of the twentieth century, global correlation of Carboniferous strata became important for understanding climate cycles, but the North American names were so engrained in the North American literature, most American geologists did not want to abandon them. Like-wise western and eastern European geologists did not want to abandon European and Russian names.

In the process of formally adopting a worldwide classification scheme for the Carboniferous, the Mid-Carboniferous Boundary Working Group of the Subcommission on Carboniferous Stratigraphy (SCCS) was established after the 10th Congress on Carboniferous Stratigraphy and Geology in Madrid, Spain, 1983. The Working Group was to find a Global Stratotype Section and Point (GSSP) for a boundary in the middle of the Carboniferous System that would coincide with the evolutionary first appearance of the conodont *Declinognathodus noduliferus* s. l. in its evolutionary sequence from *Gnathodus girtyi simplex*. In 1995, the Working Group recommended to the SCCS that a GSSP for the middle of the Carboniferous be established at 82.90 meters above the top of the Battleship Wash Formation and within the lower part of the Bird Spring Formation at Arrow Canyon, Nevada, USA. This GSSP proposal was overwhelmingly approved by the voting members of the SCCS and later ratified by the Executive Committee of the IUGS in January 1996. See Lane and others (1999).

Pennsylvanian Subsystem

Partially because of ambiguity in the use of the terms 'Upper' and 'Lower' Carboniferous, the Sub-Commission on Carboniferous Stratigraphy (SCCS) of the International Commission on Stratigraphy (ICS) of the International Union of Geological Sciences (IUGS), voted to officially recognize the Mississippian and Pennsylvanian as subsystems of the Carboniferous System on a worldwide basis (see Heckel, 2004).

UPPER PENNSYLVANIAN SERIES

Swallow (1855) divided the Coal Measures of North America into an 'Upper, Middle, and Lower Coal Series.' Later the 'Lower' and 'Middle' series were combined into the 'Lower Coal Measures.' This led to the use of the names 'Upper Coal Measures' and 'Lower Coal Measures' for the two major divisions of what is now the Pennsylvanian. Workers in the midcontinent realized that Appalachian stratigraphic nomenclature was inadequate for the midcontinent, because of lateral facies changes in units, unconformities and faunal changes. By the 1960s (e.g., Branson, 1962a, 1962b, 1962c), midcontinent workers had dropped the usage of all Appalachian names and they started using midcontinent names. Keyes (1893) had proposed the name 'Des Moines' (which essentially applied to the 'Lower Coal Measures') and the name 'Missouri' (which essentially applied to the 'Upper Coal Measures'). Moore (1932) divided the 'Missouri 'of Keyes into a lower 'Missouri' and an upper 'Virgil' at a major unconformity, in what is now the Douglas Group. Although some workers (e.g., Moore, 1937; Cheney et al., 1945) used only the terms Morrowan, Desmoinesian, Missourian, and Virgilian series, with the Atoka Formation placed in the lower part of the Desmoinesian, Jewett and others (1968, *in* Zeller, ed.) used the five subdivision names Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian as stages in Kansas, and these are still in use today

Pennsylvanian System
- Upper Pennsylvanian Series
  - Virgilian stage
  - Missourian stage
- Middle Pennsylvanian Series
  - Desmoinesian Stage
  - Atokan Stage
- Lower Pennsylvanian Series
  - Morrowan Stage

SYSTEM	SUB SYSTEM	GLOBAL SERIES	GLOBAL STAGES	North American Regional Stages
CARBONIFEROUS	PENNSYLVANIAN	UPPER	GZHELIAN	Virgilian
			KASIMOVIAN	Missourian
		MIDDLE	MOSCOVIAN	Desmoinesian
				Atokan
		LOWER	BASHKIRIAN	Morrowan

Figure 3. Approximate equivalency of global subdivisions to regional stage subdivisions in Midcontinent North America. Dashed line shows current position of Moscovian-Kasimovian boundary. Modified from Heckel and Clayton (2006).

The Pennsylvanian Subsystem now has an official global series and stage classification and nomenclature (Heckel, 2004; Heckel and Clayton, 2006), which were ratified by the SCCS of the ICS and IUGS (Figure 3). Because Global Stratotype Sections and Points (GSSPs) have not yet been determined, the exact boundaries of all the stages have not been selected at this time.

The ratified global upper Carboniferous System (Pennsylvanian Subsystem) subdivisions are as follows:

- Carboniferous System
  - Pennsylvanian Subsystem
    - Upper Pennsylvanian Series
      - Gzhelian (mostly = Virgilian) Stage
      - Kasimovian (mostly = Missourian) Stage
    - Middle Pennsylvanian Series
      - "upper" Moscovian (mostly = Desmoinesian) Stage
      - "lower" Moscovian (mostly = "upper" Atokan) Stage
    - Lower Pennsylvanian Series
      - "upper" Bashkirian (mostly = "lower" Atokan) Stage
      - "lower" Bashkirian (= Morrowan) Stage

The Eastern European stage names (Gzhelian, Kasimovian, Moscovian, and Bashkirian) are officially recognized as global stage names, while the Virgilian, Missourian, Desmoinesian, Atokan, and Morrowan will be retained as regional stages in North America (Heckel, 2004; Heckel and Clayton, 2006).

Pennsylvanian-Permian Boundary

Early geologists chose series and stage boundaries at what they thought were major unconformities, but it was later discovered that many of these unconformities were either local or only regional in extent, and were not useful for worldwide correlation. Most geologists now pick boundaries based on the first (sometimes last) occurrence of specific fossils among widespread groups (e.g., conodonts, spores, fusulinids, ammonoids, etc.). This is called biostratigraphic zonation, and it has allowed much more refined global correlation of units.

The Pennsylvanian-Permian boundary in the Midcontinent (Figure 4) has been placed at several stratigraphic horizons ranging from the base of the Admire Group up to the base of the Neva Limestone Member of the Grenola

Formation, Council Grove Group. Moore (1932) thought the base of the Americus Limestone (Foraker Formation, Council Grove Group) should be the boundary, but Moore and Moss (1934) and Moore (1940) later placed the boundary at what they thought was a major unconformity at the base of the Admire Group (at the top of the Brownville Limestone, top of the Wabaunsee Group). This disconformity at the base of the Admire Group was recognized by Kansas, and most other Midcontinent states, as the base of the Permian. See Moore (1949, Fig. 3, p. 6), for boundary placement between 1859 and 1937.

Baars and others (1992), Baars, Ritter and others (1994), and Baars, Ross and other (1994) proposed moving the boundary to the base of the Neva Limestone Member of the Grenola Formation, Council Grove Group, based on fusulinid foraminifer zonation, with Baars, Ritter, Maples, and Ross (1994) expanding the Virgilian Series (Stage) to include the Admire and lower Council Grove groups.

Since pelagic conodonts are usually more useful than benthic foraminifers for global correlation, the Global Stratotype Section and Point (GSSP) for the base of the Permian System (see Davydov, et al., 1998; Wardlaw, Davydov, and Gradstein, 2004) is defined by the first occurrence of the conodont *Streptognathodus isolatus* (Chernykh et al., 1997) in the Ural Mountains of Kazakhstan, the type region of the Permian System. In Kansas, the first occurrence of *Streptognathodus isolatus* is at the base of the Bennett Shale (Boardman, 1999; Wardlaw and Davydov, 2000; Wardlaw, Boardman, and Nestell, 2004; Sawin et al., 2006; Sawin et al., 2008), above the Glen Rock Limestone of the Red Eagle Limestone.

Ross and Ross (1994, 1998, 2002) proposed the Bursum Stage to include the Admire Group and lower Council Grove Group up to the top of the Glenrock Limestone Member (base of the Bennett Shale Member) of the Red Eagle Limestone, instead of expanding the Virgilian Stage. Davydov (2001) proposed the Orenburgian Stage, a name derived from the Ural Mountains, as the top of the Carboniferous, but this proposal was rejected by Ross and Ross (2002) on the basis of lower boundary problems between the Orenburgian of the Urals and its equivalent horizon in the North American Pennsylvanian succession. Wilde (2002) rejected use of the Bursumian Stage and instead proposed the Newwellian as a substage of the Wolfcampian, leaving the Wolfcampian-Virgilian boundary where it has historically been. Since none of these proposed stage names have been formally approved by the SCCS or ICS, at this time the Virgilian is extended upward to include all units to the base of the Bennett Shale.

VIRGILIAN STAGE

Moore (1932) defined the Virgilian series as all the strata between the unconformity in the Douglas Group to the base of the Permian. After 1936 the upper boundary was stabilized at the base of a ‘major’ unconformity above the Brownville Limestone, marked by the Indian Cave Sandstone in the northern Midcontinent. These strata were the former upper ‘Missourian’ of Keyes (1893). Condra (1949) designated the type locality of the Virgilian as being along the Verdigris River from west of Madison to Virgil (Greenwood County) southeastward to central Wilson County, Kansas. Jewett, et al. (1968) proposed the Virgilian as a stage in the Upper Pennsylvanian Series.

The Virgilian Stage (Figures 4, 5) comprises five groups in ascending order (Boardman, 1999): Douglas, Shawnee, Wabaunsee, Admire, and Council Grove. For a discussion of the Virgilian-Permian boundary, see the section on the Pennsylvanian-Permian boundary above. Boardman and others (1989), Barrick and others (1995), Heckel (1999), Heckel and others (1999), and Heckel and Watney (2002), suggested that the best position for the Missourian-Virgilian boundary is near the top of the Haskell Limestone Member of the Cass Formation, Douglas Group, just below the first appearance of the conodont *Streptognathodus zethus*.

Avcin and Koch (1979) recognized about 500 feet (152 m) of Virgilian strata in Iowa, but Witzke (2003a; 2003b) shows approximately 647 feet (197 m) of Virgilian strata in the Riverton core from Fremont County. In Iowa, the upper part of the Virgilian Stage is absent, having probably been removed by erosion.

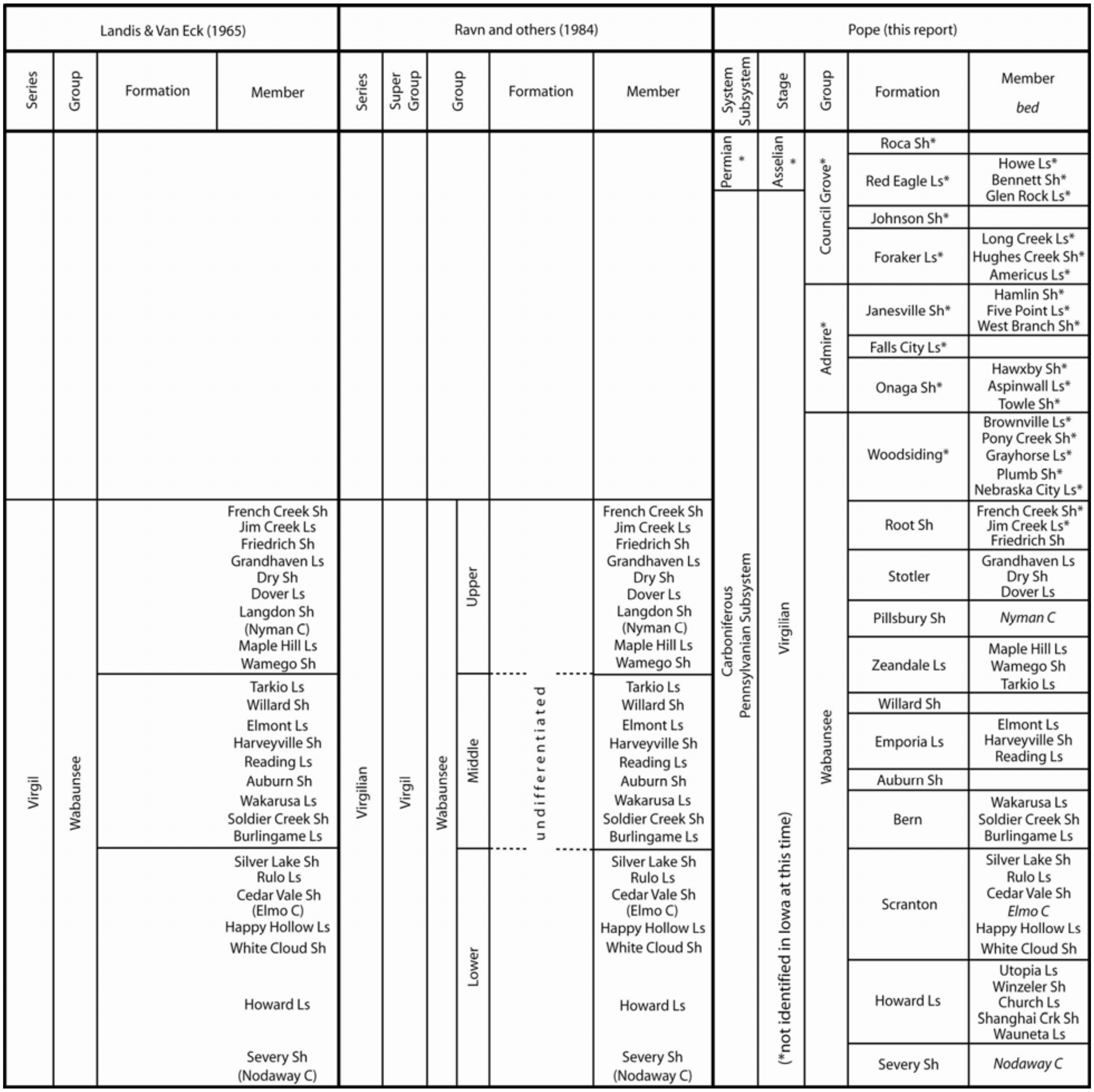

Figure 4. Upper Virgilian Stage (Wabaunsee Group) stratigraphy of Iowa, showing relationship to Permian System. Stratigraphy of upper Wabaunsee (above Friedrich Shale), Admire, and Council Grove groups in the Pennsylvanian and lower Council Grove Group in the Permian, is from Kansas.

These missing Pennsylvanian units include the lower part of the Council Grove Group, the entire Admire Group, and the top of the Wabaunsee Group.

The 174.0-788.5 foot interval in the Riverton core is designated as a reference section for the Virgilian Stage, below the lower Dry Shale Member of the Stotler Formation, Wabaunsee Group.

COUNCIL GROVE GROUP*
(* not recognized in Iowa)

Red Eagle Limestone*

Howe Limestone Member (Permian)*
Bennett Shale Member (Permian)*
Glenrock Limestone Member (Pennsylvanian)*

Johnson Shale*

Foraker Limestone*

Long Creek Limestone Member*
Hughes Creek Shale Member*
Americus Limestone Member*

ADMIRE GROUP*

Janesville Shale*

Hamlin Shale Member*
Five Point Limestone Member*
West Branch Shale Member*

Falls City Limestone*

Onaga Shale*

Hawxby Shale Member*
Aspinwall Limestone Member*
Towle Shale Member*

WABAUNSEE GROUP
(subgroups removed; new formations, members recognized)

The Wabaunsee Group (Figure 4) was named by Prosser (1895), who stated "This series of limestones and shales is well exposed along the Neosho River below and above Emporia, and especially to the north, in the eastern and northern portions of Wabaunsee county [Kansas]." Prosser's (1895) Wabaunsee formation ranged from the Nodaway Coal in what is now the Howard Limestone to the Cottonwood Limestone in the middle of the Council Grove Group (now considered Permian). In Iowa and Missouri, what is now the Wabaunsee Group and Topeka Limestone (part of the Shawnee Group) were called the Atchison shales. Smith (1909) divided the Atchison shales in ascending order, into the Braddyville limestones (essentially the Topeka Limestone), City Bluffs shales, Tarkio limestones, and McKissick Grove shales (everything above the Tarkio). Condra (1927) defined the McKissick Grove shales to include all strata between the Tarkio limestones and the base of the Brownville Limestone. Moore (1931) defined the base of the Wabaunsee Group as the top of the Topeka Limestone and Moore and Moss (1934), Condra (1935), and Moore (1936) placed the top of the group at a 'major unconformity' at the top of the Brownville Limestone (base of the Admire Group). Searight and Howe (1961) defined the base of the group as the top of the Topeka Limestone, and placed the top of the group at the top of the Dry Shale Member of the Stotler Formation.

Moore (1949), O'Connor and others (1968), Boardman and Nestell (1993), Boardman (1999) placed the base of the Wabaunsee Group at the top of the Topeka Limestone, and recognized the top as the top of the Brownville Limestone Member of the Wood Siding Formation. The Wabaunsee Group in Kansas, Missouri, and Nebraska comprises three subgroups (Sacfox, Nemaha, and Richardson) with twelve formations in ascending order: Severy Shale, Howard Limestone, Scranton Shale, Bern Formation, Auburn Shale, Emporia Limestone, Willard Shale, Zeandale Limestone, Pillsbury Shale, Stotler Formation, Root Shale, and Wood Siding Formation. These formations are divided into a total of thirty members. In southeastern Nebraska, where it is relatively completely preserved, the Wabaunsee Group is about 400 feet (122 m) thick (Burchett, 1979). The

Wabaunsee Group overlies the Shawnee Group and underlies the Admire Group.

In Iowa the upper seven members are not presently known, having probably been removed by erosion, but some of them may be present under thick loess and glacial till in the extreme southwestern part of the state. Avcin and Koch (1979) recognized 210 feet (64 m) of strata in Iowa, but Witzke (2003a; 2003b) shows approximately 332 feet (101 m) of Wabaunsee strata in the SW-4 Riverton core in Fremont County. In Iowa, the three subgroups, Sacfox, Nemaha, and Richardson (lower, middle and upper in Ravn et al., 1984; Fig. 28, p. 57), are not recognized. Ravn and others (1984; Fig. 28, p. 57) did not recognize formations in the Wabaunsee Group, but it is needful to divide the Wabaunsee into formations, following the nomenclature of Witzke (2003b).

The 174.0-482.5 foot interval (lower Dry Shale to base of Severy Shale) of the Riverton core is designated as a reference section. Strata above the Dry Shale were once reported (Smith, 1909; Condra, 1927) to exist at McKissick's Grove, near the northeast corner of section 24 and the southeast corner of section 13, T. 67 N., R. 42 W., Fremont County, about 2.5 miles (4.0 km) east northeast of Hamburg. The author could not locate these outcrops due to the building of pond dikes in the ravines.

Wood Siding Formation*

Brownville Limestone Member*
Pony Creek Shale Member*
Grayhorse Limestone Member*
Plumb Shale Member*
Nebraska City Limestone Member*

Root Shale
(new name in Iowa)

The Root Shale was named by Moore and Mudge (1956) from exposures in a roadcut along an east-flowing stream near the C of the N ½ SE section 20, T. 21 S., R. 11 E., Lyon County, Kansas. The name was derived from the Root Railway Station on the Atchison, Topeka, and Santa Fe Railroad in the SE section 23, T. 21 S., R. 11 E. The Root Shale comprises three members in ascending order: Friedrich Shale, Jim Creek Limestone, and French Creek Shale. The Root Shale overlies the Stotler Formation and underlies the Wood Siding Formation.

The lower member of the Root Shale (lower few feet of the Friedrich Shale) is seen at an exposure on a farm on the east side of County Road L44 (Bluff Road) about 2.5 miles (4.0 km) south of Thurman, in the E ½ W ½ SW section 12, T. 69 N., R. 43 W., Fremont County.

French Creek Shale Member*
*Lorton Coal bed (NE, KS)**
Jim Creek Limestone Member*

Friedrich Shale Member
(unchanged)

The Friedrich Shale Member was named by Moore and others (1934) and a type locality was designated at exposures along Friedrich Creek in section 6, T. 32 S., R. 11 E., Greenwood County, Kansas. The Friedrich Shale Member overlies the Grandhaven Limestone Member of the Stotler Formation and underlies the Jim Creek Limestone Member.

The lower few feet of the light gray (N7) Friedrich Shale is exposed on a farm on the east side of County Road L44 (Bluff Road) about 2.5 miles (4.0 km) south of Thurman, in the E ½ W ½ SW section 12, T. 69 N., R. 43 W., Fremont County.

Stotler Formation
(new name in Iowa)

The Stotler Formation was named by Moore and Mudge (1956) from exposures in the spillway of a pond in the SE section 13, T. 16 S., R. 12 E., Lyon County, Kansas, about two miles (3.2 km) west of Miller. The name is derived from the Stotler Post Office which was in the SW section 10, T. 16 S., R. 13 E. The Stotler Limestone comprises three members in ascending order: Dover Limestone, Dry Shale, and Grandhaven Limestone. The Stotler Formation overlies the Pillsbury Shale and underlies the Root Shale.

The Grandhaven Limestone and upper Dry Shale members are exposed at a farm on the east side of County Road L44 (Bluff Road) about 2.5 miles (4.0 km) south of Thurman, in the E ½ W

½ SW section 12, T. 69 N., R. 43 W., Fremont County. The Dover Limestone is exposed on the east side of County Road L44 (Bluff Road) about one mile (1.6 km) south of Thurman, in the SE SE NE NE NE section 2, T. 69 N., R. 43 W., Fremont County. The lower Dry Shale occurs in the 174.0-189.0 foot interval of the Riverton core.

Grandhaven Limestone Member
(unchanged)

The Grandhaven Limestone Member was named by Moore and others (1934) from exposures in section 31, T. 13 S., R. 14 E., near Grandhaven, Shawnee County, Kansas. It was revised by Moore and Mudge (1956). The Grandhaven Limestone Member overlies the Dry Shale Member and underlies the Friedrich Shale Member of the Root Shale. In Fremont County, Iowa, the Grandhaven is about three feet (0.9 m) of abraded-grain skeletal packstone to wackestone with limestone-clasts.

A reference section is designated at an exposure at a farm on the east side of County Road L44 (Bluff Road) about 2.5 miles (4.0 km) south of Thurman, in the E ½ W ½ SW section 12, T. 69 N., R. 43 W., Fremont County.

Dry Shale Member
(unchanged)

The Dry Shale Member was named by Moore and others (1934) from outcrops on Dry Creek in section 5, T. 20 S., R 11 E., southwest of Emporia, Lyon County, Kansas. In Iowa and Nebraska, Condra (1927) called it the Pony Creek shale of the McKissick shale member of the Wabaunsee formation. The Dry Shale was revised by Moore and Mudge (1956) as used today. The Dry Shale Member overlies the Dover Limestone Member and underlies the Grandhaven Limestone Member. Burchett (1979) described the Dry Coal in this unit in Nebraska. At the reference section in Fremont County, the Dry Shale from top to exposed base is six inches (15 cm) of sandy, micaceous light gray (N7) shale above three feet (0.9 m) of greenish gray (5GY 6/1) very micaceous, bioturbated sandstone.

A reference section for the upper ten feet (3.0 m) is designated at an exposure at a farm on the east side of County Road L44 (Bluff Road) about 2.5 miles (4.0 km) south of Thurman, in the E ½ W ½ SW section 12, T. 69 N., R. 43 W., Fremont County. The lower Dry Shale occurs in the 174.0-189.0 foot interval of the Riverton core.

Dover Limestone Member
(unchanged)

The Dover Limestone Member was named by Beede (1898) from exposures in the vicinity of Dover, Shawnee County, Kansas. No location was ever designated. The Dover Limestone was revised by Condra (1927) and later by Moore and Mudge (1956). The Dover Limestone Member overlies the Pillsbury Shale and underlies the Dry Shale Member. At the reference section in Fremont County, the Dover Limestone is about one foot (30 cm) of argillaceous packstone above a massive 18 inch (45 cm) thick bed of lime wackestone.

The 189.0-192.8 foot interval in the Riverton core is designated as a reference section. A reference section is also designated at backslope exposures on the east side of County Road L44 (Bluff Road) about one mile (1.6 km) south of Thurman, in the SE SE NE NE NE section 2, T. 69 N., R. 43 W., Fremont County.

Pillsbury Shale
(new name in Iowa)

The Pillsbury Shale was named by Moore and Mudge (1956) from exposures near Pillsbury Crossing, with the type section in the SE NE NE section 28, T. 10 S., R. 9 E., Riley County, Kansas. The name was derived from Pillsbury Crossing, a ford across Deep Creek, in the NE NW section 5, T. 11 S., R. 9 E., Riley County, Kansas. The Pillsbury Shale was called the Langdon Formation by Condra and Reed (1943), but Moore and Mudge (1956) rejected the name Langdon, because the type section of the Langdon Shale correlates with the Wamego Shale of the Zeandale Formation. Landis and Van Eck (1965) still used the name Langdon Shale in Iowa. Condra (1927) used the name Table Creek Shale for the strata between the Maple Hill Limestone and the Dover Limestone. The Pillsbury Shale overlies the Zeandale Limestone and underlies the Stotler Limestone.

The 192.8-218.5 foot interval in the Riverton core is designated as a reference section. A reference section for the upper ten feet (3.0 m) is also designated at backslope exposures on the east side of County Road L44 (Bluff Road) about one mile (1.6 km) south of Thurman, in the SE SE NE NE NE section 2, T. 69 N., R. 43 W., Fremont County.

Nyman Coal bed
(unchanged)

The Nyman Coal was originally called the Lindquist Coal by early geologists (e.g., Hinds, 1909), from an exposure at a coal mine on the Charles Lindquist farm on the Middle Tarkio River in the NW NW section 24, T. 70 N., R. 38 W., about ten miles northwest of Clarinda, Page County, Iowa. Smith (1909) believed the coal should have a geographic location name, so he renamed it after the nearby town of Nyman near the center of section 10, about two miles (3.2 km) northwest of the Lindquist farm. It varies from 6-18 inches (15-45 cm) thick along the Middle Tarkio River in Page County. At the reference section in Fremont County the Nyman Coal underlies six inches (15 cm) of light gray (N7) shale and is four inches (10 cm) thick. It lies above six inches (15 cm) of light gray (N7) rooted, blocky mudstone and three feet (0.9 m) of sandy, micaceous shale, exposed by trenching.

The Nyman Coal occurs at about the 193.0 foot level in the Riverton core. A reference section is also designated at backslope exposures on the east side of County Road L44 (Bluff Road) about one mile (1.6 km) south of Thurman, in the SE SE NE NE NE section 2, T. 69 N., R. 43 W., Fremont County.

Zeandale Limestone
(new name in Iowa)

The Zeandale Limestone was named by Moore and Mudge (1956) from exposures in a north-south farm access road south of Deep Creek, about one mile (1.6 km) east and 0.25 mile (0.4 km) south of the town of Zeandale, in the SE NE NE section 28, T. 10 S., R. 9 E., Riley County, Kansas. The Zeandale Limestone comprises three members in ascending order: Tarkio Limestone, Wamego Shale, and Maple Hill Limestone. The Zeandale Limestone overlies the Willard Shale and underlies the Pillsbury Shale.

The 218.5-228.5 foot interval in the Riverton core and a west side roadcut exposure about nine miles (15 km) west of Clarinda, in the NE corner NW section 27, T. 69 N., R. 38 W., Page County, are designated as reference sections.

Maple Hill Limestone Member
(unchanged)

The Maple Hill Limestone Member was named by Condra (1927) from exposures on ‘Maple’ Creek [= Mill Creek of USGS Maple Hill 7.5’ topo sheet], about two miles (3.2 km) southwest of Maple Hill, Wabaunsee County, Kansas. From the description, this location would be in an unidentified section in T. 11 S., R. 12 W. The Maple Hill Limestone Member overlies the Wamego Shale Member and underlies the Pillsbury Shale. At the reference section in Page County, the Maple Hill Limestone is a massive bed of argillaceous, fusulinid-rich, skeletal packstone about one foot (30 cm) thick.

The 218.5-221.5 foot interval in the Riverton core and a west side roadcut exposure about nine miles (15 km) west of Clarinda, in the NE corner NW section 27, T. 69 N., R. 38 W., Page County, are designated as reference sections.

Wamego Shale Member
(unchanged)

The Wamego Shale Member was named by Condra and Reed (1943) from exposures in the bluffs of the Kansas River north of U.S. Highway 40 (along the Military Trail Road), about 4 miles (6.4 km) west of Wamego, Pottawatomie County, Kansas. From the description, this location would be in an unidentified section in T. 10 S., R. 9 E. The Wamego Shale was revised by Moore and Mudge (1956) to replace the name Pierson Point Shale. Howe (1958), Thompson (1995), and Gentile and Thompson (2004) placed the Nyman Coal in the Wamego Shale. Burchett (1979) listed the Wamego Coal in the Wamego Shale below the Maple Hill Limestone. The Wamego

Shale Member overlies the Tarkio Limestone Member and underlies the Maple Hill Limestone Member. At the Page County reference section, the upper six feet (1.8 m) of light gray (N7) Wamego Shale is exposed. In the Riverton core it is represented by two feet (60 cm) of dark reddish brown (10R 3/4) grayish green (10GY 5/2) mottled blocky mudstone.

The 221.5-223.5 foot interval in the Riverton core and a west side roadcut exposure about nine miles (15 km) west of Clarinda, in the NE corner NW section 27, T. 69 N., R. 38 W., Page County, are designated as reference sections.

Tarkio Limestone Member
(unchanged)

The Tarkio Limestone was named by Calvin (1901) from exposures in Tarkio Township along Tarkio Creek (River), north of the town of Coin, Page County, Iowa. Ver Wiebe and Vickery (1932) located a type section in T. 68 N., R. 38 W., on Tarkio Creek (River), north of Coin. It is not clear, but from the description, Calvin's outcrop may have been in the NE corner NW section 27, T. 68 N., R. 38 W. Calvin's original Tarkio formation included the following strata in ascending order: Reading Limestone, Harveyville Shale, Elmont Limestone, Willard Shale, and Swallow's 'Chocolate Limestone' (presently defined as the Tarkio Limestone).

Condra (1935) revised the Tarkio (using the name for a single limestone unit, the 'Chocolate Limestone' of Swallow) and designated a type locality in the Missouri River Bluffs, west of the Tarkio [River] Valley, northeast of Corning, Holt County, Missouri. It is unclear where Condra's type section was, but it was possibly in section 20, T. 63 N., R. 40 W., Holt County, but more likely just to the north in Atchison County in any of the following sections: sections 7, 8, 17, 18, T. 63 N., R. 40 W., or sections 1, 2, 12, 13, T. 63 N., R. 41 W. Moore (1936) selected a cotype for the Tarkio and designated a new type section on Mill Creek, southwest of Maple Hill, Wabaunsee County, Kansas, because it is thicker and better developed there. From the description, the location is probably that of the type Maple Hill Limestone in an unidentified section in T. 11 S., R. 12 W. The Mill Creek site was the location where Swallow (1867) had named the 'Chocolate Limestone.' The name 'Chocolate Limestone' had been dropped, because it was not a geographic name. There are three type sections for the Tarkio Limestone Member; one in Iowa, one in Kansas, and one in Missouri. See Condra (1949) and Baars and Maples (1998) for a complete discussion on the revision of the unit. The Tarkio Limestone Member overlies the Willard Shale and underlies the Wamego Shale Member. At the Page County reference section the Tarkio Limestone consists of an upper six inch (15 cm) thick skeletal wackestone to packstone overlying a three inch (7.5 cm) thick shale, which overlies a massive bed of skeletal wackestone about 15 inches (38 cm) thick. The Tarkio Limestone often contains abundant fusulinid foraminifers.

The 223.5-228.5 foot interval in the Riverton core and a west side roadcut exposure about nine miles (15 km) west of Clarinda, in the NE corner NW section 27, T. 69 N., R. 38 W., Page County, are designated as reference sections.

Willard Shale
(raised in rank)

The Willard Shale was named by Beede (1898) from exposures south of the town of Willard, Shawnee County, Kansas, and was revised by Moore and Mudge (1956). It is not clear, but from the description, the outcrop may have been in T. 11 S., R. 13 E. The Willard Shale overlies the Emporia Limestone and underlies the Zeandale Limestone. The upper part of the Willard Shale varies from light gray (N7) silty shale with plant debris to a light gray (N7) blocky mudstone, while the lower part is bioturbated clay shale that contains marine fossils. It varies from 4-15 feet (1.2-4.6 m) thick in southwest Iowa.

The 228.5-243.0 foot interval in the Riverton core is designated as a reference section.

Emporia Limestone
(new name in Iowa)

The Emporia Limestone was named by Kirk (1896) from outcrops southeast of Emporia, Kansas. Ver Wiebe and Vickery (1932) located a type section in T. 19 S., R. 11 E., near Emporia, Lyon County, Kansas. The Emporia was revised and a reference section was designated by Moore and Mudge (1956) on Kansas Highway 10 in the NW section 31, T. 11 S., R. 14 E., Shawnee County, Kansas. The Emporia Limestone comprises three members in ascending order: Reading Limestone, Harveyville Shale, and Elmont Limestone. The Emporia Limestone overlies the Auburn Shale and underlies the Willard Shale.

The 243.0-255.5 foot interval in the Riverton core is designated as a reference section.

Elmont Limestone Member
(unchanged)

The Elmont Limestone was named by Beede (1898) from exposures in the hills near Elmont, Shawnee County, Kansas. It is unclear where Beede's section was, but it was possibly in T. 10 S., R. 15 E. The Elmont Limestone was revised by Moore and Mudge (1956). The Elmont Limestone Member overlies the Harveyville Shale Member and underlies the Willard Shale. The Elmont Limestone is usually a thin, argillaceous, limestone with abundant crinoid debris, brachiopods and fusulinid foraminifers.

The 243.0-245.5 foot interval in the Riverton core is designated as a reference section.

Harveyville Shale Member
(unchanged)

The name Harveyville Shale was first used by Moore and others (1934) and later by Condra (1935). The Harveyville Shale was formally defined by Moore (1936) who located the type exposures near Harveyville in southeastern Wabaunsee County, Kansas. According to Condra (1935) it is well exposed in section 25, T. 15 S., R. 13 E. It was revised by Moore and Mudge (1956). Thompson (1995) noted a coal in the unit in Missouri. The Harveyville Shale Member overlies the Reading Limestone Member and underlies the Elmont Limestone Member. The upper part of the Harveyville Shale is often light gray (N7) and calcareous, while the lower part is often laminated and contains ostracodes.

The 245.5-250.0 foot interval in the Riverton core is designated as a reference section.

Reading Limestone Member
(unchanged)

The Reading Limestone (Reading Blue Limestone) was named by Smith (1905) and Moore (1936) located the type section near Reading, Lyon County, Kansas. Moore located exposures in a roadcut at the NW corner section 33, T. 17 S., R. 13 E., one mile (1.6 km) east and one mile (1.6 km) north of Reading. Moore also removed the descriptive term 'blue.' The Reading Limestone was revised by Moore and Mudge (1956). The Reading Limestone Member overlies the Auburn Shale and underlies the Harveyville Shale Member. The Reading Limestone is thin, argillaceous, and contains abundant marine fossils, including brachiopods, crinoids debris and fusulinid foraminifers.

The 250.0-255.5 foot interval in the Riverton core is designated as a reference section. A limestone at an east side roadcut, exposed on County Road L44 (Bluff Road) just north of Thurman, in the SW NE SW NE section 35, T. 70 N., R. 43 W., Fremont County, is tentatively identified as the Reading.

Auburn Shale
(raised in rank)

The Auburn Shale was named by Beede (1898) from exposures near Auburn, Shawnee County, Kansas. No type section was designated, but Moore (1936) located exposures on Wakarusa Creek near the NE corner section 26, T. 63 S., R. 14 E., southwest of the town of Auburn. The Auburn Shale overlies the Bern Formation and underlies the Emporia Limestone. Witzke (2003a, 2003b) noted a local coaly zone above a moderate reddish brown (10R 4/6) blocky mudstone, near the top of the Auburn Shale in the Riverton core, Fremont County, Iowa. The lower part of the Auburn

Shale is clay-rich, often laminated, and contains abundant pecten-like clams or plant debris.

The 255.5-281.0 foot interval in the Riverton core is designated as a reference section.

Bern Formation
(new name in Iowa)

The Bern Formation was named by Moore and Mudge (1956) from exposures in a roadcut in the SE SE section 7, T. 1 S., R. 13 E., 0.5 mile (0.8 km) north and one mile (1.6 km) west of the town of Bern, Nemaha County, Kansas. The Bern Formation comprises three members in ascending order: Burlingame Limestone, Soldier Creek Shale, and Wakarusa Limestone. The Bern Formation overlies the Scranton Shale and underlies the Auburn Shale.

The 281.0-343.0 foot interval in the Riverton core is designated as a reference section. An east side roadcut exposure along County Road L44 (Bluff Road), about 0.4 mile (0.6 km) north of Thurman in the NE NE NW section 35, T. 70 N., R. 43 W., Fremont County, is also designated as a reference section for the Wakarusa Limestone Member and the upper 15 feet (4.6 m) of the Soldier Creek Shale Member.

Wakarusa Limestone Member
(unchanged)

The name Wakarusa Limestone was originally used by Beede (1898) from exposures on Wakarusa Creek south of Auburn, Shawnee County, Kansas. It is not clear, but from the description, the location may have been in T. 13 S., R. 14 E. Beede's original strata were later identified as the Reading Limestone Member of the Emporia Formation. Condra (1927) used the name Wakarusa for a lower limestone, and was revised by Moore and Mudge (1956). The Wakarusa Limestone Member overlies the Soldier Creek Shale Member and underlies the Auburn Shale. In the Riverton core and north of Thurman, the Wakarusa Limestone is split by a thin light gray (N7) shale. The upper limestone layer is an argillaceous, skeletal wackestone to packstone about one foot (30 cm) thick. The lower limestone layer varies from 0.5 foot (15 cm) to about four feet (1.2 m) of massive thick to thin-bedded, argillaceous skeletal wackestone.

The 281.0-289.5 foot interval in the Riverton core is designated as a reference section. An east side roadcut exposure along County Road L44 (Bluff Road), about 0.4 mile (0.6 km) north of Thurman in the NE NE NW section 35, T. 70 N., R. 43 W., Fremont County, is also designated as a reference section.

Soldier Creek Shale Member
(unchanged)

The Soldier Creek Shale was named by Beede (1898) from exposures on Big and Little Soldier creeks about 3 miles (4.8 km) from Silver Lake, Shawnee County, Kansas. It is unclear where Beede's exposures were, but they may have been northeast of Silver Lake in T. 10 S., R. 14 E. The Soldier Creek Shale was revised by Condra (1935), Moore (1936) and by Moore and Mudge (1956). The Soldier Creek Shale Member overlies the Burlingame Limestone Member and underlies the Wakarusa Limestone Member. Witzke (2003a, 2003b) showed the possibility that a thin local coal near the middle of the Soldier Creek Shale, in Iowa (C-36 core, Montgomery County), may represent the beginning of a separate cycle of deposition. The coal bed will not be named at this time. The Soldier Creek Shale varies from 32-47 feet (9.8-14.3 m) thick in cores and outcrops in southwest Iowa. It is often laminated, with plant debris in the lower and middle parts, and contains a moderate reddish brown (10R 4/6) blocky mudstone near the top, up to 30 inches (75 cm) thick.

The 289.5-339.0 foot interval in the Riverton core is designated as a reference section. An east side roadcut exposure along County Road L44 (Bluff Road), about 0.4 mile (0.6 km) north of Thurman in the NE NE NW section 35, T. 70 N., R. 43 W., Fremont County, is also designated as a reference section.

Burlingame Limestone Member
(unchanged)

The Burlingame Limestone was named by Hall (1896), and Ver Wiebe and Vickery (1932) located the type section at a prominent mound mentioned by Hall (1896) in T. 14 S., R. 15 E., two miles (3.2 km) west of the town of Burlingame, Osage County, Kansas. Thompson

(2001) erroneously lists the location in Chase County. The Burlingame was revised by Condra and Bengtson (1915), Condra (1935), Moore (1936), Condra (1949), and by Moore and Mudge (1956). The Burlingame Limestone Member overlies the Silver Lake Shale Member of the Scranton Shale and underlies the Soldier Creek Shale Member. The Burlingame Limestone is thin, argillaceous, and contains abundant marine fossils, including brachiopods, crinoid debris, gastropods and clams.

The 339.0-343.0 foot interval in the Riverton core is designated as a reference section.

Scranton Shale
(new name in Iowa)

The Scranton Shale was named by Haworth and Bennett (1908) from exposures in T. 15 S., R. 15 E., near the town of Scranton, Osage County, Kansas. The Scranton was revised by Condra (1927), Condra (1930), and by Moore and Mudge (1956) who also designated a reference section along an eastward-flowing stream extending through the middle part of section 34, T. 12 S., R. 15 E., Shawnee County, Kansas. Because of a misidentification, Condra (1927) used the names (in ascending order) Rock Lake Shale, South Bend Limestone, Plattford Shale, and Cass Limestone for a series of beds between the underlying Howard Limestone and the overlying White Cloud Shale, as it was then defined. The Scranton Shale comprises five members in ascending order: White Cloud Shale, Happy Hollow Limestone, Cedar Vale Shale with Elmo Coal bed, Rulo Limestone, and Silver Lake Shale. The Scranton Shale overlies the Howard Limestone and underlies the Bern Formation.

The 343.0-462.0 foot interval in the Riverton core is designated as a reference section.

Silver Lake Shale Member
(unchanged)

The Silver Lake Shale was named by Beede (1898) and was defined by Condra (1927) from exposures near Silver Lake, Shawnee County, Kansas. The Silver Lake Shale was revised by Moore and Mudge (1956). The Silver Lake Shale Member overlies the Rulo Limestone Member and underlies the Burlingame Limestone Member of the Bern Formation. In the Riverton core the upper part of the Silver Lake Shale is a calcareous, fractured and brecciated blocky mudstone. The middle part has burrows and clams, while the lower part is laminated and contains pectin-like clams.

The 343.0-358.5 foot interval in the Riverton core is designated as a reference section.

Rulo Limestone Member
(unchanged)

The Rulo Limestone was named by Condra and Bengtson (1915) from exposures about 2.5 miles (3.8 km) north of Rulo, Richardson County, Nebraska. It is unclear, but from the description, the exposures may have been in northwest corner of T. 1 N., R. 18 E., or the southwest corner of T. 2 N., R. 18 E. The Rulo Limestone was revised by Condra (1927) and Moore and Mudge (1956). The Rulo Limestone Member overlies the Cedar Vale Shale Member and underlies the Silver Lake Shale Member. In the Riverton core the Rulo Limestone is a thin argillaceous limestone with crinoids, clams and brachiopods.

The 358.5-359.5 foot interval in the Riverton core is designated as a reference section.

Cedar Vale Shale Member
(unchanged)

The Cedar Vale Shale was named by Condra (1930), and the type section was defined by Moore (1936) from exposures in the east bluff of the Caney River in section 12, T. 34 S., R. 8 E., east of the town of Cedar Vale, Chautauqua County, Kansas. The Cedar Vale Shale was revised by Moore and Mudge (1956). The Cedar Vale Shale contains the Elmo Coal bed near the top. In the Riverton core, Fremont County, Witzke (2003a, 2003b) recognized another thin coal overlain by a limestone and a thick, calcareous, fractured mudstone, near the middle of the Cedar Vale Shale, which may represent a separate cycle of deposition. This coal and limestone will not be named at this time. The lower Cedar Vale is mostly medium gray (N5) laminated shale with abundant clams, gastropods and linguloid brachiopods. The Cedar Vale Shale Member overlies the Happy Hollow Limestone Member and underlies the Rulo Limestone Member.

The 359.5-426.5 foot interval in the Riverton core is designated as a reference section.

Elmo Coal bed
(unchanged)

The Elmo Coal was named by Hinds and Greene (1915) from exposures northwest of Burlington Junction, near the town of Elmo, Nodaway County, Missouri. The Elmo was also called the Silver Lake Coal (Beede, 1898) in Nebraska, by Condra (1927). The author is using the name Elmo Coal for the coal bed that lies near the top of the Cedar Vale Shale Member in the Riverton core, where the Elmo Coal is represented by a thin, black, carbonaceous shale with pecten-like bivalves. A composite section (Wood, 1941) from near Dickieville in sections 25 and 36, T. 72 N., R. 36 W., Montgomery County, and section 31, T. 72 N., R. 35 W., Adams County, shows that the Elmo Coal thickens to 0.8 foot (25 cm) in this area.

The coaly zone just below the Rulo Limestone, at the top of the Cedar Vale Shale at the 359.5 foot level of the Riverton core is designated as a reference section.

Happy Hollow Limestone Member
(unchanged)

The Happy Hollow Limestone was named by Condra (1927) from exposures in the bluffs at the mouth of Happy Hollow Creek (ravine) in the NW corner of section 26, T. 1 N., R. 18 E., northeastern Richardson County, Nebraska. A map on page eight of Condra (1927), shows Happy Hollow just below (east of) the mouth of the Big Nemaha River in Richardson County, Nebraska. There are outcrops in the north-facing bluff (along the Missouri River) both to the east of Happy Hollow in the NW of section 26 and to the west of Happy Hollow in the NE of section 27, T. 1 N., R. 18 E., that were probably described by Condra in 1927. Moore (1936) gave the location as Happy Hollow Creek in northeastern Doniphan County, Kansas. The Happy Hollow Limestone was revised by Condra (1930) and Moore and Mudge (1956). The Happy Hollow Limestone Member overlies the White Cloud Shale Member and underlies the Cedar Vale Shale Member. In the Riverton core the Happy Hollow Limestone is a thin, argillaceous limestone with abundant clams, bryozoans and brachiopods.

The 426.5-428.5 foot interval in the Riverton core is designated as a reference section. Because of core loss, the base of the Happy Hollow Limestone may be missing in the Riverton core.

White Cloud Shale Member
(unchanged)

The White Cloud Shale was named by Condra (1927) from exposures west of the town of White Cloud, Doniphan County, Kansas. It is unclear where Condra's exposures were, but they may have been in T. 1 S., R. 19 E. It is also possible that Condra was describing outcrops near Happy Hollow (see Happy Hollow Limestone Member) in Richardson County, Nebraska. The White Cloud Shale originally included what is now the entire Scranton Formation, but it was revised by Condra (1930) and Moore and Mudge (1956) to be the basal member of the Scranton. The White Cloud Shale overlies the Utopia Limestone Member of the Howard Limestone and underlies the Happy Hollow Limestone Member. Burchett (1979) described the White Cloud Coal in Nebraska. In the Riverton core, the upper ten feet (3 m) of the White Cloud Shale is missing due to core loss. The middle and lower parts of the shale are laminated and contain scattered clams and plant debris. In Atchison and Nodaway counties in Missouri, a thin coal occurs near the top of the unit.

The 428.5-462.0 foot interval in the Riverton core is designated as a reference section.

Howard Limestone
(raised in rank; revised; known members now recognized in Iowa)

The Howard Limestone was named by Haworth (1898) from exposures in T. 30 S., R. 10 E., near the town of Howard, Elk County, Kansas. The Howard was further defined by Hinds and Greene (1915) and was revised by Moore (1932) who also described a measured section at the type section of the Bachelor Creek Limestone in the NW NE section 4, T. 26 S., R. 11 E., Greenwood County, Kansas. Moore (1936) revised the Howard to include five members and one bed in ascending order: Bachelor Creek Limestone Member, Aarde Shale Member with Nodaway Coal bed, Church Limestone Member, Winzeler Shale Member, and Utopia Limestone Member, and described a measured section in the NE section 7, T. 20 S. [T. 30 S.], R. 11 E., Elk County, Kansas. Heckel and others (1999), in Kansas, placed the Shanghai Creek Shale and Wauneta Limestone as beds in the Aarde Shale Member. They also placed the Nodaway Coal bed in the upper Severy Shale. Gentile and Thompson (2004), in Missouri, stated the Howard comprised the following units in ascending order: Aarde Shale Member with Nodaway coal bed, Church Limestone Member, Winzeler Shale Member, and Utopia Limestone Member.

Moore (1936) placed the base of the Aarde Shale Member, of the Howard Limestone, at the top of the Bachelor Creek Limestone Member. This placed the Nodaway Coal bed in the Aarde Shale Member. Moore (1936) also stated that if the Bachelor Creek Limestone was absent, the top of the Severy Shale was placed at the base of the Church Limestone Member. This would place the Nodaway Coal in the Severy Shale. Thus the Nodaway Coal bed could be in two formations at the same time. Gentile and Thompson (2004) remedied this dilemma by placing the top of the Severy Shale at the base of the underclay below the Nodaway Coal, if the Bachelor Creek Limestone is absent. This places the Nodaway Coal bed and its underclay in the Aarde Shale Member of the Howard Formation.

The author recommends, in Iowa, the Howard Limestone comprise five units in ascending order: Wauneta Limestone Member, Shanghai Creek Shale Member, Church Limestone Member, Winzeler Shale Member, and Utopia Limestone Member. This would bring the Howard into agreement with other formations in the Virgilian. Since the Bachelor Creek Limestone has not been identified in Iowa, the author recommends placing the Nodaway Coal as a bed in the underlying Severy Shale. The author also defines the top of the Severy Shale as the base of the Wauneta Limestone, where present, or the top of the Nodaway Coal where present, if the Wauneta Limestone is absent. If both the Wauneta Limestone and Nodaway Coal are absent, the top of the Severy Shale would be at the horizon of the Nodaway Coal (top of the paleosol) or the base of the black (N1) fissile facies of the Shanghai Creek Shale.

The author also recommends dropping the name Aarde Shale (see below) and using the name Wauneta Limestone Member for the lowest limestone member of the Howard Limestone. This would eliminate beds in the Aarde Shale, and would permit naming of the ‘transgressive limestone’ and ‘core shale’ of Heckel (1977, 1994) as separate members as in other “cyclothems” [limestone dominated formations]. The author proposes the name Shanghai Creek Shale Member be restricted to the ‘core shale,’ a dark gray (N3) to black (N1) fissile shale, which overlies the Wauneta Limestone Member (‘transgressive limestone’) and underlies the Church Limestone Member (‘regressive limestone’), following the nomenclature of Merriam (1989). The Howard Limestone overlies the Severy Shale and underlies the Scranton Shale.

The 462.0-472.5 foot interval in the Riverton core is designated as a reference section.

Utopia Limestone Member
(new name in Iowa)

The Utopia Limestone was named by Moore (1932) from the town of Utopia, where a type section was designated just to the east in section 5, T. 25 S., R. 11 E., Greenwood County, Kansas. Condra (1927) used the name that Condra and Bengtson (1915) used, the Louisville Limestone from Louisville, Nebraska, based on a miscorrelation, but the name was preoccupied, so Moore (1936) dropped it. The Utopia Limestone Member overlies the Winzeler Shale Member and underlies the White Cloud Shale Member of the Scranton Shale. In the Riverton core the Utopia Limestone is a thin, argillaceous, bioturbated limestone with brachiopods and crinoids.

The 462.0-463.0 foot interval in the Riverton core is designated as a reference section.

Winzeler Shale Member
(new name in Iowa)

The Winzeler Shale was named by Moore (1932), who in 1936 located the type section at exposures on the Winzeler farm in section 4, T. 26 S., R. 11 E., Greenwood County, Kansas. Condra (1927) had named this unit the Kiewitz Shale of the Howard Formation, Shawnee Group, in Nebraska, based on a miscorrelation. The Winzeler Shale Member overlies the Church Limestone Member and underlies the Utopia Limestone Member. In the Riverton core the Winzeler Shale is a thin, slightly bioturbated light gray (N7) shale.

The 463.0-465.5 foot interval in the Riverton core is designated as a reference section.

Church Limestone Member
(new name in Iowa)

The Church Limestone was named by Condra (1927) from exposures on Turner Creek where it crossed the Church farm southeast of DuBois, Pawnee County, Nebraska. It is unclear, but Condra's exposures may have been in T. 1 N., R. 12 E. The Church Limestone was revised by Moore (1932) who also described exposures at the type section for the Bachelor Creek Limestone in the NW NE section 4, T. 26 S., R. 11 E., Greenwood County, Kansas. The Quitman cap rock of Gallaher (1898) is probably equivalent to the Church Limestone and possibly the overlying Utopia Limestone. The Church Limestone Member overlies the Shanghai Creek Shale Member (as proposed in this paper) and underlies the Winzeler Shale Member. In the Riverton core the Church Limestone is argillaceous and contains an abundant open marine fauna including brachiopods, crinoids, clams, and bryozoans.

The 465.5-469.0 foot interval in the Riverton core is designated as a reference section.

Shanghai Creek Shale Member
(new name in Iowa)

The Aarde Shale Member was named by Moore (1932), and defined by Moore (1936) for exposures on the Aarde farm, NW NE section 4, T. 26 S., R. 11 E., Greenwood County, Kansas. The Aarde Shale Member, in Kansas and Missouri, comprise four units in ascending order: an unnamed shale (underclay), the Nodaway Coal, a limestone (Wauneta), and a dark gray (N3) to black (N1) fissile shale (Shanghai Creek). The name was spelled 'Aard' by Condra (1949).

The Aarde was originally called the Shunganunga Shale by Beede (1898) and later the dark gray (N3) to black (N1) fissile shale part was called the Shangai (sic) Creek Shale by Merriam (1989). Merriam (1990) corrected the spelling to Shanghai Creek Shale. It was revised by Searight and Howe (1961) and Gentile and Thompson (2004) for Missouri.

In Iowa, the name Shanghai Creek Shale will be used, instead of the Aarde Shale, and will be restricted to the black (N1) fissile to light gray (N7) shale above the Wauneta Limestone (or Nodaway Coal where the Wauneta is absent) and below the Church Limestone. If neither the Nodaway Coal nor Wauneta Limestone is present the base of the Shanghai Creek Shale is placed at the top of the paleosol at the top of the Severy Shale. The name Aarde Shale will not be used in Iowa, since the Bachelor Creek Limestone has not been recognized in the state.

The Shanghai Creek Shale was named by Merriam (1989) for exposures in a roadcut on U.S. Highway 166, about 7.5 miles (12.2 km) east of the town of Cedar Vale, Chautauqua County, Kansas. From the description, this location would be in the northwest part of T. 34 S., R. 10 E. The name was derived from nearby Shanghai Creek. In the Riverton core the Shanghai Creek Shale is three feet (91 cm) of dark gray (N3) with two thin streaks of black (N1) shale and slightly phosphatic, with abundant conodonts.

The 469.0-472.0 foot interval in the Riverton core is designated as a reference section.

Wauneta Limestone Member
(new name in Iowa)

The Wauneta Limestone was named by Merriam (1989) from exposures in a roadcut on U.S. Highway 166, about 7.5 miles (12.2 km) east of the town of Cedar Vale, Chautauqua County, Kansas. From the description, this location would be in the northwest part of T. 34 S., R. 10 E. The name was derived from the nearby town of Wauneta by R.C. Moore, (see Mendoza, 1959). The Wauneta Limestone overlies the Nodaway Coal bed and underlies the Shanghai Creek Shale. In the Riverton core the Wauneta Limestone is a thin, argillaceous, bioturbated limestone with brachiopods. At Forest City in Holt County, Missouri the Wauneta is a 0.5 foot (15 cm) thick, argillaceous, ostracode packstone.

The 472.0-472.5 foot interval in the Riverton core is designated as a reference section.

Severy Shale
(raised in rank; revised)

The Severy Shale was named by Haworth (1898) from exposures in T. 28 S., R. 11 E., near the town of Severy, Greenwood County, Kansas. In this report the top of the Severy Shale is placed at the top of the Nodaway Coal bed or at the base of the Wauneta Limestone if the Nodaway Coal is absent. If both the Wauneta Limestone and Nodaway Coal are absent, the top of the Severy Shale would be at the horizon of the Nodaway Coal (top of the paleosol) or the base of the black (N1) fissile facies of the Shanghai Creek Shale. In the Riverton core the Severy Shale is a light gray (N7) laminated shale with scattered clams with a thin rooted mudstone at the top. The Severy Shale overlies the Topeka Limestone and underlies the Howard Limestone.

The 472.5-482.2 foot interval in the Riverton core is designated as a reference section.

Nodaway Coal bed
(unchanged)

Smith (1909) considered an outcrop one mile (0.6 km) southeast of Clarinda, Iowa, as the type section of the Nodaway Coal. It is unclear, but Smith's exposures were probably at the bluff on the east side of the West Nodaway River, near the site of Shambaugh Mill, in the NW SE section 7, T. 68 N., R. 36 W. Hinds (1912) described a "type" section for the Nodaway Coal as an exposure along the east bank of the Nodaway River at Quitman, Nodaway County, Missouri, where it was locally known by early miners as the 'Quitman' coal bed. It is also unclear where Hinds' section was, but it may have been in T. 64 N., R. 37 W. The Quitman (Nodaway) Coal bed was named by Gallaher (1898) for exposures near Quitman, Nodaway County, Missouri. The Nodaway was also mined northeast of the town of Nodaway in southwest Adams County, Iowa. The name is probably derived from the Nodaway River and less likely from Nodaway County, Missouri, or the town of Nodaway in Adams County, Iowa. In the Riverton core and in quarries north of Thurman, Fremont County, the Nodaway Coal is about 0.5 foot (15 cm) thick. Hershey and others (1960) reported that the Nodaway Coal was extensively mined in Adams, Page and Taylor counties where the coal ranged from 0.5-3.0 feet (15-90 cm) thick. The Nodaway is the equivalent of the Topeka Coal or Osage Coal referred to by Beede (1898). Case (1982) reported a paleoniscoid fish associated with the Nodaway Coal, from the Evans coal mine near Clarinda, in Page County.

The 472.5-473.5 foot interval in the Riverton core is designated as a reference section.

SHAWNEE GROUP
(unchanged)

The Shawnee Group (Figure 5) was originally named the Shawnee formation by Haworth (1898) from exposures in Shawnee County, Kansas. The Shawnee was originally defined to include strata from the top of the Oread Limestone to the base of the Tarkio (Burlingame of present usage) Limestone. Condra (1927) revised the Shawnee to include in ascending order the: Kanwaka Shale, Lecompton Limestone, Tecumseh Shale, Deer Creek Limestone, Calhoun Shale, Topeka Limestone, Severy Shale, Howard Limestone, and Scranton Shale members. Moore (1931) revised the Shawnee to include the Topeka

Landis and Van Eck (1965)				Ravn and others (1984)					Pope (this report)			
Series	Group	Formation	Member	Series	Super Group	Group	Formation	Member	Stage	Group	Formation	Member *bed*
Virgil	Shawnee	Topeka	Coal Creek Ls Holt Sh DuBois Ls Turner Creek Sh Sheldon Ls Jones Point Sh Curzon Ls Iowa Point Sh Hartford Ls	Virgilian	Virgil	Shawnee	Topeka	Coal Creek Ls Holt Sh DuBois Ls Turner Creek Sh Sheldon Ls Jones Point Sh Curzon Ls Iowa Point Sh Hartford Ls	Virgilian	Shawnee	Topeka Ls	Coal Creek Ls Holt Sh DuBois Ls Turner Creek Sh Sheldon Ls Jones Point Sh Curzon Ls Iowa Point Sh Hartford Ls
		Calhoun					Calhoun	undifferentiated			Calhoun Sh	
		Deer Creek	Ervine Creek Ls Burroak Sh Haynies Ls Larsh Sh Rock Bluff Ls Oskaloosa Sh Ozawkie Ls				Deer Creek	Ervine Creek Ls Burroak Sh Haynies Ls Larsh Sh Rock Bluff Ls Oskaloosa Sh Ozawkie Ls			Deer Creek Ls	Ervine Creek Ls Burroak Sh Haynies Ls Larsh Sh Rock Bluff Ls Oskaloosa Sh Ozawkie Ls
		Tecumseh	Rakes Creek Sh Ost Ls Kenosha Sh				Tecumseh	Rakes Creek Sh Ost Ls Kenosha Sh			Tecumseh Sh	Rakes Creek Sh Ost Ls Kenosha Sh
		Lecompton	Avoca Ls King Hill Sh Beil Ls Queen Hill Sh Big Springs Ls Doniphan Sh Spring Branch Ls				Lecompton	Avoca Ls King Hill Sh Beil Ls Queen Hill Sh Big Springs Ls Doniphan Sh Spring Branch Ls			Lecompton Ls	Avoca Ls King Hill Sh Beil Ls Queen Hill Sh Big Springs Ls Doniphan Sh Spring Branch Ls
		Kanwaka	Stull Sh Clay Creek Ls Jackson Park Sh				Kanwaka	Stull Sh Clay Creek Ls Jackson Park Sh			Kanwaka Sh	Stull Sh Clay Creek Ls Jackson Park Sh
		Oread	Kereford Ls Heumader Sh Plattsmouth Ls Heebner Sh Leavenworth Ls Snyderville Sh Toronto Ls				Oread	Kereford Ls Heumader Sh Plattsmouth Ls Heebner Sh Leavenworth Ls Snyderville Sh Toronto Ls			Oread Ls	Kereford Ls Heumader Sh Plattsmouth Ls Heebner Sh Leavenworth Ls Snyderville Sh Toronto Ls
	Douglas	Lawrence				Douglas	Lawrence			Douglas	Lawrence Sh	Wathena Sh Amazonia Ls Robbins Sh *Lwr Williamsburg C*
											Cass Ls	Shoemaker Ls Little Pawnee Sh Haskell Ls
		Stranger					Stranger	unnamed coal	Missourian		Stranger	"middle-upper" Iatan Weston

Figure 5. Lower Virgilian Stage (Douglas and Shawnee groups) stratigraphy, showing relationship to Missourian Stage, in Iowa.

Limestone at the top and the Oread Limestone at the base, as it is presently known, and raised it to group rank. In Iowa, the Shawnee Group comprises seven formations: Oread, Kanwaka, Lecompton, Tecumseh, Deer Creek, Calhoun, and Topeka, in ascending order, with thirty-six named members. The Shawnee Group overlies the Douglas Group and underlies the Wabaunsee Group. According to Avcin and Koch (1979) the Shawnee Group averages about 180 feet (55 m) thick in Iowa, and Witzke (2003a, 2003b) shows approximately 208 feet (63 m) of strata in the Riverton core (Fremont County).

The 483.9-693.0 foot interval in the Riverton core is designated as a reference section.

Topeka Limestone
(unchanged)

The name Topeka was first used by Bennett (1896). Ver Wiebe and Vickery (1932) located the type section one mile (1.6 km) east and one mile (1.6 km) south of Topeka, Kansas. Moore (1936) located good exposures in the SE section 5, T. 11 S., R. 16 E., northeast of Topeka, Shawnee County, Kansas. In Iowa, Smith (1909) used the name Braddyville limestones for the strata between the Forbes limestone (Ervine Creek Limestone) and Nodaway Coal. Condra and Reed (1937) established the present definition of the Topeka, which comprises nine members in ascending order: Hartford Limestone, Iowa Point Shale, Curzon Limestone, Jones Point Shale, Sheldon Limestone, Turner Creek Shale, DuBois Limestone, Holt Shale and Coal Creek Limestone. The Topeka Limestone overlies the Calhoun Shale and underlies the Severy Shale of the Wabaunsee Group.

The 483.9-510.0 foot interval in the Riverton core is designated as a reference section. The entire Topeka Formation is presently exposed in the Thurman quarry, in the SE NW section 14, T. 70 N., R. 43 W., Fremont County.

Coal Creek Limestone Member
(unchanged)

The Coal Creek Limestone was named by Condra (1927) from exposures on Coal Creek 0.75 mile (1.2 km) north of Union, Cass County, Nebraska. It is unclear, but Condra is assumed to have described a section in T. 10 N., R. 13 E. The Coal Creek had been named the Union Limestone by Condra and Bengtson (1915). The Coal Creek Limestone Member overlies the Holt Shale Member and underlies the Severy Shale of the Wabaunsee Group. In the Riverton core the Coal Creek Limestone is a very argillaceous skeletal wackestone with abundant shale partings and interbeds. The limestone contains an open marine fauna, including brachiopods, crinoids, clams, and bryozoans.

The 483.9-491.3 foot interval in the Riverton core is designated as a reference section.

Holt Shale Member
(unchanged)

The Holt Shale was named by Condra (1927) from exposures in Holt County, Missouri. Condra (1949) further defined the type section as in the SW NE section 32, T. 60 N., R. 38 W., at the southeast edge of Forest City, Holt County, Missouri. The Holt Shale Member overlies the DuBois Limestone Member and underlies the Coal Creek Limestone Member. In the Riverton core the Holt Shale is slightly phosphatic and shows banding in the form of three interbedded dark gray (N3) and three medium gray (N5) zones. These interbedded, conodont-rich, dark and lighter gray shales were also reported in the Holt Shale south of Forest City (Holt County, Missouri) by Leger and Pope (2007) and Pope and others (2008), and were interpreted as being caused by minor changes in sea level.

The 491.3-493.9 foot interval in the Riverton core and an exposure on the west bank of the Nodaway River, just south of the highway bridge at the east edge of Braddyville, in the E ½ NW NE section 31, T. 67 N., R. 36 W., Page County, are designated as reference sections.

DuBois Limestone Member
(unchanged)

The DuBois Limestone was named by Condra (1927) for exposures on Turner Creek about four miles (6.4 km) southeast of DuBois, Pawnee County, Nebraska. It is unclear, but Condra is assumed to have described a section in T. 1 N., R. 12 E. This appears to be the same as the Turner Creek Shale Member type section. Condra (1927) spelled the limestone ‘Du Bois,’ Moore (1932) spelled it ‘Dubois,’ whereas the town is spelled ‘DuBois.’ The DuBois Limestone Member overlies the Turner Creek Shale Member and underlies the Holt Shale Member. In the Riverton core the DuBois Limestone is a thin argillaceous limestone with brachiopods, crinoids and fusulinids.

The 493.9-494.8 foot interval in the Riverton core and an exposure on the west bank of the Nodaway River, just south of the highway bridge at the east edge of Braddyville, in the E ½ NW NE section 31, T. 67 N., R. 36 W., Page County, are designated as reference sections.

Turner Creek Shale Member
(unchanged)

The Turner Creek Shale was named by Condra (1927) from exposures in Turner Creek about four miles (6.4 km) southeast of DuBois, Pawnee County, Nebraska. It is unclear, but Condra is assumed to have described a section in T. 1 N., R. 12 E. This appears to be the same as the DuBois Limestone Member type section. The Turner Creek Shale Member overlies the Sheldon Limestone Member and underlies the DuBois Limestone Member. In the Riverton core the Turner Creek Shale is a light gray (N7) shale and mudstone.

The 494.8-495.8 foot interval in the Riverton core and an exposure on the west bank of the Nodaway River, just south of the highway bridge at the east edge of Braddyville, in the E ½ NW NE section 31, T. 67 N., R. 36 W., Page County, are designated as reference sections.

Sheldon Limestone Member
(unchanged)

The Sheldon Limestone was named by Condra (1930), and Condra (1949) indicated it was named from exposures at the Sheldon quarry and farm about one mile (1.6 km) east of Nehawka, Cass County, Nebraska. It is unclear, but Condra is assumed to have described a section in T. 10 N., R. 13 E. The Sheldon Limestone had been called the Meadow Limestone by Condra (1927) in Nebraska. The Sheldon Limestone Member overlies the Jones Point Shale Member and underlies the Turner Creek Shale Member. In the Riverton core the Sheldon Limestone is a thin limestone with "*Osagia*" coated grains.

The 495.8-496.4 foot interval in the Riverton core is designated as a reference section.

Jones Point Shale Member
(unchanged)

The Jones Point Shale was named by Condra (1927) from exposures at Jones Point in the Missouri River Bluffs, and Condra (1949) designated the type area about four miles (6.4 km) east of Union, Cass County, Nebraska. It is unclear, but from the description, Condra may have described outcrops in T. 10 N., R. 14 E. The Jones Point Shale Member overlies the Curzon Limestone Member and underlies the Sheldon Limestone Member. In the Riverton core the Jones Point Shale is thin, sparsely fossiliferous, greenish-gray (5GY 6/1) shale that grades upward to a blocky mudstone.

The 496.4-500.2 foot interval in the Riverton core is designated as a reference section.

Curzon Limestone Member
(unchanged)

The Curzon Limestone was originally called Curzen's Limestone by Gallaher (1898, 1900). Condra (1927) spelled the name Curzen. The reason for the change in spelling (noted by Condra in 1935), Curzen instead of Curzon is unknown. Condra and Reed (1937) stated the type locality was [at an unspecified location] east of Curzon Station, southeast of Forest City, Holt County, Missouri and defined its present usage. A map compiled in 1907 and used in Hinds (1912) locates Curzon [Station] about half way between Forest City and Forbes. Cordell (1947) located a section in the SW NE section 32, T. 60 N., R. 38 W., at or close to the original type section. The Curzon Limestone Member overlies the Iowa Point Shale Member and underlies the Jones Point Shale Member. In the Riverton core the Curzon Limestone is a thin, slightly argillaceous skeletal wackestone with sparse brachiopods.

The 500.2-501.7 foot interval in the Riverton core is designated as a reference section.

Iowa Point Shale Member
(unchanged)

The Iowa Point Shale was named by Condra (1927) from exposures in the Missouri River bluffs, just east of Iowa Point, Doniphan County, Kansas. It is unclear, but Condra is assumed to have described a section in T. 1 S., R. 19 E. The Iowa Point Shale was revised as presently used by Condra and Reed (1937). The Iowa Point Shale Member overlies the Hartford Limestone Member and underlies the Curzon Limestone Member. One or two unnamed coals (Thompson, 1995; J.P. Pope, unpublished field notes) occur in the Iowa Point Shale in northwestern Missouri (e.g., Forest City area and New Point quarry in Holt County; Pumpkin Center quarry in Nodaway County). Witzke (2003a) showed a coal near the base of the Iowa Point Shale, in a core near Braddyville, in Page County, Iowa. In the Riverton core the Iowa Point Shale is a two foot (30 cm) thick light gray (N7) fossiliferous shale, while in the C-100 core near Clarinda (Page County) it thickens to nearly 20 feet (6.1 m) with several thin sandstones and siltstones.

The 501.7-503.7 foot interval in the Riverton core is designated as a reference section.

Hartford Limestone Member
(unchanged)

The Hartford Limestone was named by Kirk (1896) and the type section was located by Moore (1936) underneath the highway bridge at the north edge of Hartford, Lyon County (Coffey County in Moore, 1936), Kansas. It is unclear, but Moore’s type section may have been in section 15, T. 20 S., R. 13 E. Condra (1927) called the Hartford the Meadow Limestone. The Hartford Limestone Member overlies the Calhoun Shale and underlies the Iowa Point Shale Member.

The Hartford Limestone is usually characterized by two limestone units (skeletal wackestones) separated by a conodont-rich shale that is medium gray (N4) in the upper part and black (N1) in the lower part. This sequence occurs in the roadcut south of the Thurman quarry (Mills County) and in the Braddyville quarry in Page County (Leger and Pope, 2008). At the Corning and Mt. Etna quarries (Adams County), and in the Riverton core (Fremont County), the middle shale is split by a thin limestone (Leger and Pope, 2008; Pope et al., 2008).

The 503.7-510.0 foot interval in the Riverton core and an exposure in an east backslope of County Road L44 (Bluff Road) just south of Forney Lake, in the E line NE SE section 22, T. 70 N., R. 43 W., Fremont County are designated as reference sections.

Calhoun Shale
(unchanged)

The Calhoun Shale was named by Beede (1898), and Moore (1936) located the type section near the C of the S line section 14, T. 11 S., R. 16 E., in the Calhoun Bluffs on the north side of the Kansas River, three miles (4.8 km) northeast of Topeka, Shawnee County, Kansas. In Iowa, Smith (1909) used the name Braddyville limestone for the Calhoun Shale and the overlying Topeka Limestone. The Calhoun Shale overlies the Deer Creek Limestone and underlies the Topeka Limestone. A 2-4 inch (5-10 cm) thick coal is present near the top of the Calhoun Shale at Topeka, Kansas, where the unit thickens to nearly one hundred feet. In Iowa there is no known coal in the Calhoun Shale, although a two inch (5 cm) thick coal occurs at the base of the unit in a quarry on Rakes Creek, about five miles (8 km) north northeast of Union, Cass County, Nebraska. At the Corning and Mt. Etna quarries (Adams County) the upper part of the Calhoun Shale is light gray (N7) and extremely fossiliferous with a diverse open marine fauna. The lower part of the Calhoun Shale is a light gray (N7) poorly-bedded shale to blocky mudstone.

The 510.0-522.0 foot interval in the Riverton core and an exposure in an east backslope of County Road L44 (Bluff Road) just south of Forney Lake, in the E line NE SE section 22, T. 70 N., R. 43 W., Fremont County, are designated as reference sections.

Deer Creek Limestone
(unchanged)

The Deer Creek was named by Bennett (1896) from exposures on Deer Creek, and Moore (1936) located a typical section in a road cut in the SE section 36, T. 11 S., R. 17 E., east of Topeka, Shawnee County, Kansas. Gallaher

(1898) used the name Nodaway, and Keyes (1898) and others used the name Forbes limestone for the "Deer Creek Limestone" which outcrops near the town of Forbes, Holt County, Missouri. Smith (1909) used the name Forbes in Iowa, while Hinds and Green (1915), in Missouri, used the name Deer Creek, for an interval that included what is now the Ozawkie Limestone, Oskaloosa Shale, Rock Bluff Limestone, Larsh Shale, Burroak Shale, and Ervine Creek Limestone. Moore (1936) dropped the name Forbes, in Kansas, in favor of Deer Creek. Keyes (1937) also questioned the validity of the name, Forbes limestone, in Iowa.

The Deer Creek Limestone, as is currently defined in Iowa, comprises seven members in ascending order: Ozawkie Limestone, Oskaloosa Shale, Rock Bluff Limestone, Larsh Shale, Haynies Limestone, Burroak Shale, and Ervine Creek Limestone. The Deer Creek Limestone overlies the Tecumseh Shale and underlies the Calhoun Shale.

The 522.0-567.0 foot interval in the Riverton core is designated as a reference section. Most of the Ervine Creek Limestone Member is seen in an exposure in an east backslope of County Road L44 (Bluff Road) just south of Forney Lake, in the E line NE SE section 22, T. 70 N., R. 43 W., Fremont County. The lower part of the Ervine Creek Limestone and members below this are seen in ravines in the SE SW section 10 and the NW section 15, T. 71 N., R. 43 W., Mills County.

Ervine Creek Limestone Member (unchanged)

The Ervine Creek Limestone (Ervine Creek limestone bed of Deer Creek member of Shawnee formation) was named by Condra (1927) from exposures on Ervine Creek, northeast of Union, Cass County, Nebraska. It is not clear, but it is assumed Condra was describing a section in T. 10 N., R. 14 E. In some of Condra's sections, his definition of the Ervine Creek Limestone included the overlying Calhoun Shale, Hartford Limestone, Iowa Point Shale and Curzon Limestone members of the Topeka Limestone. The Ervine Creek Limestone Member overlies the Burroak Shale Member and underlies the Calhoun Shale. In the Riverton core the Ervine Creek Limestone is a thick skeletal wackestone with shale partings, and an abundant open marine fauna, including brachiopods, crinoids, bryozoans, gastropods, and fusulinids.

The 522.0-539.7 foot interval in the Riverton core and an exposure in an east backslope of County Road L44 (Bluff Road) just south of Forney Lake, in the E line NE SE section 22, T. 70 N., R. 43 W., Fremont County are designated as reference sections. The Ervine Creek Limestone is currently exposed in the Corning and Mt. Etna quarries in Adams County.

Burroak (Burr Oak) Shale Member (unchanged)

Condra (1927) originally named the Burroak Shale, the Mission Creek Shale, from exposures on Mission Creek southeast of Iowa Point, Kansas, but it was later determined these exposures correlated with the Larsh Shale to the north. The Burroak Shale was named by Condra and Reed (1937) from exposures in roadcuts and ravines in the E ½ section 21, T. 71 N., R. 43 W., near Burr Oak School, Mills County, Iowa. The Burroak Shale Member overlies the Haynies Limestone Member (where present) and underlies the Ervine Creek Limestone Member. Where the Haynies limestone does not occur, the shale interval between the Rock Bluff Limestone and the Ervine Creek Limestone is known as the Larsh-Burroak Shale. In the Riverton core the Burroak Shale is mostly light gray (N7) shale with two dark gray (N3) interbeds, is slightly phosphatic and has abundant conodonts. See Britton and Pope (2004, 2005), Pope and others (2008).

The 539.7-541.0 foot interval in the Riverton core and the 14.4-16.0 foot interval in the Bedford core are designated as reference sections, as well as an outcrop below an abandoned quarry about four miles (6.4 km) north of Bartlett, in the SE SW section 10, T. 71 N., R. 43 W., Mills County.

Haynies Limestone Member
(unchanged)

The Haynies Limestone was named by Condra (1927) from exposures southeast of Haynies Railroad Station (now called Sargent's siding), Mills County, Iowa. It is unclear where Condra's exposures were, but they may have been in section 10, T. 71 N., R. 43 W. The Haynies Limestone Member (where present) overlies the Larsh Shale member and underlies the Burroak Shale Member. Where the Haynies Limestone is absent, the shale interval between the Rock Bluff Limestone and the Ervine Creek Limestone is known as the Larsh-Burroak Shale. In the Riverton core the Haynies Limestone is a light gray (N7), argillaceous skeletal wackestone. Witzke (2003a) noted the Haynies Limestone in several cores in southwest Iowa (including the Bedford core in Taylor County), but the limestone does not occur in the Braddyville core in Page County. Gentile and Thompson (2004) did not observe the Haynies Limestone in outcrop in Missouri, but it occurs in cores in Nodaway and Atchison counties in the subsurface (J.P. Pope, unpublished field notes). Britton and Pope (2004, 2005), Pope and others (2008) noted a calcareous, light gray (N7), fossiliferous shale at the horizon of the Haynies Limestone, in northwest Missouri and northeast Kansas.

The 541.0-541.8 foot interval in the Riverton core and the 16.0-17.2 foot interval foot interval in the Bedford core are designated as reference sections, as well as an outcrop below an abandoned quarry about four miles (6.4 km) north of Bartlett, in the SE SW section 10, T. 71 N., R. 43 W., Mills County.

Larsh Shale Member
(unchanged)

The Larsh Shale was named by Condra (1927) from exposures on Ervine Creek on the Larsh farm, 2.5 miles (4 km) east and 1.25 miles (2 km) north of Union, Cass County, Nebraska. It is unclear where Condra's exposures were, but they may have been in the SW section 17 or the SE section 18, T. 10 N., R. 14 E. The Larsh Shale Member overlies the Rock Bluff Limestone Member and underlies the Haynies Limestone Member (where present). Where the Haynies Limestone is absent, the shale interval between the Rock Bluff Limestone and the Ervine Creek Limestone is known as the Larsh-Burroak Shale. In the Riverton core the Larsh Shale is mostly dark gray (N3) to black (N1) shale with a light gray (N7) interbed, is slightly phosphatic and has abundant conodonts. See Britton and Pope (2004, 2005), Pope and others (2008).

The 541.8-543.8 foot interval in the Riverton core and the 17.2-19.8 foot interval in the Bedford core are designated as reference sections, as well as an outcrop below an abandoned quarry about four miles (6.4 km) north of Bartlett, in the SE SW section 10, T. 71 N., R. 43 W., Mills County.

Rock Bluff Limestone Member
(unchanged)

The Rock Bluff Limestone was named by Condra (1927) from exposures northeast of Rock Bluff, Cass County, Nebraska. It is unclear where Condra's exposures were, but they may have been in T. 11 N., R. 14 E. The Rock Bluff Limestone Member overlies the Oskaloosa Shale Member and underlies the Larsh Shale Member. In the Riverton core the Rock Bluff Limestone is a dense, medium gray (N5) skeletal wackestone with crinoids, brachiopods and fusulinids.

The 543.8-545.9 foot interval in the Riverton core and the 19.8-21.7 foot interval in the Bedford core are designated as reference sections, as well as an outcrop below an abandoned quarry about four miles (6.4 km) north of Bartlett, in the SE SW section 10, T. 71 N., R. 43 W., Mills County.

Oskaloosa Shale Member
(unchanged)

The name Oskaloosa Shale was first used by Moore and others (1934) and Condra (1935). The Oskaloosa Shale was later defined by Moore (1936). The type section is in the vicinity of Oskaloosa, Jefferson County, Kansas. It is unclear where the type section was described, but it may have been in T. 9 or 10 S., R. 19 E. The Oskaloosa Shale Member overlies the Ozawkie Limestone Member and underlies the Rock Bluff Limestone Member. In the Riverton core the lower part of the Oskaloosa Shale is a mottled, slickensided, blocky mudstone, with carbonate nodules. The middle part is sandy and another blocky mudstone occurs near the top of the unit. Locally in Iowa (e.g., Bedford core, Taylor County), a coaly zone occurs near the top of the shale. The coal will not be named at this time.

The 545.9-560.0 foot interval in the Riverton core and the 21.7- 29.3 foot interval in the Bedford core are designated as reference sections.

Ozawkie Limestone Member
(unchanged)

The name Ozawkie Limestone was first used by Moore and others (1934) and Condra (1935). The Ozawkie was later defined by Moore (1936) who also located a type section in the NE section 31, T. 9 S., R. 18 E., in a roadcut near the town of Ozawkie, Jefferson County, Kansas. The Ozawkie Limestone Member overlies the Tecumseh Shale and underlies the Oskaloosa Shale Member. In the Riverton core the Ozawkie Limestone is a thin argillaceous limestone with clams, bryozoans and "*Osagia*" coated grains. In a ravine north northeast of Burr Oak in the NW section 15, T. 71 N., R. 43 W., Mills County, Iowa, a limestone identified as the Ozawkie by Fagerstrom and Burchett (1972) contains abundant domal stromatolites.

The 560.0-567.0 foot interval in the Riverton core and the 29.3-38.6 foot interval in the Bedford core are designated as reference sections.

Tecumseh Shale
(unchanged)

The Tecumseh Shale was named by Beede (1898), and Moore (1936) located the type section in section 15, T. 11 S., R. 16 E., near the town of Tecumseh, Shawnee County, Kansas. Condra (1927) recognized the Tecumseh Shale as all strata between the Deer Creek Limestone and the Lecompton Limestone.

In Missouri and Nebraska the Tecumseh Shale comprises three members in ascending order: Kenosha Shale, Ost Limestone, and Rakes Creek Shale (Gentile and Thompson, 2004). The Tecumseh Shale overlies the Lecompton Limestone and underlies the Deer Creek Limestone. Joeckel (1994, 1995) recognized the three members of the Tecumseh Shale in Iowa, in a ravine north northeast of Burr Oak in the NW section 15, T. 71 N., R. 43 W., Mills County. The Tecumseh Shale thickens to 35 feet (10.7 m) in the Bedford core, where it consists of laminated gray shale with scattered clams.

The 567.0-591.3 foot interval in the Riverton core and the 38.6-74.0 foot interval in the Bedford core are designated as reference sections, although the three members have not been recognized in either core. The outcrop in the ravine about four miles (6.4 km) north of Bartlett, in the NW section 15, T. 71 N., R. 43 W., Mills County, is also designated as a reference section.

Rakes Creek Shale Member
(unchanged)

The Rakes Creek Shale Member was named by Condra (1930) from exposures on Rakes Creek in the NW section 5, T. 10 N., R. 14 E., Cass County, Nebraska. The Rakes Creek Shale Member overlies the Ost Limestone Member and underlies the Ozawkie Limestone Member of the Deer Creek Limestone. At an outcrop in a ravine, north northeast of Burr Oak in the NW section 15, T. 71 N., R. 43 W., Mills County, the Rakes Creek Shale is about 4.6 feet (1.4 m) thick. The lower 1.6 feet (0.5 m) is a greenish gray (5GY 6/1) blocky mudstone. The middle part is a 2.3 foot (0.7 m) thick, yellowish gray (5Y 7/2), silty sandstone. The upper part is a 0.7 foot (0.2 m) thick, olive gray (5Y 4/1) and light olive gray (5Y 6/2) mottled blocky mudstone.

The outcrop in a ravine about four miles (6.4 km) north of Bartlett, in the NW section 15, T. 71 N., R. 43 W., Mills County, is designated as a reference section.

Ost Limestone Member
(unchanged)

The Ost Limestone Member was first named by Condra (1927) as the Cedar Creek Limestone. Condra (1930) renamed it the Ost Limestone from outcrops on the Ost farm, on the South Fork of Weeping Water Creek, 3.5 miles (5.6 km) east of Avoca, Cass County, Nebraska. It is not clear, but it is assumed Condra was describing outcrops in section 34, T. 10 N., R.

12 E. The Ost Limestone Member overlies the Kenosha Shale Member and underlies the Rakes Creek Shale Member. At an outcrop in a ravine, north northeast of Burr Oak in the NW section 15, T. 71 N., R. 43 W., Mills County, the Ost Limestone is seen as a yellowish gray (5Y 8/1), single bed of skeletal wackestone, about 1.6 feet (0.5 m) thick.

The outcrop in a ravine about four miles (6.4 km) north of Bartlett, in the NW section 15, T. 71 N., R. 43 W., Mills County, is designated as a reference section.

Kenosha Shale Member
(unchanged)

The Kenosha Shale Member was named by Condra (1930) from exposures in the Missouri River bluff, near Kenosha landing, at the mouth of the second small valley (Kenosha Creek) south of King Hill, Cass County, Nebraska. It is not clear, but Condra may have been describing exposures in T. 11 N., R. 14 E. The Kenosha Shale Member overlies the Avoca Limestone Member of the Lecompton Limestone and underlies the Ost Limestone Member. At an outcrop in a ravine, north northeast of Burr Oak in the NW section 15, T. 71 N., R. 43 W., Mills County the Kenosho Shale is a 1.4 foot (0.4 m) thick greenish gray (5GY 6/1) blocky mudstone.

The outcrop in a ravine about four miles (6.4 km) north of Bartlett, in the NW section 15, T. 71 N., R. 43 W., Mills County, is designated as a reference section.

Lecompton Limestone
(unchanged)

The name Lecompton was first used by Bennett (1896) from exposures near Lecompton, Douglas County, Kansas. It is not clear, but it is assumed that Bennett was describing outcrops in T. 11 or 12 S., R. 18 E. The Lecompton was revised to formation level by Moore (1932) to comprise seven members in ascending order: Spring Branch Limestone, Doniphan Shale, Big Springs Limestone, Queen Hill Shale, Cullom (Beil) Limestone, King Hill Shale, and Avoca Limestone. The Lecompton Limestone overlies the Kanwaka Shale and underlies the Tecumseh Shale.

The 591.3-629.0 foot interval in the Riverton core and the 74.0-108.0 foot interval in the Bedford core are designated as reference sections. The entire Lecompton Formation is exposed, at this time, in the Stennett quarry, in the NE section 27, T. 73 N., R. 38 W., Montgomery County.

Avoca Limestone Member
(unchanged)

The Avoca Limestone was named by Condra (1927), and Moore (1936) located the type section at an exposure on the South Fork [Branch] of Weeping Water Creek, about three miles (4.8 km) east of Avoca, Otoe County, Nebraska. It is not clear, but Moore is assumed to have described an outcrop in section 34, T. 10 N., R. 12 E., Cass County, Nebraska, since the town of Avoca is about one mile (1.6 km) north of the Otoe-Cass county line in Cass County. The Avoca was revised by Condra in (1949). The Avoca Limestone Member overlies the King Hill Shale Member and underlies the Tecumseh Shale. In the Riverton core the Avoca Limestone is very argillaceous with numerous shale partings, and contains an open marine fauna including bryozoans, brachiopods, crinoids, and clams.

The 591.3-598.7 foot interval in the Riverton core and the 74.0-75.5 foot interval in the Bedford core are designated as reference sections.

King Hill Shale Member
(unchanged)

The King Hill Shale was named by Condra (1927), and Moore (1936) located the type section at King Hill southeast of Rock Bluff, Cass County, Nebraska. King Hill is in T. 11 N., R. 14 E., Cass County, Nebraska. The King Hill Shale Member overlies the Beil Limestone Member and underlies the Avoca Limestone Member. In the Riverton core the King Hill Shale is a light gray (N7), rooted, blocky mudstone with calcareous nodules.

The 598.7-603.9 foot interval in the Riverton core and the 75.5-87.5 foot interval in the Bedford core are designated as reference sections.

Beil Limestone Member
(unchanged)

The Beil Limestone was named by Condra (1930), because of correlation problems with the previously named Cullom Limestone (Condra and Bengtson, 1915). Moore (1936) located the type section on the Beil farm in the Missouri River bluffs, near the mouth of Kenosha Valley [Creek], two miles (3.2 km) south and one mile (1.6 km) east of Rock Bluff, Cass County, Nebraska. This location and the mouth of Kenosha Creek are in T. 11 N., R. 14 E., Cass County, Nebraska. The Beil Limestone Member overlies the Queen Hill Shale Member and underlies the King Hill Shale Member. In the Riverton core the Beil Limestone is an argillaceous skeletal wackestone to packstone with numerous shale partings, and an abundant open marine fauna including brachiopods, gastropods, bryozoans, corals and fusulinids.

The 603.9-611.5 foot interval in the Riverton core and the 87.5-98.2 foot interval in the Bedford core are designated as reference sections.

Queen Hill Shale Member
(unchanged)

The Queen Hill Shale was named by Condra (1927), and a type section was located by Moore (1936) at Queen Hill, T. 11 N., R. 14 E., northeast of Rock Bluff, Cass County, Nebraska. No section number was indicated. The Queen Hill Shale Member overlies the Big Springs Limestone Member and underlies the Beil Limestone Member. In the Riverton core the Queen Hill Shale is black (N1), fissile and phosphatic in the lower part, while the upper part is medium light gray (N6) with two thin interbedded black (N1) zones. Similar dark interbeds were also seen by Hunter and Pope (abst. in press) in an outcrop west of the town of Nodaway, Holt County, Missouri.

The 611.9-617.4 foot interval in the Riverton core and the 98.2-103.9 foot interval in the Bedford core are designated as reference sections.

Big Springs Limestone Member
(unchanged)

The Big Springs Limestone was named by Condra (1927) from exposures north of Big Springs, Douglas County, Kansas. Moore (1936) described typical exposures near the C of the S line section 36, T. 11 S., R. 17 E., about 4.5 miles (7.2 km) west of Lecompton. The Big Springs Limestone Member overlies the Doniphan Shale Member and underlies the Queen Hill Shale Member. In southwest Iowa, the Big Springs Limestone is often only a single thin bed of argillaceous skeletal packstone, containing abundant fusulinids, gastropods, brachiopods, crinoids and phylloid algae.

The 617.4-620.3 foot interval in the Riverton core is designated as a reference section. The 103.9-104.4 foot interval in the Bedford core is tentatively identified as the Big Springs Limestone.

Doniphan Shale Member
(unchanged)

The Doniphan Shale was named by Condra (1927) from exposures in the Missouri River bluffs in northeastern Doniphan County, Kansas. The exact location referred to by Condra is unknown. The Doniphan Shale Member overlies the Spring Branch Limestone Member and underlies the Big Springs Limestone Member. In southwest Iowa, the Doniphan Shale is relatively thin, usually less than five feet (1.5 m) of light olive gray (5Y 6/1) to light gray (N7) shale, with scattered calcareous nodules and brachiopods.

The 620.3-622.4 foot interval in the Riverton core is designated as a reference section. The 104.4-105.3 foot interval in the Bedford core is tentatively identified as the Doniphan Shale.

Spring Branch Limestone Member
(unchanged)

The Spring Branch Limestone was named by Condra (1927) from exposures on Spring Branch, north of Big Springs, Douglas County, Kansas. Moore (1936) described typical exposures near the NW corner section 35, T. 11 S., R. 18 E., and the C of the S line section 36, T. 11 S., R. 17 E. The Spring Branch Limestone overlies the Stull Shale Member of the Kanwaka Shale and underlies the Doniphan Shale Member. In the Riverton core the Spring Branch Limestone is an argillaceous skeletal wackestone to packstone with an open marine fauna, including brachiopods bryozoans, crinoids, and coated grains.

The 622.4-629.2 foot interval in the Riverton core is designated as a reference section. The 105.3-108.0 foot interval in the Bedford core is tentatively identified as the Spring Branch Limestone.

Kankwka Shale
(unchanged)

The Kanwaka Shale was named by Adams (1903), and Ver Wiebe and Vickery (1932) located the type section in T. 13 S., R. 18 E., Kanwaka Township, Douglas County, Kansas. Moore (1936) located the type section in the SE corner section 26, T. 12 S., R. 18 E., Kanwaka Township, east of Stull, Kansas. In 1933, Condra described three members; Jackson Park Shale, Clay Creek Limestone, and Stull Shale, in ascending order. The Kanwaka Shale overlies the Oread Limestone and underlies the Lecompton Limestone.

The 629.2-642.9 foot interval in the Riverton core is designated as a reference section. The 108.0-123.0 foot interval in the Bedford core is not differentiated into members at this time. The entire Kanwaka Shale is exposed at this time in the Stennett quarry, in the NE section 27, T. 73 N., R. 38 W., Montgomery County.

Stull Shale Member
(unchanged)

The Stull Shale was named by Moore (1932), and Moore (1936) located the type section in the SE corner section 26, T. 12 S., R. 18 E., near the town of Stull, Douglas County, Kansas. A coaly zone occurs in the Stull Shale in southwest Iowa (e.g., Malvern core), but no name is proposed at this time. The Stull Shale Member overlies the Clay Creek Limestone Member and underlies the Spring Branch Limestone Member of the Lecompton Limestone. In the Riverton core the Stull Shale is mainly a thin, slickensided blocky mudstone with scattered plant debris. At the Stennett quarry (Montgomery County), and the Malvern and Folsom cores (Mills County), a black (coaly?) zone occurs in the Stull Shale. Southward, in southern Holt County, Missouri, the Stull Shale thickens to nearly 30 feet (9.1 m) (Gentile and Thompson, 2004; J.P. Pope, unpublished field notes).

The 629.2-630.3 foot interval in the Riverton core is designated as a reference section.

Clay Creek Limestone Member
(unchanged)

The Clay Creek Limestone was named by Moore (1932), and Moore (1936) located the type section at exposures on Clay Creek, about one mile (1.6 km) west of Atchison, Atchison County, Kansas. It is not clear, but from the description, it is assumed that Moore was describing outcrops in T. 6 S., R. 20 E. The Clay Creek Limestone Member overlies the Jackson Park Shale Member and underlies the Stull Shale Member. In the Riverton core the Clay Creek Limestone is a very argillaceous skeletal wackestone to packstone with chert nodules near the middle of the unit. The limestone contains an open marine fauna, including crinoids, brachiopods, and bryozoans.

The 630.3-639.6 foot interval in the Riverton core is designated as a reference section.

Jackson Park Shale Member
(unchanged)

The Jackson Park Shale was named by Moore (1932) from exposures in Jackson Park, in the southeastern part of Atchison, Atchison County, Kansas. It is not clear, but Moore may have been describing exposures near the center of section 7, T. 6 S., R. 21 E. A thin, but persistent coal occurs in the Jackson Park Shale in southwest Iowa, Missouri and Kansas (Witzke, 2003a, 2003b), but no name is proposed at this time. The Jackson Park Shale Member overlies the Kereford Limestone Member of the Oread Limestone and underlies the Clay Creek Limestone Member. In the Riverton core the Jackson Park Shale contains a thin coal just below the middle of the unit.

Below the coal there is a light gray (N7), rooted, blocky mudstone. Above the coal there is a medium gray (N5) shale with brachiopods and clams. The coaly zone was also noted in the Malvern core (Mills County), the quarries near Grant and Red Oak (Montgomery County), and the quarry near Lewis (Cass County). The coal will not be named at this time. Southward, in southern Holt County, Missouri, the Jackson Park Shale thickens to nearly 27 feet (8.2 m) (Gentile and Thompson, 2004; J.P. Pope, unpublished field notes).

The 639.6-643.0 foot interval in the Riverton core is designated as a reference section.

Oread Limestone

(unchanged)

The name Oread was first used by Haworth (1894) for what is now the Toronto Limestone. Haworth (1895a) redefined the Oread to include the overlying Plattsmouth Limestone, which included the then unnamed Heumader Shale and Kereford Limestone. The Oread Limestone was later redefined by Moore (1932) to include strata from the Weeping Water (Toronto) Limestone to the top of the Kereford Limestone, named by Moore in 1927. The Oread Limestone was named after Mount Oread, site of the University of Kansas, and caps all hills in the vicinity of Lawrence, Douglas County, Kansas. The Oread Limestone comprises seven members in ascending order: Toronto Limestone, Snyderville Shale, Leavenworth Limestone, Heebner Shale, Plattsmouth Limestone, Heumader Shale, and Kereford Limestone. The Oread Limestone overlies the Lawrence Shale and underlies the Kanwaka Shale.

In Iowa, the top two members of the Oread Limestone, Kereford Limestone Member and Heumader Shale Member in descending order, are difficult to distinguish in core and outcrop from the underlying Plattsmouth Limestone Member. In the Riverton core, Witzke (2003a, 2003b) tentatively assigned a 0.5 foot (15 cm) thick shale at the 651.6-652.0 foot interval to the Heumader Shale. This shale could also be considered a shale parting in the upper part of the Plattsmouth Limestone. Witzke (2003a, 2003b) did not show any clearly recognizable Heumader Shale-Kereford Limestone interval in any core or outcrop in southwest Iowa. To the south in Missouri the Heumader Shale thickens and is more easily recognized. In Andrew County, Missouri, west of the town of Nodaway, the Heumader Shale thickens to nearly two feet (60 cm) with the overlying Kereford Limestone at 3.5 feet (1.1 m) thick. At the neostratotype for the Heumader Shale (Gentile and Thompson, 2004), in northwestern Buchanan County, Missouri, the unit is about 4.5 feet (1.4 m) of gray shale.

The 643.0-693.0 foot interval in the Riverton core is designated as a reference section for the Oread Limestone. The 123.0-174.3 foot interval in the Bedford core is also a reference section, although the upper two members (Heumader Shale and Kereford Limestone) are not differentiated at this time. The upper three members of the Oread Limestone are exposed, at this time, in the Stennett quarry, in the NE section 27, T. 73 N., R. 38 W., Montgomery County.

Kereford Limestone Member

(unchanged)

The Kereford Limestone was named by Condra (1927) from exposures in the Kereford Quarry, southeast of Atchison, Atchison County, Kansas. It is not clear, but Condra may have been describing outcrops near the SW SE section 7, T. 6 S., R. 21 E. Before 1927 the Kereford Limestone was known as the "Waverly Flagging" or "Flaggin", in east central Kansas, a non-geographic name rejected by Condra (1927). The Kereford Limestone Member overlies the Heumader Shale Member and underlies the Jackson Park Shale Member of the Kanwaka Shale. In the Riverton core, the interval tentatively assigned to the Kereford Limestone contains an open marine fauna, including brachiopods, phylloid algae, fusulinids, gastropods and crinoids.

The 643.0-651.6 foot interval in the Riverton core is tentatively assigned to the Kereford Limestone and is designated as a reference section.

Heumader Shale Member
(unchanged)

The Heumader Shale was named by Moore (1932) from exposures in the Heumader Quarry in the east bluff of the Missouri River Valley, in the NE NW section 30, T. 58 N., R. 35 W., two miles north of Aviation Field, northwest of St. Joseph, Buchanan County, Missouri. The Heumader Shale Member overlies the Plattsmouth Limestone Member and underlies the Kereford Limestone Member.

The 651.6-652.0 foot interval in the Riverton core is tentatively assigned to the Heumader Shale and is designated as a reference section.

Plattsmouth Limestone Member
(unchanged)

The name Plattsmouth limestone was first used by Meek (1872) and was defined by Keyes (1899) to include the entire Oread Formation. Condra (1927) redefined and restricted the name to the top and thickest limestone of Keyes' Plattsmouth member. It was named for exposures in the Missouri River bluffs in the vicinity of Plattsmouth, Cass County, Nebraska. It is not clear, but it is assumed the type exposures are in T. 12 N., R. 13 or 14 E. The Plattsmouth was also revised by Moore (1932), Condra (1935) and Moore (1936) to its present usage. The Plattsmouth Limestone Member overlies the Heebner Shale Member and underlies the Heumader Shale Member. In the Riverton core the Plattsmouth Limestone is a thick, mainly skeletal wackestone to packstone with numerous shale partings, and an abundant open marine fauna, including brachiopods, bryozoans, corals, crinoids, phylloid algae, gastropods and fusulinids.

The 652.0-670.8 foot interval in the Riverton core is designated as a reference section. The 123.0-145.8 foot interval in the Bedford core is identified as Plattsmouth Limestone, although the Heumader Shale and Kereford Limestone may occur at the top of the interval. Most of the Plattsmouth Limestone is currently exposed in the Stennett quarry, in the NE section 27, T. 73 N., R. 38 W., Montgomery County.

Heebner Shale Member
(unchanged)

The Heebner Shale was named by Condra (1927) from exposures on Heebner Creek and Heebner Farm, Cass County, Nebraska. Baars and Maples (1998) located the type section as 2.5 miles (4 km) west and 1.5 miles (2.4 km) north of Nehawka, Cass County, Nebraska. It is unclear where the type section is, but from the description, this location is in an undetermined section in T. 10 N., R. 12 E. The Heebner Shale Member overlies the Leavenworth Limestone Member and underlies the Plattsmouth Limestone Member. In the Riverton core the Heebner Shale is black (N1), phosphatic and fissile in the lower part, and medium (N5) to light gray (N7) in the upper part.

The 670.8-673.8 foot interval in the Riverton core and the 145.8-150.0 foot interval in the Bedford core are designated as reference sections.

Leavenworth Limestone Member
(unchanged)

The Leavenworth Limestone was named by Condra (1927) from roadcut exposures northwest of the federal penitentiary at Leavenworth, Leavenworth County, Kansas. It is not clear, but it is assumed Condra was describing exposures in T. 8 S., R. 22 E. The Leavenworth Limestone Member overlies the Snyderville Shale Member and underlies the Heebner Shale Member. In the Riverton core the Leavenworth Limestone is a single bed of skeletal wackestone with marine fossils.

The 673.8-675.3 foot interval in the Riverton core, the 150.0-152.0 foot interval in the Bedford core, and the 7.5-8.8 foot interval in the Malvern core are designated as reference sections.

Snyderville Shale Member
(unchanged)

The Snyderville Shale was named by Condra (1927) from exposures on Heebner Creek, east of the Snyderville quarry, three to four miles (4.8-6.4 km) west of Nehawka, Cass County, Nebraska. It is unclear, but it is assumed Condra was describing exposures in T. 10 N., R.

12 E. The Snyderville Shale Member overlies the Toronto Limestone Member and underlies the Leavenworth Limestone Member. In the Riverton core the lower Snyderville Shale is mainly a blocky, greenish gray (5GY 6/1) blocky mudstone with abundant limestone nodules. The middle part is mainly a brecciated, blocky, medium gray (N5) to light gray (N7) mudstone. The upper two feet (60 cm) is a medium gray (N5) shale with limestone nodules and marine fossils.

The 675.3-682.6 foot interval in the Riverton core, the 152.0-165.5 foot interval in the Bedford core, and the 8.8-22.7 foot interval in the Malvern core are designated as reference sections.

Toronto Limestone Member
(unchanged)

The name Toronto Limestone was originally used by Haworth and Piatt (1894) with the type section near Toronto, Woodson County, Kansas. In Nebraska the Toronto was called the Weeping Water (Weepingwater) Limestone (e.g. Condra and Bengtson, 1915). The Toronto Limestone Member overlies the Wathena Shale Member of the Lawrence Shale and underlies the Snyderville Shale Member. In the Riverton core the Toronto Limestone is a very argillaceous skeletal wackestone in the lower part with crinoids, brachiopods and fusulinids. The upper part is a lime mudstone with shale-filled vertical tubes.

The 682.6-693.0 foot interval in the Riverton core, the 165.5-174.3 foot interval in the Bedford core, and the 22.7-30.0 foot interval in the Malvern core are designated as reference sections.

DOUGLAS GROUP
(revised; new formations, members, beds recognized)

The Douglas Group (Figure 5) was named by Haworth (1898) from Douglas County, Kansas. It comprises the Stranger Formation, Cass Limestone, and Lawrence Shale, in ascending order. The Douglas Group overlies the South Bend Limestone (Lansing Group) and underlies the Oread Limestone (Shawnee Group).

Historically the Douglas, Shawnee, and Wabaunsee groups were included in the Virgilian Stage. The Douglas formation originally included all units above the Stanton and below the Kanwaka Shale. Moore (1931) excluded the Oread limestone at the top and excluded at the base the Weston shale, Iatan limestone, and basal part (later named Hardesty shale) of the Lawrence shale. Moore (1932) erected the Pedee Group (from Pedee Branch in the vicinity of Weston, Missouri) to include the strata (Weston Shale and Iatan Limestone) between the Stanton Formation and the base of the overlying Tonganoxie Sandstone (basal member of the Stranger Formation and basal unit of the Douglas Group, Virgilian). The Pedee Group was considered Missourian in age (*in* Moore, 1948) by the Kansas, Missouri, Nebraska, and Iowa geological surveys. In Kansas, O'Connor (1963) and Ball (1964) abandoned the Pedee Group and redefined the Douglas Group to include all rocks between the underlying Stanton Limestone and overlying Oread Limestone. They divided the revised Douglas into two formations, the Stranger below and the Lawrence above. The Stranger Formation included in ascending order: the Weston Shale, Iatan Limestone, Tonganoxie Sandstone, Westphalia Limestone, and Vinland Shale. The Lawrence Formation included in ascending order: the Haskell Limestone, Robbins Shale, and an unnamed upper member.

In Iowa, Landis and Van Eck (1965) abandoned the use of the name Pedee Group and expanded the Douglas Group to include strata (Iatan and Weston) formerly placed in the Pedee Group (e.g., Hershey et al., 1960), recognizing only the Lawrence and Stranger formations, both placed in the Virgilian. In Kansas (Jewett et al., 1968) placed the Iatan and Weston in the Stranger Formation of the Douglas Group and also regarded them as Virgilian. The Missouri survey used the name Pedee Group (e.g., Thompson, 1995), until Gentile and Thompson (2004) abandoned the name and placed the strata in the Douglas Group.

Heckel and Watney (2002) included the Stranger Formation (Weston Shale, Iatan Limestone, Tonganoxie Sandstone, Westphalia Limestone, and Vinland Shale, in ascending order) in the Douglas Group, below the Cass

Limestone and Lawrence Formation in Kansas. The author follows the nomenclature of Heckel and Watney (2002), and in Iowa the author does not recognize the Pedee Group. The Douglas Group, in Iowa, includes the Stranger Formation at the base, the Cass Limestone in the middle, and the Lawrence Shale (Lawrence Formation of Heckel and Watney, 2002) at the top. The Douglas Group is dominated by clastic sediments in Iowa. In southwest Iowa the Douglas Group is 135 feet (41 m) thick (Witzke et al., 2003a, 2003b).

Heckel and Watney (2002) placed the Missourian-Virgilian boundary in the lower part of the Cass Limestone on the basis of the first appearance of the conodont *Streptognathodus zethus* and ammonoids (Work and Boardman, 2003). Thus the lower formation (Stranger) of the Douglas Group is Missourian, while the upper two formations (essentially the upper two members of the Cass Limestone and the Lawrence Shale) are Virgilian.

The 693.0-810.2 foot interval in the Riverton core, the 174.3-307.0 foot interval in the Bedford core, and the 30.0-122.8 foot interval in the Malvern core are designated as reference sections.

Lawrence Shale

(revised; new members and bed recognized)

The name Lawrence shale was originally used by Haworth (1894) for all units above the Ottawa (Iatan) and below the Oread. The type section of the Lawrence Shale was located by Ver Wiebe and Vickery (1932) as in T. 12 S., R. 19 E., Lawrence, Douglas County, Kansas. Condra and Bengtson (1915) called it the Andrew shales in Nebraska, a name used by Keyes (1899) in Kansas. In Iowa, the Lawrence Shale comprises three members in ascending order: Robbins Shale, Amazonia Limestone, and Wathena Shale. Where the Amazonia Limestone is absent or not recognized the entire unit is known by its formational name. The Lawrence Shale overlies the Cass Limestone and underlies the Oread Limestone.

The 693.0-779.0 foot interval in the Riverton core, the 174.3-274.3 foot interval in the Bedford core, and the 30.2-84.2 foot interval in the Malvern core are designated as reference sections.

Wathena Shale Member

(new name in Iowa)

The upper shale member of the Lawrence Formation remained unnamed until Gentile and Thompson (2004) called it the Wathena Shale. The name, Wathena Shale Member, had been proposed by Ball (1964) for an exposure in an abandoned quarry 0.6 mile (1 km) south of Wathena, in the NE SW section 33, T. 3 S., R. 22 E., Doniphan County, Kansas, in an unpublished dissertation. The Wathena Shale Member overlies the Amazonia Limestone Member or its equivalent fossiliferous shale horizon and underlies the Toronto Limestone Member of the Oread Limestone. The Upper Williamsburg Coal occurs in this unit, below the Toronto Limestone, in Missouri and Kansas, but it has not been recognized in Iowa. In the Riverton core the upper one foot (30 cm) of the Wathena Shale is a light gray (N7) shale with marine fossils. The next lower ten feet (3 m) is missing due to core loss. In the 178.0-188.0 foot interval in the Bedford core in Taylor County, the upper two feet (60 cm) of the interval corresponding to the missing interval in the Riverton core, is medium dark gray (N4) blocky mudstone, while the lower part is a dark red (10R 3/6) blocky mudstone. Below the missing section in the Riverton core is three feet (0.9 m) of red (2.5YR 4/8 to reddish brown (2.5YR 4/4), slickensided blocky mudstone, with the lower one foot (30 cm) mottled with dark yellowish green (10GY 4/4) mudstone. From about 709-720 feet it is mainly laminated and rippled gray shale, with plant debris. At about 721 feet there is a siltstone that may be equivalent to a thin limestone seen in the Malvern core (Mills County) and the Red Oak and Grant cores (Montgomery County). A carbonaceous zone, overlying a maroon mudstone occurs at about 723-724 feet. Witzke (2003a, 2003b) interpreted the interval from about 694-724 feet as a new unnamed cyclothem. From 724-736 feet the Wathena is mainly gray bioturbated to laminated shale with linguloid brachiopods.

The 693.0-736.0 foot interval in the Riverton core, the 174.3-199.8 foot interval in the Bedford core, and the 30.0-56.8 foot interval in the Malvern core are designated as reference sections.

Amazonia Limestone Member
(new name in Iowa)

The Amazonia Limestone Member was named by Hinds and Greene (1915) who mentioned the type section as at Amazonia, Missouri. Cordell (1947) described an outcrop in the NE SW section 36, T. 59 N., R. 36 W., just north of the Burlington Northern Railroad southwest of Amazonia, Andrew County, Missouri, which could be the section described by Hinds and Greene. The Amazonia Limestone Member overlies the Robbins Shale Member and underlies the Wathena Shale Member. In southwest Iowa cores, the Amazonia Limestone is often a fossiliferous, clam-rich shale, with local thin limestone shell beds or limestone septaria (Witzke, 2003a, 2003b). In the Riverton core a thin, argillaceous, skeletal wackestone is tentatively assigned to the Amazonia Limestone.

The 736.0-737.0 foot interval in the Riverton core and the 199.8-200.3 foot interval in the Bedford core are tentatively assigned to the Amazonia Limestone and are designated as reference sections. The 56.8-68.7 foot shale interval in the Malvern core is tentatively considered to be the Amazonia Limestone equivalent.

Robbins Shale Member
(new name in Iowa)

The Robbins Shale Member was named by Moore (1936) from exposures on the Robbins farm in section 11, T. 26 S., R. 15 E., southwest of Yates Center, Woodson County, Kansas. The original definition of the Robbins Shale was shale and sandstone overlying the Haskell Limestone [Cass Limestone] and underlying the unconformity at the base of the Ireland Sandstone in the Lawrence Shale. Because the Ireland Sandstone Member does not occur in Iowa, in this report, the Robbins Shale Member is defined as all strata overlying the Shoemaker Limestone Member of the Cass Limestone and underlying the Amazonia Limestone Member or its equivalent fossiliferous shale horizon. In the Riverton core the Robbins Shale varies from bioturbated to laminated gray shale to rippled siltstones. The upper three feet (0.9 m) is a rooted, slickensided gray mudstone. In the Bedford core the Robbins Shale thickens to about 75 feet (22.9 m) of silty shale and mudstone.

The 737.0-779.0 foot interval in the Riverton core, the 200.3-274.2 foot interval in the Bedford core, and the 69.0-84.2 foot interval in the Malvern core are designated as reference sections.

Lower Williamsburg Coal bed
(new name in Iowa)

In Franklin County, Kansas, two coals occur in the Lawrence Formation. Whitla (1940) named the upper coal (occurring below the Toronto Limestone Member of the Oread Limestone and above the Amazonia Member of the Lawrence Shale) the Williamsburg Coal (Ransomville Coal of Moore, 1929), but did not name the lower coal bed. Bowsher and Jewett (1943) named the lower coal the Lower Williamsburg Coal, and the upper coal bed (Williamsburg Coal) the Upper Williamsburg Coal. The name Williamsburg was derived from the town of Williamsburg, in section 18, T. 18 S., R. 18 E., Franklin County, Kansas.

A thin coal (Witzke, 2003a, 2003b), below the Amazonia Limestone or its equivalent fossiliferous shale horizon, in cores in southwest Iowa is hereby tentatively assigned to the Lower Williamsburg Coal.

The coal that occurs at the 737.5 foot level in the Riverton core, at the 200.3 foot level in the Bedford core, and at the 68.7-69.0 foot interval in the Malvern core are tentatively assigned to the Lower Williamsburg Coal and are designated as reference sections.

Cass Limestone
(new name in Iowa)

The Cass Limestone was named by Condra (1927) from exposures in the Platte River bluffs and Burlington quarries located 1.5-2 miles (2.4-3.2 km) northwest of South Bend, Cass County, Nebraska. It is unclear, but from the description, it is assumed that Condra was describing exposures in T. 12 N., R. 10 E. The Cass Limestone, as defined today, comprises three members in ascending order: Haskell Limestone, Little Pawnee Shale, and Shoemaker Limestone (Heckel and Watney, 2002). In 1949, Condra subdivided the Cass into three members in ascending order: Shoemaker Limestone, Little Pawnee Shale and Haskell Limestone. However the Little Pawnee Shale Member is known to overlie the type Haskell Limestone Member near Lawrence, Kansas, so the lower limestone northward was identified as the Haskell, and the upper limestone was renamed the Shoemaker (Heckel and Watney, 2002).

The Missourian-Virgilian stage boundary was provisionally placed within the Cass Limestone, near the top of the Haskell Limestone Member, in Kansas (Heckel, 1999; Heckel et al., 1999). See discussions under Haskell Limestone Member below and Virgilian Stage above. The Cass Limestone overlies the Stranger Formation and underlies the Lawrence Shale.

The 84.2-90.2 foot interval in the Malvern core is designated as a reference section, where the three members are easily distinguished. The 779.0-784.0 foot interval in the Riverton core is also designated as a reference section, although the three members are not differentiated in the core. The 274.2-276.2 foot interval in the Bedford core is also a reference section, although the lower limestone member (Haskell) is not recognized.

Shoemaker Limestone Member
(new name in Iowa)

The Shoemaker Limestone was named by Condra (1927) and was originally applied to the entire Cass Formation in Nebraska. Later the name was restricted to the lower member (Condra, 1949), when the upper limestone was miscorrelated with the Haskell Limestone of Kansas. Finally the name Shoemaker was applied to the upper limestone when the lower limestone was correctly correlated with the Haskell (Heckel and Watney, 2002). Condra (1949) located the type section as just west of Shoemaker bridge alongside Shoemaker farm, about 2.5-3 miles (4-4.8 km) NW of Nehawka, Cass County, Nebraska. From Condra's description, this location may be in T. 10 N., R. 12 E. The Shoemaker Limestone Member overlies the Little Pawnee Shale Member and underlies the Robbins Shale Member of the Lawrence Shale. In the Malvern core the Shoemaker Limestone is an argillaceous skeletal wackestone with an open marine fauna, including brachiopods, crinoids and bryozoans.

The 84.2-87.3 foot interval in the Malvern core is designated as a reference section.

Little Pawnee Shale Member
(new name in Iowa)

The Little Pawnee Shale was named by Condra (1949) from exposures along Little Pawnee Creek in the SE section 9, T. 12 N., R. 10 E., Saunders County, Nebraska. The Little Pawnee Shale Member overlies the Haskell Limestone Member and underlies the Shoemaker Limestone Member. In the Malvern core the Little Pawnee Shale is dark gray (N3) in the upper part, black (N1) with phosphate laminae in the middle part, and medium gray (N5) in the lower part.

The 87.3-88.3 foot interval in the Malvern core is designated as a reference section.

Haskell Limestone Member
(new name in Iowa)

The Haskell Limestone was named by Moore (1932) from the Haskell Indian Institute (now Haskell Indian Nations University) in Lawrence, Douglas County, Kansas. The type section was designated by Moore (1936) as along 15th Street, in the C of the N line NE section 5, T. 13 S., R. 20 E. The Haskell Limestone Member overlies the Vinland Shale Member of the Stranger Formation and underlies the Little Pawnee Shale Member, in most of Kansas. In Iowa the Haskell Limestone Member underlies the Little Pawnee Shale Member and overlies the "middle-upper" part of the Stranger Formation, since the Vinland Shale and Westphalia Limestone members of the Stranger Formation are not recognized.

The upper part of the Haskell Limestone contains the first appearance of the conodont *Streptognathodus zethus*, near its top, while the lower part contains its ancestor *S*. "pre-zethus", hence contains the provisional Missourian-Virgilian stage boundary in Kansas. Thus the top of the Haskell Limestone is Virgilian and the lower part is Missourian (Heckel, 1999; Heckel et al., 1999; Heckel and Watney, 2002, Fig. 1, p. 2). See discussion under Virgilian Stage above. In the Malvern core the Haskell Limestone is an argillaceous skeletal wackestone with crinoids, brachiopods, snails and echinoids.

The 88.3-90.2 foot interval in the Malvern core is designated as a reference section.

MISSOURIAN STAGE

The Missourian Stage (Figure 6) was derived from the Missouri terrane, named by Keyes (1893) from exposures along the Missouri River in Missouri and Iowa. It corresponds to the lower part of the 'Upper Coal Measures' of Broadhead (1873) and Winslow (1892). Keyes' (1894) original definition included all strata above the Des Moines Series up to the Cottonwood Limestone, and the Iowa, Missouri, and Kansas State Geological surveys recognized the base of the Hertha Limestone as the base of the Missouri Series. Moore (1932) and Cheney and others (1945) restricted the definition to include all strata between the unconformity (base of the Chariton Conglomerate in Iowa) at the top of the Des Moines Series in a shale between the Exline and Hertha limestones, up to an unconformity (base of the Tonganoxie Sandstone in northeastern Kansas) in the Douglas Group. These strata were the lower 'Missourian' of Keyes (1898). Jewett and others (1968) regarded the Missourian as a stage in the Upper Pennsylvanian Series. Landis and Van Eck (1965), in Iowa, also placed the lower boundary of the Missourian at the base of the Chariton Conglomerate.

Prior to 1932, the Missourian in Kansas consisted of four groups in ascending order: Bourbon, Bronson, Kansas City, and Lansing. Moore (1932) erected the Pedee Group (from Pedee Branch in the vicinity of Weston, Missouri) to include the strata (e.g., Weston Shale and Iatan Limestone) between the Stanton Formation and the base of the overlying Tonganoxie Sandstone (basal member of the Stranger Formation and basal unit of the Douglas Group, and considered Virgilian). In Iowa, prior to 1947 the Missourian comprised three groups in ascending order: Pleasanton, Kansas City, and Lansing (Moore, 1948). After the state survey meeting in 1948 the name Bourbon Group (in Kansas) was dropped and the Pleasanton Formation was raised to group rank (replacing the Bourbon Group). The Bronson Group was lowered in rank to a subgroup of the expanded Kansas City Group in which the subgroups, in ascending order, were the Bronson, Linn, and Zarah.

In Iowa, Ravn and others (1984) reduced the Kansas City Group to its original definition used by Moore (1936) and resurrected the Bronson Group as the lowermost division of the Missourian, reducing the Pleasanton to formational rank within the Bronson Group. See discussion under Pleasanton Formation below. Ravn and others (1984) dropped the Linn and Zarah subgroups of the Kansas City Group, in Iowa (p. 52), although the subgroups remained in their stratigraphic column (Fig. 27, p. 51). The author follows the nomenclature of Ravn and others (1984) in this report, including dropping of the subgroup names.

For a discussion of the Desmoinesian-Missourian boundary, see the section on the Desmoinesian Stage below. For a discussion of the Missourian-Virgilian boundary, see the section on the Virgilian Stage above.

The Missourian comprises about 650 feet (~200 m) of mainly limestone and shale with some sandstone in eastern Kansas, thinning northward to about 500 feet (152 m) in Iowa. The Missourian Stage overlies the Desmoinesian Stage and underlies the Virgilian Stage.

The 783.5-1078.5 foot interval in the Riverton core is designated as a reference section. The 276.2-585.5 (bottom of core) in the Bedford core is also designated as a reference section, although the base of the Exline Limestone was not reached.

Stranger Formation

(revised; new members recognized)

The Stranger Formation first used by Moore (1931) in a correlation chart, was described by Moore (1932), and was formally named by Newell (1935). Moore (1936) located the type section at exposures along Stranger Creek in the NE SE SE section 3, T. 12 S., R. 21 E., east of Tonganoxie, Leavenworth County, Kansas. Heckel and Watney (2002) included in the

Landis & Van Eck (1965)

Series	Group	Formation	Member
Virgil	Douglas	Lawrence	
		Stranger	
Missouri	Lansing	Stanton	
		Vilas Sh	
		Plattsburg	
	Kansas City	Bonner Spring Sh	
		Wyandotte	Farley Ls Island Crk Sh Argentine Ls Quindaro Sh Frisbie Ls
		Lane Sh	
		Iola	Raytown Ls Muncie Crk Sh Paola Ls
		Chanute Sh	
		Drum	Corbin City Ls Cement City Ls
		Quivira Sh	
		Westerville Ls	
		Cherryvale Sh	Wea Sh Block Ls Fontana Sh
		Dennis	Winterset Ls Stark Sh Canville Ls
		Galesburg Sh	
		Swope	Bethany Falls Ls Hushpuckney Sh Middle Creek Ls
		Ladore Sh	
		Hertha	
	Pleasanton		Exline Ls Ovid C Chariton Conglomerate
Des Moines	Marmaton	Lenapah Ls	Cooper Crk Ls

Ravn and others (1984)

Series	Super Group	Group	Formation	Member
Virgilian	Virgil	Douglas	Lawrence	
			Stranger	unnamed coal
Missourian	Missouri	Lansing	Stanton	South Bend Rock Lake Sh Stoner Ls Eudora Sh Captain Crk Ls
			Vilas Sh	
			Plattsburg	Spring Hill Ls Hickory Crk Sh Merriam Ls
		Kansas City	Bonner Springs Sh	
			Wyandotte	Farley Ls Island Crk Sh Argentine Ls Quindaro Sh Frisbie Ls
			Lane Sh	
			Iola	Raytown Ls Muncie Crk Sh Paola Ls
			Chanute Sh	
			Drum	Corbin City Ls Cement City Ls
			Cherryvale Sh	Quivira Sh Westerville Ls Wea Sh Block Ls Fontana Sh
		Bronson	Dennis	Winterset Ls Stark Sh Canville Ls
			Galesburg Sh	
			Swope	Bethany Falls Ls Hushpuckney Sh Middle Creek Ls
			Ladore Sh	
			Hertha	Sniabar Ls Mound City Sh
			Pleasanton	unnamed sh Exline Ls unnamed sh
Desmoinesian	Des Moines	Marmaton	Lost Branch	Cooper Crk Ls unnamed sh Sni Mills Ls

Pope (this report)

Stage	Group	Formation	Member *bed*
Virgilian	Douglas	Cass Ls	Shoemaker Ls Little Pawnee Sh Haskell Ls
Missourian		Stranger	"middle-upper" Iatan Ls Weston Sh
	Lansing	South Bend Ls	Kitaki Ls Gretna Sh Little Kaw Ls
		Rock Lake Sh	*Arbor Hill C*
		Stanton Ls	Stoner Ls Eudora Sh Captain Crk Ls
		Vilas Sh	
		Plattsburg Ls	Spring Hill Ls Hickory Crk Sh Merriam Ls
	Kansas City	Lane Sh	Bonner Spgs Sh Farley Ls Island Crk Sh
		Wyandotte Ls	Argentine Ls Quindaro Sh Frisbie Ls
		Liberty Memorial Sh	
		Iola Ls	Raytown Ls Muncie Crk Sh Paola Ls
		Chanute Sh	
		Dewey Ls	Cement City Ls Quivira Sh Pammel Park Ls
		Nellie Bly Sh	*Harmon Tunnel C*
		Cherryvale	Westerville Ls Wea Sh Block Ls Fontana Sh
	Bronson	Dennis Ls	Winterset Ls Stark Sh Canville Ls
		Galesburg Sh	*Davis City C*
		Swope Ls	Bethany Falls Ls Hushpuckney Sh Middle Creek Ls
		Elm Branch Sh	
		Hertha Ls	Sniabar Ls Mound City Sh East Peru Ls
		Pleasanton	Shale Hill Sh *Ovid C* Exline Ls Hepler Sh *Grain Valley C*
Desmoinesian	Marmaton	Lost Branch	Cooper Crk Ls Nuyaka Crk Sh Sni Mills Ls

Figure 6. Missourian Stage (Bronson, Kansas City, Lansing and lower Douglas groups) stratigraphy, showing relationship to Desmoinesian and Virgilian stages, in Iowa.

Stranger Formation, the Weston Shale, Iatan Limestone, Tonganoxie Sandstone, Upper Sibley Coal bed, Westphalia Limestone, and Vinland Shale, in ascending order in Kansas. Since the Tonganoxie Sandstone and Westphalia Limestone are not known to exist in Iowa, the Stranger comprises three units in ascending order: Weston Shale, Iatan Limestone and the "middle-upper" Stranger (interval between the Iatan Limestone and overlying Haskell Limestone, where the Westphalia Limestone is absent). The Stranger Formation overlies the South Bend Limestone and underlies the Cass Limestone.

The 784.0-810.2 foot interval in the Riverton core, the 90.2-122.8 foot interval in the Malvern core, and the 276.2-307.0 foot interval in the Bedford core are designated as reference sections.

"middle-upper" Stranger
(new informal name in Iowa)

The name Vinland Shale was first used by Patterson (1933) in an unpublished master's thesis and was formally described by Moore (1936) who also located the type section as about 2 miles (3.2 km) northeast of Vinland, Douglas County, Kansas. The Vinland Shale was originally described by Moore (1936) to encompass all strata overlying the Westphalia Limestone and underlying the Haskell Limestone.

Since the Tonganoxie Sandstone, Upper Sibley Coal bed, and Westphalia Limestone are not known to occur in Iowa, the name Vinland Shale Member cannot be used for the interval overlying the Iatan Limestone Member of the Stranger Formation and underlying the Haskell Limestone Member of the Cass Limestone. At this time, the interval above the Iatan Limestone and below the Haskell Limestone, will be called the "middle-upper" Stranger as suggested by Heckel (1992, Fig. 2), Heckel and Watney (2002, Fig. 33), and Heckel (personal communication 2009). In the Riverton core the "middle-upper" Stranger consists of fossiliferous shale in the upper part, is mainly dark reddish brown (10R 3/4) to moderate reddish brown (10R 4/6) mudstone with calcareous nodules in the middle part, and is grayish green (5G 5/2) mudstone in the lower part.

The 784.0-799.0 foot interval in the Riverton core, the 90.2-106.0 foot interval in the Malvern core, and the 276.2-289.5 foot interval in the Bedford core are designated as reference sections.

Iatan Limestone Member
(new name in Iowa)

The Iatan Limestone Member was named by Keyes (1899) from exposures on the Missouri River, and Ver Wiebe and Vickery (1932) located the type area as T. 54 N., R. 36 W., near Iatan, Missouri. Gentile and Thompson (2004) located the type section as the Burlington Northern-Santa Fe railroad cut at the north edge of Iatan, in the C SE NW section 19, T. 54 N., R. 36 W., Platte County, Missouri. The Iatan was called the Kickapoo in Kansas by Haworth and Bennett (1908) and the Nehawka Limestone in Nebraska by Condra and Bengtson (1915). In Iowa, the Iatan Limestone Member overlies the Weston Shale Member and underlies the "middle-upper" Stranger. In the Bedford Core in Taylor County, Goebel (1985) described a shale near the base of the Iatan that she interpreted as a core shale of Heckel's (1980) depositional model. A cross-section of the Iatan and adjacent units in the Iowa subsurface is provided by Goebel and others (1989). In the Riverton core the Iatan Limestone is an argillaceous skeletal wackestone with an open marine fauna, including brachiopods, crinoids, bryozoans and fusulinids.

The 799.0-807.5 foot interval in the Riverton core, the 106.0-114.1 foot interval in the Malvern core, and the 289.6-292.2 foot interval in the Bedford core are designated as reference sections.

Weston Shale Member
(new name in Iowa)

The Weston Shale Member was named by Keyes (1899). Hinds and Greene (1915) described the type section as 0.5 mile (0.8 km) north of the depot at Weston, in the SW SE section 11, T. 53 N., R. 36 W., Platte County, Missouri. The Weston Shale was revised by Moore (1932) and O'Connor (1963). Ball (1964) designated a type section near Beverly, in the SW SE NE section 31, T. 53 N., R. 35 W., Platte County, Missouri. The Weston Shale Member overlies the South Bend Limestone and underlies the Iatan Limestone Member. In the Riverton core the Weston Shale is very calcareous and contains brachiopods, bryozoans and crinoids. The Weston Shale increases in thickness to 15 feet (4.6 m) in the Bedford core (Taylor County).

The 807.5-810.2 foot interval in the Riverton core, the 114.1-122.8 foot interval in the Malvern core, and the 292.2-307.0 foot interval in the Bedford core are designated as reference sections.

LANSING GROUP

(new formations, members, beds recognized)

The Lansing formation was originally described by Hinds (1912) from the town of Lansing, Leavenworth County, Kansas, as including strata from the base of the Wyandotte Limestone to the top of the Stanton Limestone. The Lansing was defined as a group by Moore (1932), and the strata below the Plattsburg were retained in the Lansing Group. Moore (1932) stated the Lansing Group comprised five formations in ascending order: Wyandotte Limestone, Bonner Springs Shale, Plattsburg Limestone, Vilas Shale, and Stanton Limestone. He also transferred the strata between the top of the Stanton and the unconformity at the base of the Douglas Group, to the Pedee Group.

Condra (1935) revised the Lansing Group to include three formations in ascending order: Plattsburg Limestone, Vilas Shale, and Stanton Limestone. Heckel and Watney (2002) removed the Rock Lake Shale and South Bend Limestone from the Stanton Limestone and raised them in rank to formations, but kept them in the Lansing Group. In Iowa, the Lansing group (Figure 6) contains five formations, nine members and one bed. The Lansing Group overlies the Kansas City Group and underlies the Douglas Group. The Lansing Group is 45-78 feet (14-24 m) thick in southwestern Iowa (Witzke et al., 2003a).

The 810.2-866.0 foot interval in the Riverton core, the 122.8-170.3 foot interval in the Malvern core, and the 307-375.7 foot interval in the Bedford core are designated as reference sections.

South Bend Limestone

(revised; raised in rank; new members recognized)

The South Bend Limestone was named by Condra and Bengtson (1915) from exposures in bluffs along the Platte River 1.5 miles (2.4 km) northwest of the town of South Bend, Cass County, Nebraska. It is unclear, but it is assumed Condra and Bengtson were describing outcrops in T. 12 N., R. 10 E. The South Bend Limestone overlies the Rock Lake Shale and underlies the Stranger Formation. The South Bend was revised by Condra (1927) and Condra (1930). The South Bend was removed from the Stanton Formation and raised in rank to formation level by Heckel and Watney (2002). This was because the South Bend represents a distinct cycle of deposition separate from the Stanton Formation. Heckel and Watney (2002) located a reference section in Kansas in a roadcut at an intersection just south of US Highway 40, along the southwest side of Kansas Highway K-7 in the NW SW NW section 8, T. 11 S., R. 23 E., Wyandotte County, Kansas. The South Bend Limestone comprises three members in ascending order: Little Kaw Limestone, Gretna Shale, and Kitaki Limestone. The South Bend Limestone overlies the Rock Lake Shale and underlies the Stranger Formation.

The 810.2-814.0 foot interval in the Riverton core, the 122.8-125.8 foot interval in the Malvern core, and the 307.0-311.8 foot interval in the Bedford core are designated as reference sections.

Kitaki Limestone Member

(new name in Iowa)

The Kitaki Limestone Member was named by Pabian and Strimple (1993) from exposures at Camp Kitaki in the lower Platte River Valley, C S line SW section 10, T. 12 N., R. 10 E., Cass County, Nebraska. The Kitaki Limestone Member overlies the Gretna Shale Member and underlies the Weston Shale Member of the Stranger Formation (Douglas Group). In the Riverton core the Kitaki Limestone is an argillaceous skeletal wackestone with gastropods, crinoids and brachiopods. In the Bedford core the Kitaki Limestone is represented by two feet (60 cm) of very calcareous, fossiliferous shale.

The 810.2-811.9 foot interval in the Riverton core, the 122.8-125.0 foot interval in the Malvern core, and the 307.0-309.0 foot interval in the Bedford core are designated as reference sections.

Gretna Shale Member
(new name in Iowa)

The Gretna Shale Member was named by Pabian and Strimple (1993) from exposures near the former Gretna Fish Hatchery (now Schramm Park) in the NE SW section 12, T. 12 N., R. 10 E., near Gretna, Sarpy County, Nebraska. The Gretna Shale Member overlies the Little Kaw Limestone Member and underlies the Kitaki Limestone Member. In the Riverton core the Gretna Shale is very calcareous with crinoids and brachiopods. In the Bedford core the Gretna Shale is dark gray (N3) with crinoids, brachiopods, and abundant conodonts.

The 811.9-813.0 foot interval in the Riverton core, the 125.0-125.7 foot interval in the Malvern core, and the 309.0-310.0 foot interval in the Bedford core are designated as reference sections.

Little Kaw Limestone Member
(new name in Iowa)

The name Little Kaw was derived by Newell (1935) from exposures along Little Kaw Creek, two miles (3 km) southwest of Bonner Springs, Leavenworth County, Kansas. It was believed that the Little Kaw represented the entire South Bend of Nebraska. Moore (1949) abandoned the name Little Kaw in favor of the earlier named South Bend Limestone. It is now known that the South Bend in Nebraska includes three distinct lithologic units. Pabian and Strimple (1993) revived the name Little Kaw, on the advice of P. H. Heckel, to apply to the basal limestone unit of the South Bend Formation. Heckel and Watney (2002) located a type section at the principal reference section of the South Bend Limestone in Kansas, in a roadcut at an intersection just south of US highway 40, along the southwest side of Kansas Highway K-7 in the NW SW NW section 8, T. 11 S., R. 23 E., Wyandotte County, Kansas. The Little Kaw Limestone Member overlies the Rock Lake Shale and underlies the Gretna Shale Member. In the Riverton core the Little Kaw Limestone contains algae, crinoids and brachiopods. In the Bedford core the Little Kaw Limestone is mainly an "*Osagia*" coated skeletal packstone, with crinoids, brachiopods and bryozoans.

The 813.0-814.0 foot interval in the Riverton core, the 125.7-125.8 foot interval in the Malvern core, and the 310.0-311.8 foot interval in the Bedford core are designated as reference sections.

Rock Lake Shale
(raised in rank; new bed recognized)

The Rock Lake Shale was named by Condra (1927) from exposures along the bluffs at Rock Lake in SW section 13, T. 12 N., R. 10 E., Sarpy County, Nebraska. The Rock Lake Shale was removed from the Stanton Limestone and raised in rank to formation level by Heckel and Watney (2002), because it comprises mainly terrestrial deposits, lithologically unlike shale within the South Bend or Stanton. The Rock Lake Shale overlies the Stanton Limestone and underlies the South Bend Limestone. Joeckel (1989) described a paleosol in the Rock Lake Shale in Nebraska. In the Malvern core the Rock Lake Shale is mainly a light gray (N7) blocky mudstone.

Since the 807.5-810.2 foot interval in the Riverton core is missing due to core loss, the 311.8-312.6 foot interval in the Bedford core and the 125-131.5 foot interval in the Malvern core are designated as reference sections. Exposures of up to ten feet (3 m) of shale and mudstone in a west-facing cutbank of Middle River in the NW NE NE section 22, T. 76 N., R. 30 W., west to the NW NE NE section 18, T. 76 N., R. 30 W., Adair County, are also designated as reference sections.

Arbor Hill Coal bed
(newly named this report)

The Arbor Hill Coal bed is named in this report from exposures along Middle River between a west-facing cutbank of Middle River in the SW SW SE SE section 22, T. 76 N., R. 30

W., west to the NE SE section 18, T. 76 N., R. 30 W., Adair County. The Arbor Hill Coal is lenticular, but may reach one inch (2.5 cm) in thickness. The coal, when present, usually occurs about one foot (30 cm) below the base of the South Bend Limestone. The name is derived from the nearby town of Arbor Hill, about one mile (1.6 km) to the southeast of the latter section.

Stanton Limestone
(revised; restricted)

The Stanton Limestone was named by Swallow and Hawn (1865), and Moore (1936) recognized typical exposures near the SE corner of section 3, T. 13 S., R. 21 E., Douglas County, Kansas, about 25 miles (40 km) north of the town of Stanton, after Newell (1935) realized that the original type Stanton, in Miami County, had been miscorrelated with the Plattsburg Formation. Haworth and Bennett (1908) applied the name to the limestone and shale beds between the Vilas Shale and the Weston Shale. The Stanton Limestone, as now defined, overlies the Vilas Shale and underlies the Rock Lake Shale, since Heckel and Watney (2002) removed the two upper members of the Stanton Limestone (Rock Lake Shale and South Bend Limestone) from the formation and raised them in rank to separate formations. The principal reference section for the complete Stanton Limestone was designated by Heckel and Watney (2002) for exposures along the westbound onramp from Edgerton Road to K-10 in westernmost Johnson County, Kansas (NE SE SE section 36, T. 12 S., R. 21 E). The Stanton Limestone now comprises three members in ascending order: Captain Creek Limestone, Eudora Shale, and Stoner Limestone.

The 817.0-847.6 foot interval in the Riverton core, the 131.5-156.9 foot interval in the Malvern core, and the 312.6-337.8 foot interval in the Bedford core are designated as reference sections. An exposure of most of the Stanton Formation at an outcrop along a west-facing cutbank of a ravine in the SW SW NW section 7, T. 75 N., R. 29 W., about 0.5 mile (0.8 km) south of State Highway 92 and 150 yards (137 m) east of the Madison-Adair county line, is also designated as a reference section.

Stoner Limestone Member
(unchanged)

The Stoner Limestone Member was named by Condra (1930) from exposures on the Stoner farm northwest of South Bend, Cass County, Nebraska in T. 12 N., R. 10 E., but no section number was indicated. The Stoner Limestone Member overlies the Eudora Shale Member and underlies the Rock Lake Shale. The Stoner Limestone often has a fossiliferous shale in its lower middle part. This led Condra (1949) to divide the Stoner into an upper unnamed limestone, the Kiewitz middle shale and the Dyson Hollow lower limestone. At the Madison-Adair county line outcrop the highest exposed strata are fusulinid-rich skeletal wackestones to packstones, overlain by skeletal grainstone. The middle Stoner is mostly fossiliferous light gray (N7) shale, while the lower Stoner is an argillaceous skeletal wackestone.

Reference sections are designated in the 817.0-843.8 foot interval in the Riverton core, the 131.5-153.2 foot interval in the Malvern core, the 312.6-330.0 foot interval in the Bedford core, and at an exposure of the lower part of the Stoner Limestone along a west-facing cutbank of a ravine in the SW SW NW section 7, T. 75 N., R. 29 W., about 0.5 mile (0.8 km) south of State Highway 92 and 150 yards (137 m) east of the Madison-Adair county line. The upper Stoner, a skeletal wackestone, may be seen at a south-side roadcut seven miles (11.3 km) northwest of the Madison-Adair county line outcrop, in the NE SE section 18, T. 76 N., R. 30 W., Adair County.

Eudora Shale Member
(unchanged)

The Eudora Shale Member was named by Condra (1930), and Moore (1936) designated the type locality east of Eudora, Douglas County, Kansas, with recent exposures located north of Kansas Route 10 in the SE SE SW section 3, T. 13 S., R. 21 E., by Heckel and Watney (2002). The Eudora Shale Member overlies the Captain Creek Limestone Member and underlies the Stoner Limestone Member. In the Madison-Adair county line outcrop the Eudora Shale is dark gray (N3) at the base; black (N1), fissile, phosphatic with abundant conodonts in the middle; and dark gray (N3) at the top.

Reference sections are designated in the 843.8-845.5 foot interval in the Riverton core, the 153.2-154.9 foot interval in the Malvern core, the 330.0-333.2 foot interval in the Bedford core, and at an exposure along a west-facing cutbank of a ravine in the SW SW NW section 7, T. 75 N., R. 29 W., about 0.5 mile (0.8 km) south of State Highway 92 and 150 yards (137 m) east of the Madison-Adair county line.

Captain Creek Limestone Member
(unchanged)

The Captain Creek Limestone Member was named by Newell (1935), and Moore (1936) designated the type locality from exposures near Captain Creek two miles (3.2 km) east of the town of Eudora near the SE corner section 3, T. 13 S., R. 21 E., Douglas County, Kansas. In Nebraska, Condra (1930) called the Captain Creek, the Meadow Limestone. The Captain Creek Limestone Member overlies the Vilas Shale and underlies the Eudora Shale Member. In the Madison-Adair county line outcrop the entire Captain Creek Limestone is a medium gray (N5) skeletal wackestone, while in the Bedford core it is three feet (0.9 m) of skeletal grainstone with fusulinids and "*Osagia*" coated grains.

Reference sections are designated in the 845.5-847.6 foot interval in the Riverton core, the 154.9-156.8 foot interval in the Malvern core, the 333.2-337.7 foot interval in the Bedford core, and at an exposure along a west-facing cutbank of a ravine in the SW SW NW section 7, T. 75 N., R. 29 W., about 0.5 mile (0.8 km) south of State Highway 92 and 150 yards (137 m) east of the Madison-Adair county line.

Vilas Shale
(unchanged)

The Vilas Shale was named by Adams (1898), and Moore (1936) described typical exposures near the town of Vilas in section 30, T. 27 S., R. 17 E., Wilson County, Kansas. The Vilas Shale overlies the Plattsburg Limestone and underlies the Stanton Limestone. In the Bedford core the Vilas Shale is over 30 feet (9.1 m) of mainly gray laminated shale. In the Malvern core several limestones appear in the middle and upper parts, above a green mudstone. In western Madison County several limestones occur in the middle part, with green and red mudstone in the upper and lower parts.

The 847.6-852.0 foot interval in the Riverton core, the 156.8-165.8 foot interval in the Malvern core, and the 337.7-370.6 foot interval in the Bedford core are designated as reference sections.

Plattsburg Limestone
(unchanged)

The Plattsburg Limestone was named by Broadhead (1868), and Moore (1936) described the type section at exposures near the town of Plattsburg in T. 55 N., R. 35 W., Clinton County, Missouri. The correct location is NE SE SW section 24, T. 55 N., R. 32 W. (Gentile and Thompson, 2004). Newell (1935) defined the Plattsburg as comprising three members in ascending order: Merriam Limestone, Hickory Creek Shale, and Spring Hill Limestone. In west-central Madison County the Plattsburg is represented by a single, three-foot (0.9 m) unit of moderate red (5R 4/6) stained, thin, wavy-bedded, argillaceous, skeletal packstone with abundant fossils including: *Composita* sp., *Linoproductus missouriensis*, *Pulchratia* sp., spirorbid worm tubes, carbonized wood fragments, and a specimen of a partial and a nearly complete edrioasteroid (*Postibulina hyperbolus*, Sumrall, Garbisch, and Pope, 2000). The Plattsburg Limestone overlies the Lane Shale and underlies the Vilas Shale. In the Bedford and Malvern cores all three members of the formation are recognized.

The 165.8-169.9 foot interval in the Malvern core and the 370.6-375.8 foot interval in the Bedford core are designated as reference sections. The 852.0-866.0 foot interval in the Riverton core is also designated as a reference section, although the three members are not recognized.

Spring Hill Limestone Member
(unchanged)

The Spring Hill Limestone was named by Moore (1932), and defined by Newell (1935). Moore (1936) located the type section at exposures in a railroad cut near the town of Spring Hill in the center of the E side of section 14, T. 15 S., R. 23 E., Johnson County, Kansas. The Spring Hill Limestone Member overlies the Hickory Creek Shale Member and underlies the Vilas Shale. In the Malvern core the Spring Hill Limestone is about three feet (0.9 m) of slightly argillaceous skeletal wackestone to packstone, with bryozoans, brachiopods, gastropods and fusulinids.

The 370.6-374.7 foot interval in the Bedford core and the 165.8-168.9 foot interval in the Malvern core are designated as reference sections.

Hickory Creek Shale Member
(unchanged)

The Hickory Creek Shale Member was named by Moore (1932), and defined by Newell (1935). Moore (1936) described the type section at exposures in a roadcut near Hickory Creek in the SE section 1, T. 17 S., R. 29 E., near Peoria, Franklin County, Kansas. The Hickory Creek Shale Member overlies the Merriam Limestone Member and underlies the Spring Hill Limestone Member. In the Malvern core the Hickory Creek Shale is about six inches (15 cm) of dark gray (N3) shale in the lower part with abundant conodonts, while the upper part is medium gray (N5) shale.

The 374.7-374.8 foot interval in the Bedford core and the 168.9-169.4 foot interval in the Malvern core are designated as reference sections.

Merriam Limestone Member
(unchanged)

The Merriam Limestone Member was named by Moore (1932), and defined by Newell (1935). Moore (1936) located the type section at exposures in a quarry in the NW corner of section 7, T. 12 S., R. 25 E., near the town of Merriam, Johnson County, Kansas. The Merriam Limestone was called the Meadow limestone by Condra and Bengtson (1915). The Merriam Limestone Member overlies the Lane Shale and underlies the Hickory Creek Shale Member. The Merriam Limestone is typically a thin medium gray (N5), dense, skeletal wackestone to packstone.

The 374.8-375.8 foot interval in the Bedford core and the 169.4-170.3 foot interval in the Malvern core are designated as reference sections.

KANSAS CITY GROUP
(subgroups abandoned; new formations, members, bed recognized)

The term Kansas City limestone (for the Hertha to Argentine interval) was originally used by Hinds (1912), and was raised to formational rank by Hinds and Greene (1915), and later raised to group rank by Moore (1936) who included in it all strata between the Fontana and Bonner Springs shales. The Kansas City formation was revised by Moore (1948) and Condra (1949) to include all strata from the base of the Hertha Formation to the top of the Lane Shale (Bonner Springs Shale Member), as it is used today in Kansas.

Moore and others (1951) divided the Kansas City Group into three subgroups in ascending order: Bronson, Linn, and Zarah, from the top of the Pleasanton Group to the base of the Lansing Group. These subgroup divisions are still being used today in Kansas (Heckel and Watney, 2002) and Missouri (Gentile and Thompson, 2004).

In Iowa, Ravn and others (1984) returned to the group designations of Moore (1936), by raising the Bronson Subgroup to the rank of group (Bronson Group). In Iowa, the Kansas City Group (Figure 6) is defined as all strata from the base of Fontana Shale Member (Cherryvale Formation) to the top of the Bonner Springs Shale Member (Lane Shale). The Kansas City Group overlies the Bronson Group and underlies the Lansing Group. In Iowa, the Kansas City Group is divided into eight formations with sixteen members and one bed. The author follows the recommendation of Ravn and others (1984) and does not recognize the Linn and Zarah subgroups in Iowa. The Kansas City Group is about 300 feet (90 m) thick in the type region of Kansas City, and thins to the north to about 100-150 feet (30-45 m) in Iowa (Heckel, 1999).

The 866.0-984.0 foot interval in the Riverton core and the 375.8-489.7 foot interval in the Bedford core are designated as reference sections. The 170.3-246.0 foot interval in the Malvern core is also designated a reference section, although the core bottom is in the Quivira Shale Member of the Dewey Formation.

Lane Shale

(revised; reclassified)
(new members recognized)

The Lane Shale was named by Haworth and Kirk (1894), and was defined by Moore (1936) for river bluff exposures in the S1/2 section 33, T. 18 S., R. 21 E., near the town of Lane, Franklin County, Kansas.

Haworth and Kirk (1894) also used the name Lane for what is now called the Liberty Memorial Shale, between the Iola and Wyandotte Formations, in the Kansas City area. Keyes (1889) used the name Lane shale (a member of the Parkville shale) for what is now called the Bonner Springs Shale. Thus the name was used for two shales, one above the Wyandotte and one below the Wyandotte. Adams (1904) used the name Concreto for the shale between the Iola and Allen (Plattsburg) limestones, in southeastern Kansas.

Watney and Heckel (1994) and Heckel and Watney (2002), revised the Lane Shale, since it has been determined that the type Lane Shale as recognized by Moore (1936) correlates with the Island Creek Shale Member between the Argentine and Farley Limestone Members, all previously included in the Wyandotte Formation. It also was determined that the Farley Limestone Member is lenticular (extending only from northeastern Anderson County, Kansas, to about the Missouri-Iowa border) within a much larger body of shale that extends along the entire outcrop belt. Therefore, it was 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 Formation as a dominantly limestone formation below (Heckel and Watney, 2002). Therefore, the Island Creek Shale Member and Farley Limestone Member were removed from the Wyandotte Formation and combined with the Bonner Springs Shale (which was reduced in rank to member) to constitute an expanded Lane Shale (Heckel and Watney, 2002). The author follows the recommendations of Heckel and Watney (2002) for their revision and reclassification of the Lane Shale.

The Lane Shale overlies the Wyandotte Limestone and underlies the Plattsburg Limestone. Where the Farley Limestone Member is not present, the Island Creek Shale cannot be distinguished from the overlying Bonner Springs Shale, and the entire shale unit is known as the Lane Shale (Heckel and Watney, 2002). In its revised form in Iowa, the formation comprises three members in ascending order: Island Creek Shale, Farley Limestone (where present), and Bonner Springs Shale. In the Malvern core the Lane Shale is over 20 feet (6.0 m) of mainly a red to brown blocky mudstone with gray shale at the base. The entire Lane Shale can be seen in Schildberg's Stanzel quarry in Madison County.

The 866.0-879.0 foot interval in the Riverton core and the 170.3-193.5 foot interval in the Malvern core are designated as reference sections, even though the Farley Limestone has not been recognized in these cores. The 375.8-402.0 foot interval in the Bedford core and the 184.0-217.0 foot interval in the R-46 core are also designated as reference section, because all three members are present. In the Omaha area of western Iowa and adjacent Nebraska, the Lane has long been considered to be represented by only the Bonner Springs Member, ranked as a formation (e.g., Burchett and Reed, 1967).

Bonner Springs Shale Member

(reduced in rank; reclassified)

The Bonner Springs Shale Member was named by Moore (1931, 1932), and was defined as a formation by Newell (1935) for exposures in the Lone Star Cement Plant quarry in the W ½ section 28, T. 11 S., R. 23 E., northeast of Bonner Springs, Wyandotte County, Kansas. According to Heckel and Watney (2002) the Bonner Springs Shale Member can only be differentiated from the lower Island Creek Shale Member, where the lenticular Farley Limestone is present in east-central Kansas. Therefore, Heckel and Watney (2002) reduced the Bonner Springs in rank to a member and included it in the revised Lane Shale. The Bonner Springs Shale Member overlies the Farley Limestone

Member (where present) and underlies the Merriam Limestone Member of the Plattsburg Limestone. See discussion of Lane Shale above. Witzke and McKay (Riverton core description, 1986) reported a thin coal near the top of the Bonner Springs in the Riverton core, and Thompson (1995) reported a thin coal in the unit in Missouri. The coal will not be named at this time.

The 375.8-394.9 foot interval in the Bedford core and the 184.0-209.0 foot interval in the R-46 core are designated as reference sections.

Farley Limestone Member
(reclassified)

The Farley Limestone Member was named by Hinds and Greene (1915) and Moore (1936) located the type section at exposures near the town of Farley just N of C section 34, T. 52 N., R. 35 W., Platte County, Missouri. The Farley was included in the Wyandotte Limestone by Moore (1932) and Newell (1935), but was placed in the revised Lane Shale by Watney and Heckel (1994) and Heckel and Watney (2002). The Farley Limestone Member overlies the Island Creek Shale Member and underlies the Bonner Springs Shale Member.

The 394.9-397.0 foot interval in the Bedford core, consisting of dark gray (N3) calcareous shale with common brachiopods (including productids) and echinoderms, is designated as a reference section. Preliminary evaluation of the R-46 core indicates the Farley Limestone is present at the 209.0-212.0 foot interval, as fossiliferous shale and thin limestones.

Island Creek Shale Member
(reclassified)

The Island Creek Shale Member was named by Moore (1932), and defined by Newell (1935) from exposures in a quarry near Island Creek in the NW corner section 11, T. 10 S., R. 23 E., Wyandotte County, Kansas. The Island Creek Shale was included in the Wyandotte Limestone by Moore (1932) and Newell (1935), but was placed in the revised Lane Shale by Watney and Heckel (1994) and Heckel and Watney (2002). The Island Creek Shale overlies the Argentine Limestone Member of the Wyandotte Limestone and underlies the Farley Limestone Member where present. See discussion of the Lane Shale and Bonner Springs Shale above. In the Bedford core the Island Creek Shale is mainly a dark gray (N3) calcareous shale.

The 397.0-402.0 foot interval in the Bedford core and the 212.0-217.0 foot interval in the R-46 core are designated as reference sections.

Wyandotte Limestone
(revised; restricted)

The Wyandotte Limestone was named by Moore (1932), and defined by Newell (1935) from exposures along the Kansas River in southern Wyandotte County, Kansas. Heckel and Watney (2002) designated the principal reference section for the Wyandotte Limestone and its currently recognized members along the southbound off ramp from I-435 to Holliday Road (NE NW section 6, T. 12 S., R. 24 E.) in Johnson County, Kansas. Because of miscorrelations, Moore (1932) originally placed the Wyandotte Limestone in the Lansing Group. The Wyandotte Limestone was revised by Watney and Heckel (1994), Heckel and others (1999) and Heckel and Watney (2002) to comprise only its former three lower members, in ascending order: Frisbie Limestone, Quindaro Shale, and Argentine Limestone. This is because the previously included Island Creek Shale Member and Farley Limestone Member, above the Argentine Limestone, are now known to correlate with the middle to lower part of the type and neostratotype Lane Shale. The Wyandotte Limestone overlies the Liberty Memorial Shale and underlies the Lane Shale.

The 879.0-889.7 foot interval in the Riverton core, the 402.0-405.0 foot interval in the Bedford core, and the 217.0-223.0 foot interval in the R-46 core are designated as reference sections.

Argentine Limestone Member
(unchanged)

The name Argentine limestone was first used by Moore (1931) in a correlation chart and was formally named by Moore (1932) as a unit in the Lansing Group, and later in 1932 it was revised to a unit of the Kansas City Group. Newell (1935) redefined it and located a type section at an exposure in a quarry south of the C of the N line section 29, T. 11 S., R. 25 E., (south of 26th Street and Metropolitan Avenue) near the Argentine Railway Station on the south side of Kansas City, Wyandotte County, Kansas. See Wyandotte Limestone above for a modern principal reference section. The Argentine Limestone Member overlies the Quindaro Shale Member and underlies the Island Creek Shale Member of the Lane Shale. In the R-46 core the Argentine Limestone is a light gray (N7) very calcareous shale to an argillaceous skeletal wackestone with brachiopods and crinoids. The Argentine is about two feet (0.6 m) of skeletal wackestone in Schildberg's Stanzel quarry in western Madison County.

The 402.0-403.0 foot interval in the Bedford core and the 217.0-221.5 foot interval in the R-46 core are designated as reference sections. In the Omaha area of western Iowa and adjacent Nebraska, the Argentine has long been misidentified as the Farley Limestone Member of the Wyandotte Formation (e.g., Burchett and Reed, 1967).

Quindaro Shale Member
(unchanged)

The Quindaro Shale Member was named by Moore (1932), as a unit in the Lansing Group, and defined by Newell (1935). Moore (1936) located typical exposures in Boyne's quarry in the NW corner section 30, T. 10 S., R. 25 E., northeast of Welborn, Quindaro Township, Wyandotte County, Kansas. See Wyandotte Limestone above for modern principal reference section. The Quindaro Shale Member overlies the Frisbie Limestone Member and underlies the Argentine Limestone Member. In the R-46 core (Ringgold County) and Schildberg's Stanzel quarry (Madison County), the Quindaro Shale is a thin, dark gray (N3) to black (N1) shale with abundant *Crurithyris* brachiopods and conodonts, overlain by a medium gray (N5) shale.

The 403.0-404.3 foot interval in the Bedford core and the 221.5-222.0 foot interval in the R-46 core are designated as reference sections.

Frisbie Limestone Member
(unchanged)

The Frisbie Limestone Member was named by Moore (1932), as a unit in the Lansing Group, and defined by Newell (1935). Moore (1936) located the type section at an exposure east of the old railroad station of Frisbie in the C of the N line section 17, T. 12 S., R. 23 E., north-central Johnson County, Kansas. See Wyandotte Limestone above for a modern principal reference section. The Frisbie Limestone Member overlies the Liberty Memorial Shale and underlies the Quindaro Shale Member. In the R-46 core (Ringgold County) the Frisbie Limestone is a thin, argillaceous skeletal wackestone. The Frisbie Limestone has not been observed in western Madison County.

The 404.3-405 foot interval in the Bedford core is designated as a reference section.

Liberty Memorial Shale
(new name in Iowa)

The Liberty Memorial Shale was named by Clair (1943) from exposures near the Liberty Memorial monument in Penn Valley Park in the SW section 8, T. 49 N., R. 33 W., Jackson County, Missouri. The name was dropped after Moore (1948) correlated this unit incorrectly with the Lane Shale. Heckel (1992), Heckel and Pope (1992), Watney and Heckel (1994) and Heckel and Watney (2002) reinstated the name as it was originally proposed by Clair (1943), to replace the 'Lane' Shale of Moore (1948) at Kansas City, which is below the Wyandotte, rather than above it. The Liberty Memorial Shale overlies the Iola Limestone and underlies the Wyandotte Limestone. At Schildberg's Stanzel quarry in western Madison County the upper part of the Liberty Memorial is a highly fossiliferous, medium gray (N5) shale, while the lower part is a medium light gray (N6) blocky mudstone. See Heckel and Pope (1992) for an extensive fossil list.

The 889.7-893.0 foot interval in the Riverton core, the 406.8-408.7 foot interval in the Bedford core, and the 223.0-231.0 foot interval in the R-46 core are designated as reference sections. In the Omaha area of western Iowa and adjacent Nebraska, the Liberty

Memorial has long been misidentified as the Island Creek Shale Member of the Wyandotte Formation (e.g., Burchett and Reed, 1967).

Iola Limestone
(unchanged)

The Iola Limestone was named by Haworth and Kirk (1894) from exposures in quarries near the town of Iola, Allen County, Kansas. Moore (1936) located the type section as the cement plant quarry in the NE section 2, T. 25 S., R. 18 E. The Iola Formation overlies the Chanute Shale and underlies the Liberty Memorial Shale. The formation comprises three members in ascending order: Paola Limestone, Muncie Creek Shale, and Raytown Limestone.

Reference sections for the Iola Limestone are designated in the 893.0-925.0 foot interval in the Riverton core, the 408.7-433.4 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of North River in the SE SW NE NW section 11, T. 76 N., R. 29 W., Madison County, about 300 feet (91 m) east of the Elmwood Avenue bridge.

Raytown Limestone Member
(unchanged)

The Raytown Limestone Member was named by Hinds and Greene (1915), and Moore (1936) located the type section at Raytown, Jackson County, Missouri, as exposures in a railroad cut just east of town in the SE SE NE section 5, T. 48 N., R. 32 W. Heckel and Watney (2002) designated a principal reference section in the NW NE NW section 6, T. 12 S., R. 24 E., Johnson County, Kansas. The Raytown Limestone Member overlies the Muncie Creek Shale Member and underlies the Liberty Memorial Shale. In western Madison County and northern Adair County the Raytown Limestone ranges from 22-27 feet (6.7-8.2 m) thick, and has been extensively quarried. The lower part is a thin-bedded, argillaceous, skeletal wackestone, while the middle part is a thicker-bedded skeletal wackestone with scattered chert nodules. A shale 1-3 feet (0.3-0.9 m) thick usually separates the upper part of the limestone from the middle part. The upper part consists of a massive bed of "*Osagia*" grainstone, overlain by argillaceous skeletal wackestone and lime mudstone.

Reference sections for the Raytown Limestone are designated in the 893.0-923.0 foot interval in the Riverton core, the 408.7-426.8 foot interval in the Bedford core, and at an exposure of the lower Raytown in a south-facing cutbank of North River in the SE SW NE NW section 11, T. 76 N., R. 29 W., Madison County, about 300 feet (91 m) east of the Elmwood Avenue bridge. In the Omaha area of western Iowa and adjacent Nebraska, the Raytown has long been misidentified as the Argentine Limestone Member of the Wyandotte Formation (e.g., Burchett and Reed, 1967).

Muncie Creek Shale Member
(unchanged)

The Muncie Creek Shale Member was named by Moore (1932), and was defined by Newell (1935). Moore (1936) located the type section at exposures along Muncie Creek, Wyandotte County, Kansas. Typical exposures were along the bluffs between Muncie and City Park. Heckel and others (1999) and Heckel and Watney (2002) designated a principal reference section along Kaw Drive in the NE SE SW section 12, T. 11 S., R. 24 E. The Muncie Creek Shale Member overlies the Paola Limestone Member and underlies the Raytown Limestone Member. In most of Iowa, the Muncie Creek Shale is black (N1), fissile, slightly phosphatic and conodont-rich in the lower part, and medium gray (N5) in the upper part.

Reference sections for the Muncie Creek Shale are designated in the 923.0-924.0 foot interval in the Riverton core, the 426.8-431.9 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of North River in the SE SW NE NW section 11, T. 76 N., R. 29 W., Madison County, about 300 feet (91 m) east of the Elmwood Avenue bridge. In the Omaha area of western Iowa and adjacent Nebraska, the Muncie Creek has long been misidentified as the Quindaro Shale Member of the Wyandotte Formation (e.g., Burchett and Reed, 1967).

Paola Limestone Member
(unchanged)

The Paola Limestone Member was named by Moore (1932), and was defined by Newell (1935) for exposures on the north edge of the town of Paola, Miami County, Kansas. Heckel and others (1999) and Heckel and Watney (2002) designated a principal reference section in a roadcut southeast of Paola in the NE NW NW section 22, T. 17 S., R. 23 E., Miami County, Kansas. The Paola Limestone Member overlies the Chanute Shale and underlies the Muncie Creek Shale Member. The Paola Limestone is often a single bed of dense, skeletal wackestone.

Reference sections for the Paola Limestone are designated in the 924.0-925.0 foot interval in the Riverton core, the 431.9-433.4 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of North River in the SE SW NE NW section 11, T. 76 N., R. 29 W., Madison County, about 300 feet (91 m) east of the Elmwood Avenue bridge. In the Omaha area of western Iowa and adjacent Nebraska, the Paola has long been misidentified as the Frisbie Limestone Member of the Wyandotte Formation (e.g., Burchett and Reed, 1967).

Chanute Shale
(unchanged)

The Chanute Shale was named by Haworth and Kirk (1894) from exposures near the town of Chanute, Neosho County, Kansas. The Chanute Shale originally included units between the Dennis (upper Erie limestone) and Iola formations. The Chanute Shale was stabilized by Moore (1936), and applied to strata between the Drum Limestone and the Iola Limestone. Moore (1936) located a typical exposure in the SE section 33, T. 26 S., R. 18 E., but it is actually located in the C of the S line SE SE section 34, T. 26 S., R. 18 E. (Heckel and Watney, 2002). The Chanute Shale overlies the Dewey Limestone and underlies the Iola Limestone. The Thayer Coal bed occurs in the Chanute Shale in Kansas and Missouri, but no coal is known to occur in Iowa. At the Iola reference section in Madison County, the Chanute Shale is mainly a light gray (N7) blocky mudstone, with a nodular limestone (interpreted as a caliche horizon) occurring near the top.

Reference sections for the Chanute Shale are designated in the 925.0-936.0 foot interval in the Riverton core, the 433.4-444.5 foot interval in the Bedford core, and in the upper 5 feet (1.5 m) of the Chanute Shale at a south-facing cutbank of North River in the SE SW NE NW section 11, T. 76 N., R. 29 W., Madison County, about 300 feet (91 m) east of the Elmwood Avenue bridge. In the Omaha area of western Iowa and adjacent Nebraska, the Chanute has long been misidentified as the Lane Shale (e.g., Burchett and Reed, 1967).

Dewey Limestone
(new name in Iowa)

The Dewey Limestone was named by Ohern (1910) from exposures near the town of Dewey in the old quarry of the Dewey Portland Cement Company, in section 26, T. 27 N., R. 13 E., Washington County, Oklahoma.

Historically (from 1947 to 2000) the Dewey and Corbin City limestones had been considered members of the Drum Formation in southeast Kansas. In the Kansas City area the Cement City Limestone was correlated with the Drum and the Quivira Shale was designated the uppermost member of the Cherryvale Shale, overlying the Westerville Limestone Member (for further discussion, see Heckel and Watney, 2002). When the miscorrelation was rectified by the discovery of the Cement City Limestone Member and underlying Quivira Shale Member above the Drum Limestone in its type area in southeast Kansas, the problem arose of how to classify what was called Drum in the Kansas City area. The problem was later resolved by the discovery of the Quivira Shale at the base of the type Dewey Limestone, considered a formation in Oklahoma. The Quivira Shale was removed from the Cherryvale Shale and included as a member of the Dewey Limestone, below the Cement City Limestone Member (Heckel and Watney, 2002). The Westerville Limestone (now at the top of the Cherryvale Shale) of the Kansas City area and northward, is now correlated with the Drum Limestone of southeastern Kansas (Heckel, 1992; Heckel and Watney, 2002). The Dewey Limestone overlies the Nellie Bly Shale and underlies the Chanute Shale. In Iowa, the formation comprises three members in ascending order: Pammel Park Limestone, Quivira Shale, and Cement City Limestone.

Reference sections are designated in the 936.0-948.5 foot interval in the Riverton core, the 444.5-453.9 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Dewey has long been misidentified as the Iola Formation (e.g., Burchett and Reed, 1967).

Cement City Limestone Member (reclassified)

The Cement City Limestone Member was named by Hinds and Greene (1915) for Cement City, Jackson County, Missouri. Moore (1936) located the type section at the Lafarge Corporation quarry (formerly the quarry of the Missouri Portland Cement Company Sugar Creek plant) in the SE section 14, SW SW section 13 and NE section 23, T. 50 N., R. 32 W. Heckel and Watney (2002) established the principal reference section for the Dewey Limestone along the westbound exit ramp from I-70 to Park Drive/Kaw Drive (E half of NE NE section 18, T. 11 S., R. 25 E., Wyandotte County, Kansas. The Cement City Limestone (along with the Corbin City Limestone) was previously classified as a member of the Drum Formation (Ravn et al., 1984), but is now recognized as the upper member of the Dewey Formation, since the miscorrelation of both units with the Drum Limestone, have been rectified (Heckel, 1992; Heckel and Watney, 2002). The Cement City Limestone Member overlies the Quivira Shale Member and underlies the Chanute Shale. The Cement City correlates with the limestone in the Flat Creek Cyclothem of Illinois (Pope, 1999). In southwest and south-central Iowa, the Cement City Limestone is mainly a skeletal wackestone with shaly beds, overlain by an "*Osagia*" grainstone.

Reference sections are designated in the 936.0-945.0 foot interval in the Riverton core, the 444.5-450.0 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Cement City has long been misidentified as the Raytown Limestone Member of the Iola Formation (e.g., Burchett and Reed, 1967).

Quivira Shale Member (revised; reclassified)

The Quivira Shale Member was named by Moore (1931, 1932), and was defined by Newell (1935). Moore (1936) located the type section at exposures near Quivira Lake, east of Holiday, in section 32, T. 11 S., R. 24 E., Johnson County, Kansas. In Kansas, Heckel (1992), Watney and Heckel (1994) and Heckel and Watney (2002), reclassified the Quivira as the lower member of the Dewey Formation. Heckel and Watney (2002) also recognized the Nellie Bly Shale, as a separate formation, between the Westerville Limestone and the Quivira Shale. In Iowa, the Quivira Shale Member overlies the Pammel Park Limestone Member, or the Nellie Bly Shale where the Pammel Park Limestone is absent, and underlies the Cement City Limestone Member. If the Pammel Park Limestone Member is absent, the base of the Quivira Shale is placed at the top of the Harmon Tunnel Coal bed. If the Pammel Park Limestone and Harmon Tunnel Coal are both absent, the bottom of the dark gray (N3) or black (N1) shale facies of the Quivira Shale, or the top of the paleosol in the Nellie Bly Shale, is considered the base of the Quivira Shale. In southwest and south-central Iowa, the Quivira Shale is usually black (N1), phosphatic, fissile and conodont-rich in the lower part, and medium gray (N5) in the upper part.

Reference sections are designated in the 945.0-948.5 foot interval in the Riverton core, the 450.0-453.9 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Quivira has long been denoted only as a black shale bed in the misidentified

Chanute Formation (e.g., Burchett and Reed, 1967).

Pammel Park Limestone Member
(new name in Iowa)

The Pammel Park Limestone was named by Heckel and Pope (1992) from exposures in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County, Iowa. Pammel Park was named after Louis Pammel, botany professor at Iowa State College (now Iowa State University), Ames. The limestone also occurs in several outcrops and cores in Iowa and Missouri and rarely as a lenticular limestone at outcrops in Kansas. In Iowa, the Pammel Park Limestone Member, where present, overlies the Nellie Bly Shale and underlies the Quivira Shale Member. At the Middle River section west of Pammel Park, the Pammel Park Limestone is a medium light gray (N6) skeletal wackestone. It varies from 3-12 inches (7.5-30 cm) thick in Madison County.

A reference section is designated at an exposure in a west-facing cutbank of Tom Creek, about 3.5 miles (5.6 km) south of Earlham, in the SW NW SW section 30, T. 77 N., R. 28 W., Madison County, Iowa.

Nellie Bly Shale
(new name in Iowa)

The name Nellie Bly was applied by Gould (1925), from an unpublished 1914 manuscript by Ohern, to shale and sandstone above the Hogshooter (Dennis) Formation and below the Dewey Formation. Oakes (1940) designated the type area for exposures along Nellie Bly Creek in sections 28, 29, 31, 32, T. 24 N., R 13 E., southwest of Ramona, Washington County, Oklahoma. Heckel and Watney (2002) recognized the Nellie Bly Shale as a separate formation, between the Westerville Limestone (to the north)/Drum Limestone (to the south) below, and the Quivira Shale above, in Kansas. The Nellie Bly Shale overlies the Cherryvale Formation and underlies the Dewey Limestone. In Iowa, where the Pammel Park Limestone Member is absent, the top of the Nellie Bly Shale is at the top of the Harmon Tunnel Coal bed, or its horizon (top of paleosol), at the base of the dark gray (N3) or black (N1) shale facies of the Quivira Shale Member of the Dewey Formation. At the Middle River section west of Pammel Park (see below), the Nellie Bly Shale is greenish gray (5GY 6/1) mudstone in the lower part, dark reddish brown (10R 3/4) mottled in the middle part, and greenish gray (5GY 6/1) mudstone below the Harmon Tunnel Coal in the upper part.

Reference sections are designated in the 948.5-950.8 foot interval in the Riverton core, the 453.9-458.0 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Nellie Bly has long been misidentified as the Chanute Formation (e.g., Burchett and Reed, 1967).

Harmon Tunnel Coal bed
(newly named this report)

The Harmon Tunnel Coal bed is named in this report at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County (type Pammel Park Limestone). Here it is about two inches (5 cm) thick and overlies a thick, blocky, light gray (N7) to greenish gray (5GY 6/1) moderate red-mottled (5R 4/6) mudstone. The name is derived from the Harmon Tunnel, the only highway tunnel in the state of Iowa, located in Pammel Park. The tunnel was originally dug through the Hushpuckney and upper Elm Branch shales in 1858 by William Harmon to supply water to a saw mill and later a grist mill. A coal has also been reported near the top of the Nellie Bly Shale in the Kansas City area (Gentile and Thompson, 2004). The Harmon Tunnel Coal has been observed in the Riverton core, the Bedford core, and the R-46 core.

A reference section is designated at an exposure in a west-facing cutbank of Tom Creek, about 3.5 miles (5.6 km) south of Earlham, in the SW NW SW section 30, T. 77 N., R. 28 W., Madison County, Iowa.

Cherryvale Formation
(revised; restricted)

The Cherryvale Formation was named by Haworth (1898) from exposures in the bluffs around Cherryvale, Kansas. Moore (1948, 1949) stabilized the subdivisions and usage of the name. Heckel and Watney (2002) located the type section two miles (3 km) north of the town of Cherryvale. It includes strata found in the hillside and road ditch down to the top of the Winterset Limestone in the bed of Cherry Creek, just south of the road intersection along the E line of the SE SE SE section 32, T. 31 S., R. 17 E., Montgomery County, Kansas.

The formation comprises four members in ascending order: Fontana Shale, Block Limestone, Wea Shale, and Westerville Limestone. Prior to Watney and others (1989) the Cherryvale contained the following members in ascending order: Fontana Shale, Block Limestone, Wea Shale, Westerville Limestone, and Quivira Shale. Watney and others (1989), Heckel and others (1999) and Heckel and Watney (2002) removed the Quivira Shale from the Cherryvale and placed it in the overlying Dewey Formation. Heckel and Watney (2002) also recognized the Nellie Bly Shale, as a separate formation, between the Westerville Limestone and the Quivira Shale, in Kansas. The Cherryvale Formation overlies the Dennis Limestone and underlies the Nellie Bly Shale.

Reference sections are designated in the 950.8-984.7 foot interval in the Riverton core, the 458.0-489.6 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County.

Westerville Limestone Member
(unchanged)

Broadhead (1868) used the term Kansas City oolite, for an oolitic limestone in Miami and Franklin counties in Kansas, and the Kansas City area (which is now called Westerville Limestone at Kansas City). The Westerville Limestone Member was named by Bain (1898) for exposures on Sand Creek near the town of Westerville, Decatur County, Iowa. It is unclear, but it is assumed Bain was describing outcrops in T. 70 N., R. 27 W. The Westerville was grouped by Moore (1948) within the Cherryvale Formation below the Cement City and Dewey members of the “Drum Limestone”, a name that had been miscorrelated into the Kansas City area from southeastern Kansas. Heckel and Watney (2002) correlated the Westerville (of northeast Kansas, Missouri, and Iowa) with the Drum Limestone of southeast Kansas (named by Adams, 1903 from exposures along Drum Creek, east of Independence, in Montgomery County), even though the unit is not known between southern Johnson and southern Neosho counties in Kansas.

The DeKalb Limestone was named by Bain (1898) for exposures near DeKalb, Decatur County, Iowa to replace the name Fusulina limestone (Westerville Limestone of today). Dunbar and Condra (1932) used the name DeKalb, but Miller, Dunbar and Condra (1932) dropped the name DeKalb in favor of Westerville. Condra (1933) thought the DeKalb was the equivalent of the Winterset Limestone, because Bain (1898) placed the Westerville ‘some little distance above the DeKalb limestone.’ It is interesting to note that Condra and Upp (1933b) correctly correlated the “Drum” Limestone at Kansas City with the Westerville Limestone of Iowa, by tracing the so-called “Drum” Limestone at Kansas City to Winterset, in Madison County, Iowa, and they also correlated it with the type Westerville, in Decatur County, Iowa. The Westerville Limestone Member overlies the Wea Shale Member and underlies the Nellie Bly Shale. At the Middle River section west of Pammel Park the Westerville Limestone is an “*Osagia*” packstone to grainstone with cephalopods, brachiopods, gastropods and clams.

Reference sections are designated in the 950.8-965.0 foot interval in the Riverton core, the 458.0-467.0 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Westerville has long been termed the Corbin City—Cement City Members of the Drum Formation (e.g., Burchett and Reed, 1967).

Wea Shale Member
(unchanged)

The Wea Shale Member was named by Moore (1932), and was defined by Newell (1935). Moore (1936) located the type section at exposures near Wea Creek in the C east side section 12, T. 18 S., R. 22 E., Miami County, Kansas. The Wea Shale was stabilized by Moore (1948, 1949b) to apply to the shale between the Block and Westerville limestones. The Wea Shale Member overlies the Block Limestone Member and underlies the Westerville Limestone Member. The Wea Shale is very fossiliferous and in Madison County, Decatur County, and Schildberg's Thayer Quarry (Union County) there are several thin argillaceous limestones within the Wea Shale. See Heckel and Pope (1992) for an extensive fossil list.

Reference sections are designated in the 965.0-974.0 foot interval in the Riverton core, the 467.0-483.0 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Wea has long been termed the Richfield Shale Member of the Drum Formation (e.g., Burchett and Reed, 1967).

Block Limestone Member
(unchanged)

The Block Limestone Member was named by Moore (1932), was defined by Newell (1935), and Moore (1936, 1948) located the type section at exposures in roadcuts near the town of Block in the C of the S line section 6, T. 18 S., R. 24 E., and near the C of the W line section 18, T. 19 S., R. 23 E., Miami County, Kansas. The Block Limestone Member overlies the Fontana Shale Member and underlies the Wea Shale Member. In Madison County at the Middle River section west of Pammel Park, the Block Limestone consists of two layers of skeletal wackestone, with the upper bed locally a *Linoproductus* or *Derbyia* packstone.

Reference sections are designated in the 974.0-978.0 foot interval in the Riverton core, the 483.0-486.4 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Block has long been termed the P.W.A. Limestone Member of the Drum Formation (e.g., Burchett and Reed, 1967).

Fontana Shale Member
(unchanged)

The Fontana Shale Member was named by Moore (1932), and was defined by Newell (1935). Moore (1936) located the type section at exposures near the town of Fontana in the NE corner of section 11, T. 18 S., R. 23 E., and near the middle of the west side of the NW section 36, T. 18 S., R. 23 E., Miami County, Kansas. A thin coal occurs above a blocky mudstone, near the top of the Fontana Shale around Kansas City (Howe, 1986; Thompson, 1995, 2001; Heckel et al., 1999), but has not been observed in Iowa. The Fontana Shale Member overlies the Winterset Limestone Member of the Dennis Limestone and underlies the Block Limestone Member. In Decatur County the lower Fontana Shale is about four feet (1.2 m) of medium-gray (N5) blocky mudstone overlain by seven feet (2.1 m) of light gray (N7) shale. In Schildberg's Thayer quarry (Union County) the Fontana is about three feet (0.9 m) of light gray (N7) to greenish gray (5G 6/1) blocky mudstone with calcareous nodules (probably related to the underlying Winterset Limestone) in the lower part.

Reference sections are designated in the 978.0-984.7 foot interval in the Riverton core, the 486.4-489.6 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Fontana has long been misidentified as the Quivira Shale (e.g., Burchett and Reed, 1967).

BRONSON GROUP
(new members and beds recognized)

The name Bronson was originally used by Adams (1904) and comprised five units in ascending order: Hertha Limestone, Galesburg Shale, Dennis Limestone, Cherryvale Shale, and Drum Limestone. This was essentially the old 'Triple system' (Hertha, Bethany, and Winterset limestones) of Haworth (1895a). Moore (1932) revised the Bronson to include strata from the Critzer Limestone to the Dennis Limestone. Later, Moore (1948) redefined the Bronson as comprising the: Hertha Limestone, Ladore (Elm Branch) Shale, Swope Limestone, Galesburg Shale, and Dennis Limestone. Heckel and Pope (1992), Heckel and others (1999) and Heckel and Watney (2002) recognized that due to earlier miscorrelations, the true Ladore Shale overlies the Bethany Falls Member of the Swope Formation and underlies the Mound Valley Limestone in southern Kansas. They renamed the shale above the Hertha Limestone and below the Swope Limestone, the Elm Branch Shale (see Heckel and Watney, 2002, Fig. 2, p. 6.). In Kansas, the lower boundary of the Bronson Subgroup of the Kansas City Group is at the base of the Hertha Limestone.

Ravn and others (1984) in Iowa, reduced the Kansas City Group to its original definition as used by Moore (1936) and resurrected the Bronson Group (Figure 6) as the lowermost division of the Missourian, also reducing the Pleasanton to formational rank within the Bronson. The author follows the recommendation of Ravn and others (1984) to raise the Bronson to group rank and include in it the following formations in ascending order: Pleasanton, Hertha, Elm Branch, Swope, Galesburg, and Dennis, because it is dominated by thick limestone units, unlike the Kansas City Group. In Iowa, this places the lower boundary of the Bronson Group at the base of the Pleasanton Formation. As now defined in Iowa, the Bronson Group contains six formations, twelve members and three beds. The type locality of the Bronson Subgroup (Group of Iowa) is in the vicinity of Bronson, Bourbon County, Kansas. The Bronson Group is about 100-130 feet (30-40 m) thick in southwest Iowa (Witzke et al., 2003a).

The 984.7-1084.0 foot interval in the Riverton core is designated as a reference section. The 489.6-585.5 foot interval in the Bedford core is also designated as a reference section, although the base of the Exline Limestone was not reached. The interval from the top of the Winterset Limestone to the base of the Exline Limestone is presently exposed in Schildberg's Crescent quarry, in the SE NW SW Section 26, T. 76 N., R. 44 W., Pottawattamie County.

Dennis Limestone

(unchanged)

The Dennis Limestone was named by Adams (1903), and defined by Jewett (1932). Moore (1936) described typical exposures near the town of Dennis in the northwest corner of section 14, T. 31 S., R. 18 E., Labette County, Kansas. The formation overlies the Galesburg Shale and underlies the Cherryvale Formation. The formation comprises three members, the Canville Limestone, Stark Shale, and Winterset Limestone, in ascending order.

Reference sections are designated in the 984.7-1005.0 foot interval in the Riverton core, the 489.6-513.8 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Dennis has long been termed the Sarpy Formation (e.g., Burchett and Reed, 1967).

Winterset Limestone Member

(unchanged)

The Winterset Limestone Member was named by Tilton and Bain (1897) from "Number 18, which has been quarried at the edge of town [Winterset, Iowa], the quarries being west of and above the lime kiln quarry, represents the Winterset." Moore (1936) and Baars and Maples (1998) located the type locality of the Winterset Limestone in the vicinity of Winterset, Madison County, Iowa in section 22, T. 75 N., R. 28 W. Thompson and others (1956) described the type section as "Winterset Limestone…in old quarry on south edge of Winterset, Madison County, Iowa in the W 1/2 section 6, T. 75 N., R. 37 [27] W." The Winterset Limestone Member overlies the Stark Shale Member and underlies the

Fontana Shale Member of the Cherryvale Formation.

Felton and Heckel (1996) described several cycles of deposition within the Winterset Limestone that they termed 'phased regressions,' and related them to glacio-eustatic sea level changes. The fusulinids in the Winterset Limestone (Thompson, 1957) are the lowest occurrence of triticitids in the Midcontinent. The Winterset Limestone is extensively quarried at the Crescent, Thayer, Osceola, Earlham, Winterset, Decatur County, and Jefferson (north of Greenfield) quarries. The Winterset Limestone correlates with the Carthage (Shoal Creek) Limestone of the Illinois Basin (Pope, 1999). In south-central Iowa the Winterset Limestone is from 16-22 feet (4.9-6.7 m) thick. At the Martin-Marietta Winterset quarry it is a skeletal wackestone in the lower part, an "*Osagia*" grainstone in the upper middle part, and a barren, laminated lime mudstone with shale-filled tubes in the upper part.

Reference sections are designated in the 984.8-1000.0 foot interval in the Riverton core, the 489.6-511.8 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Winterset has long been misidentified as the Westerville Limestone Member of the Sarpy Formation (e.g., Burchett and Reed, 1967).

Stark Shale Member
(unchanged)

The Stark Shale Member was named by Jewett (1932), and typical exposures were described by Moore (1936) near the town of Stark, Neosho County, Kansas. Heckel and Watney (2002) designated a principal reference section in a roadcut on US Route 59, along the S line SW SE SW section 13, T. 27 S., R. 20 E., Neosho County, Kansas. Hinds and Greene (1915), Moore and Haynes (1917), McCourt (1917), Moore (1920), and Condra (1927) included the horizon now called Stark shale, and the underlying Canville limestone, in the upper part of the Galesburg shale member of the Kansas City formation. The Stark Shale Member overlies the Canville Limestone Member, or the Galesburg Shale where the Canville is not present, and underlies the Winterset Limestone Member. The Stark Shale is black (N1), fissile, phosphatic and conodont-rich in the lower part, and medium gray (N5) in the upper part. In the upper three inches (7.6 cm) of the Stark Shale where it transitions into the Winterset Limestone, at the Martin-Marietta Winterset quarry, there is an abundant and diverse open marine fauna. See Heckel and Pope (1992) for an extensive faunal list. Case (1982) reported a complete platysomoid chondrostean fish in the Stark Shale, from a quarry 3.5 miles (5.6 km) north of Winterset, Madison County.

Reference sections are designated in the 1000.0-1005.0 foot interval in the Riverton core, the 511.8-513.7 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Stark has long been misidentified as the Wea Shale Member of the Sarpy Formation (e.g., Burchett and Reed, 1967).

Canville Limestone Member
(unchanged)

The Canville Limestone Member was named by Jewett (1932) from exposures along Canville Creek, and Moore (1936) described typical exposures about three miles (4.8 km) west of Stark in roadcuts in the NE corner of section 26, T. 27 S., R. 20 E., and in the SE section 20, T. 27 S., R. 19 E., Neosho County, Kansas. Heckel and Watney (2002) located a principal reference section along US Route 59, (S line SW SE SW section 13, T. 27 S., R. 20 E.) west of Stark, Kansas. The Canville Limestone Member overlies the Galesburg Shale and underlies the Stark Shale Member. The Canville typically consists of less than one foot (30 cm) of medium-gray (N5) to dark-gray (N3) skeletal wackestone. In the south-central part of Iowa it is lenticular with lenses ranging from a few inches (cm) across in Madison County, to over 40 feet (12 m) across, in Adair County.

A reference section is designated at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. Only a few small lenses of the Canville occur at this location. In the Omaha area of western Iowa and adjacent Nebraska, the Canville has long been misidentified as the Block Limestone Member of the Sarpy Formation (e.g., Burchett and Reed, 1967).

Galesburg Shale
(new bed recognized)

The Galesburg shale was originally named by Adams (1903), and Moore (1936) described a type section south of the town of Galesburg in section 5, T. 30 S., R. 19 E., Neosho County, Kansas. In Iowa, the Galesburg Shale overlies the Swope Limestone and underlies the Dennis Limestone. In southern Kansas, the Ladore Shale overlies the Swope Limestone and underlies the Mound Valley Limestone, which is overlain by Galesburg Shale. To the north of southern Kansas, where the Mound Valley Limestone is absent, the entire shale unit is known as the Galesburg Shale. In Iowa, where the Canville Limestone Member of the Dennis Limestone is not present, the top of the Galesburg Shale is at the top of the Davis City Coal bed, or its horizon, at the base of the dark gray (N3) or black (N1) fissile shale facies of the Stark Shale Member of the Dennis Formation. In Iowa, the Galesburg Shale contains a single recognized bed, the Davis City Coal, at or near its top. The Galesburg is usually 6-10 feet (1.8-3 m) of light gray (N7) to greenish gray (5G 6/1) blocky mudstone with irregularly shaped carbonate concretions in the basal part, that seem to be related to the underlying Bethany Falls Limestone (see Joeckel, 1999).

Reference sections are designated in the 1005.0-1011.8 foot interval in the Riverton core, the 513.7-521.0 foot interval in the Bedford core, and at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Galesburg has long been misidentified as the Fontana Formation (e.g., Burchett and Reed, 1967).

Davis City Coal bed
(new name in Iowa)

The Davis City Coal bed was named by Schutter and Heckel (1985) from exposures in a quarry two miles (3.2 km) west of Davis City in SE NE section 4, T. 67 N., R. 26 W., Decatur County, Iowa. The type section is no longer exposed. There is often an ostracode-rich zone associated with the coal. In Madison and Clarke counties the Davis City Coal varies in thickness from a smut to 1.5 inches (3.81 cm). In the Thayer Quarry (Union County) a zone of compressed *Calamites* with spirorbid worm tubes, inarticulate brachiopods, and pectin-like clams, up to two feet (60 cm) thick, occurs just above the coal.

A reference section is designated at an exposure in a southwest-facing roadcut along County Road P-71 at the south edge of Winterset, in the NW SW NW section 6, T. 75 N., R. 27 W., Madison County.

Swope Limestone
(unchanged)

The name Swope was originally used by Jewett (1932) and Moore (1932), and was defined as it is presently used by Newell (1935) from exposures in Swope Park in Kansas City, Missouri. The Swope Limestone overlies the Elm Branch Shale and underlies the Galesburg Shale. In Iowa, the formation comprises three members in ascending order: Middle Creek Limestone, Hushpuckney Shale and Bethany Falls Limestone.

Reference sections are designated in the 1011.8-1040.0 foot interval in the Riverton core, the 521.0-549.9 foot interval in the Bedford core, and at an exposure in a southwest-facing roadcut along County Road P-71 at the south edge of Winterset, in the NW SW NW section 6, T. 75 N., R. 27 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Swope has long been misidentified as the Dennis Formation (e.g., Burchett and Reed, 1967).

Bethany Falls Limestone Member

(unchanged)

Keyes (1896) called the Bethany Falls limestone 'the great limestone at Winterset', with Bain (1896) and local quarrymen calling it the 'Earlham limestone' for exposures in quarries east, south and southeast of the town of Earlham, Madison County, Iowa. Bain's (1896) name Earlham was dropped (see Tilton, 1913) because the name Bethany Falls Limestone (simply called Bethany Limestone by some early workers) had already been originally used by Broadhead (1862). Early workers (e.g., Keyes, 1896) included what is now basically the Bronson Subgroup (of Kansas and Missouri nomenclature) in the Bethany limestone. In Kansas this included in ascending order, the Bethany Falls (once correlated with the Hertha, by Haworth, 1898), the Mound Valley, and the Dennis limestones. In Iowa, this interval included the Fragmental, Earlham and Winterset limestones. Bain (1898) in Iowa, made a similar mistake as Haworth, correlating the Fragmental (Hertha) limestone with the Bethany Falls. Tilton (1913) was able to show the Fragmental limestone was the Hertha, instead of the Bethany Falls. Newell (1935) redefined the Bethany Falls as the upper member of the Swope Limestone as it is used today. A type section was later described by Moore (1936) at the Falls on Big Creek at Bethany, Harrison County, Missouri. The type section is located in the SW SW NE SE section 9, T. 63 N., R. 28 W., at the west edge of Bethany (Gentile and Thompson, 2004).

The Bethany Falls Limestone Member overlies the Hushpuckney Shale Member and underlies the Galesburg Shale. The Bethany Falls Limestone Member is about 22 feet (6.7 m) thick in Madison County, and is quarried at Schildberg's Thayer quarry (Union County), the Logan quarry (Harrison County), the Crescent quarry (Pottawattamie County), the Jefferson quarry (Adair County), the Decatur City quarry (Decatur County) and the Atlantic quarry (Cass County). Pope (1993, 1994, 1995) traced minor cycles in the Bethany Falls Limestone from Winterset, Iowa to Kansas City, Missouri. Fusulinids in the Bethany Falls Limestone (Thompson, 1957) are *Eowaeringella ultimata*, which are not found above the Swope Limestone in the Midcontinent (Heckel and Pope, 1992). At the Martin-Marietta Winterset quarry it is a skeletal wackestone in the lower part, an "*Osagia*" grainstone in the upper middle part, and a barren, laminated lime mudstone with shale-filled tubes in the upper part. An unusual brachiopod (*Isogramma*), an undescribed bryozoan, an undescribed rugose coral and an ophiuroid have been found in the Bethany Falls Limestone at Winterset (J.P. Pope, unpublished field notes). See Heckel and Pope (1992) for an extensive faunal list.

Reference sections are designated in the 1011.8-1036.2 foot interval in the Riverton core, the 521.0-545.3 foot interval in the Bedford core, and at an exposure in a southwest-facing roadcut along County Road P-71 at the south edge of Winterset, in the NW SW NW section 6, T. 75 N., R. 27 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Bethany Falls has long been misidentified as the Winterset Limestone Member of the Dennis Formation (e.g., Burchett and Reed, 1967).

Hushpuckney Shale Member
(unchanged)

The name Hushpuckney Shale Member was originally used by Newell (unpublished manuscript), was formally named by Jewett (1932), and was defined by Newell (1935), who established the type section on Hushpuckney Creek, [about two miles (3.2 km)] southwest of Fontana, Miami County, Kansas. Heckel and Watney (2002) designated the principal reference section in the roadcut along the west line SW NE section 27, T. 19 N., R. 23 E., Linn County, Kansas. The Hushpuckney Shale Member overlies the Middle Creek Limestone Member and underlies the Bethany Falls Limestone Member. The Hushpuckney Shale normally consists of three to four feet (0.9-1.2 m) of dark gray (N3) to black (N1) fissile shale in its lower part and medium gray (N5) shale in its upper part in most of south-central and southwest Iowa.

Reference sections are designated in the 1036.2-1039.8 foot interval in the Riverton core, the 545.3-548.8 foot interval in the Bedford core, and at an exposure in a southwest-facing roadcut along County Road P-71 at the south edge of Winterset, in the NW SW NW section 6, T. 75 N., R. 27 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Hushpuckney has long been misidentified as the Stark Shale Member of the Dennis Formation (e.g., Burchett and Reed, 1967).

Middle Creek Limestone Member
(unchanged)

The name Middle Creek Limestone was originally used by Newell in Jewett (1932), and defined by Newell (1935). Moore (1936) located the type section at exposures on Middle Creek, Linn County, Kansas. Heckel and Watney (2002) located the type section at exposures east of Middle Creek, three miles (4.8 km) east of La Cygne, west of the SE corner of section 36, T. 19 S., R. 24 E., Linn County, Kansas. The Middle Creek Limestone Member overlies the Elm Branch Shale and underlies the Hushpuckney Shale Member. In Madison County it usually consists of a single bed of skeletal wackestone 3-6 inches (7.5-15 cm) thick, but may be two thin limestone beds separated by a shale parting.

Reference sections are designated in the 1039.8-1040.0 foot interval in the Riverton core, the 548.8-549.9 foot interval in the Bedford core, and at an exposure in a southwest-facing roadcut along County Road P-71 at the south edge of Winterset, in the NW SW NW section 6, T. 75 N., R. 27 W., Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Middle Creek has long been misidentified as the Canville Limestone Member of the Dennis Formation (e.g., Burchett and Reed, 1967).

Elm Branch Shale
(new name in Iowa)

The name Elm Branch Shale was originally planned to be proposed by Newell (*in* Moore, 1932), but was never formally adopted because it was miscorrelated with the Ladore Shale, resulting from the miscorrelation of the overlying Bethany Falls Limestone with the Mound Valley Limestone in southern Kansas. Since then, the miscorrelations have been corrected, so Heckel (1992), Heckel and Pope (1992), Watney and Heckel (1994) and Heckel and Watney (2002) revived the unused name for the shale between the Swope and Hertha formations. The name Ladore is now restricted to the shale between the top of the Swope Limestone and the base of the Mound Valley Limestone in southern Kansas (Heckel and Watney, 2002, Fig. 2, p. 6.). Newell's (1935) original measured section was from Elm Branch, a creek that empties into the Marais des Cygnes River four miles (6.4 km) north of Fontana, Miami County, Kansas. Heckel and Watney (2002) selected a more complete and readily accessible stratotype in a roadcut one mile (1.6 km) southwest of Fontana (E line SE SE NW section 10, T. 19 S., R. 23 E.), Miami County, Kansas.

A thin coal was reported near the top of the Elm Branch Shale by Watney and others (1989) at Kansas City, Missouri, but the coal has not been recognized in Iowa. The Elm Branch is about one foot (30 cm) of gray shale and mudstone in the Crescent Quarry (Pottawattamie County) and about 26 feet (8 m) thick east of Peru (Madison County). The Elm Branch Shale overlies the Hertha Limestone and underlies the Swope Limestone. At the roadcut east of Peru, the Elm Branch Shale is argillaceous sandstone in the lower part, silty light gray (N7) shale in the middle part, and light gray (N7) shale in the upper part.

The 1040.0-1046.5 foot interval in the Riverton core, the 549.8-556.5 foot interval in the Bedford core, and an exposure in west-facing roadcut backslope along County Highway G-68 about one mile (1.6 km) east of East Peru, along the W line of the W ½ E ½ NW section 12, T. 74 N., R. 27 W., Madison County, are designated as reference sections. In the Omaha area of western Iowa and adjacent Nebraska, the Elm Branch has long been misidentified as the Galesburg Formation (e.g., Burchett and Reed, 1967).

Hertha Limestone
(new member and facies recognized)

The Hertha Limestone was named by Adams (1903) from exposures around the former town of Hertha, once situated at the C of the S line, section 29, T. 29 S., R. 20 E., Neosho County, Kansas. Because of miscorrelations, explained in Heckel and Watney (2002), a neostratotype was established in cutbanks along a tributary to Bachelor Creek in the SE NW NE section 32, T. 29 S., R. 20 E., Neosho County, Kansas, just southeast of the original type section.

In Iowa, the Hertha Limestone overlies the Shale Hill Member of the Pleasanton Formation (Pleasanton Group of Kansas and Missouri) and underlies the Elm Branch Shale. In Iowa, it comprises three members, in ascending order: East Peru Limestone, Mound City Shale, and Sniabar Limestone. In their original definition of the 'Fragmental Limestone,' Tilton and Bain (1897) included the limestones now called the Cooper Creek, Exline, and Hertha (in ascending order), in the Hertha. The basal member (Cooper Creek) was regarded as the base of the Missourian. Tilton (1913, 1921) dropped the name 'Fragmental' and introduced the Kansas name Hertha Limestone. By the early 1930s, Greene, Moore, and Condra had also correlated the upper member (upper 'Fragmental Limestone' of Tilton and Bain (1897) or Tilton's (1913, 1921) upper 'Hertha Limestone') with the Hertha Limestone of Kansas. Cline (1941) then restricted the name 'Fragmental Limestone' to what is now the Cooper Creek Limestone. Moore, Frye and Jewett (1944) included the Critzer Limestone, Mound City Shale and Sniabar Limestone as members of the Hertha formation in Kansas, in ascending order. The Critzer Limestone, once thought to be the transgressive limestone of the Hertha cyclothem, is now known to be a separate cycle and is now classified as a member of the Shale Hill Formation of the Pleasanton Group in Kansas and Missouri, below the Ovid Coal (Heckel and Watney, 2002). The Critzer is not known to occur north of north-central Missouri (Heckel, 1992).

Reference sections for the Hertha Limestone are designated in the 1046.5-1063.2 foot interval in the Riverton core and the 556.5-574.5 foot interval in the Bedford core. A reference section for the Hertha Limestone where the Sniabar Limestone Member exhibits the 'middle shale facies' is designated at an outcrop in a south-facing backslope cutbank on a private road to the waste water treatment plant south of Winterset, in the SW NE SW section 5, T. 75 N., R. 27 W. A reference section for the Hertha where the Sniabar Limestone Member does not exhibit the 'middle shale facies,' is designated at an outcrop in a west-facing cutbank along a tributary to Clanton Creek in the NE SW NE section 12, T. 74 N., R. 27 W., Madison County, and at nearby exposures in a west-facing roadcut backslope along County Highway G-68 about one mile (1.6 km) east of East Peru, along the W line of the W ½ E ½ NW section 12, T. 74 N., R. 27 W. At the latter exposure the base of the Mound City Shale is difficult to recognize and the East Peru Limestone is absent. In the Omaha area of western Iowa and adjacent Nebraska, the Hertha has long been misidentified as the Swope Formation (e.g., Burchett and Reed, 1967).

Sniabar Limestone Member
(new facies recognized)

The Sniabar Limestone Member was named by Jewett (1932) for exposures just east of Kansas City along Sni-A-Bar Creek, Jackson County, Missouri. No specific type section was ever designated. Gentile and Thompson (2004) located several reference sections in Jackson County, Missouri. The Sniabar Limestone Member overlies the Mound City Shale Member and underlies the Elm Branch Shale.

North, east, and south of Winterset in Madison County, the Sniabar Limestone exhibits a three-part subdivision (Wood, 1935; Pope, 2000). The **'lower limestone facies'** is a thin-bedded, argillaceous skeletal wackestone overlain by a 13 foot (4 m) thick fossiliferous medium-gray (N5) **'middle shale facies'** with large carbonate-filled burrows at the top. The **'upper limestone facies'** is a thick-bedded skeletal packstone overlain by a skeletal grainstone. The upper limestone was informally called the 'stray limestone' by early geologists. The 'middle shale facies' is also seen in the Bedford core (Taylor County). Near Peru in Madison County the 'middle shale facies' is not present and the Sniabar Limestone is about nine feet (2.7 m) of skeletal wackestone.

Reference sections are designated in the 1046.5-1061.5 foot interval in the Riverton core and the 556.5-573.0 foot interval in the Bedford core. A reference section for the Sniabar Limestone Member exhibiting the ‘middle shale facies’ is designated at an outcrop in a south-facing backslope cutbank on a private road to the waste water treatment plant south of Winterset, in the SW NE SW section 5, T. 75 N., R. 27 W. A reference section of the Sniabar Limestone Member without the ‘middle shale facies,’ is designated at an outcrop in a west-facing cutbank along a tributary to Clanton Creek in the NE SW NE section 12, T. 74 N., R. 27 W., Madison County, and nearby at exposures in west-facing roadcut backslope along County Highway G-68 about one mile (1.6 km) east of East Peru, along the W line of the W ½ E ½ NW section 12, T. 74 N., R. 27 W. In the Omaha area of western Iowa and adjacent Nebraska, the Sniabar has long been misidentified as the Bethany Falls Limestone Member of the Swope Formation (e.g., Burchett and Reed, 1967).

Mound City Shale Member
(revised; restricted)

The Mound City Shale Member was named by Jewett (1932) for strata between the underlying Critzer Limestone and the overlying Hertha (Sniabar) limestone, and was named from exposures near Mound City, Linn County, Kansas. In Kansas, Heckel and Watney (2002) revised the Mound City Shale Member by removing the Ovid Coal bed and its underclay from the Mound City Shale, and renaming this latter interval the Guthrie Mountain Shale Member (where the Critzer Limestone is present) of the Shale Hill Formation.

In Iowa, where the East Peru Limestone Member is not present, the base of the Mound City Shale Member is at the top of the Ovid Coal bed, or its horizon at the top of the paleosol, or at the base of the dark gray (N3) or black (N1) shale facies (Pope, 2000). The Mound City Shale Member underlies the Sniabar Limestone Member and overlies the East Peru Limestone Member (where present) or the Shale Hill Member of the Pleasanton Formation, where the East Peru Limestone is absent. At some exposures in Madison County, the Mound City Shale is black (N1), fissile and phosphatic in the lower part and medium gray (N5) in the upper part. At the East Peru Limestone type section there is a thin, argillaceous limestone in a lower dark gray (N3) facies.

Reference sections are designated in the 1061.5-1062.9 foot interval in the Riverton core, the 573.0-574.5 foot interval in the Bedford core, at a south-facing backslope cutbank on a private road to the waste water treatment plant south of Winterset, in the SW NE SW section 5, T. 75 N., R. 27 W., and at west-facing cutbank exposure along a tributary to Clanton Creek in the NE SW NE section 12, T. 74 N., R. 27 W. (type East Peru Limestone location). In the Omaha area of western Iowa and adjacent Nebraska, the Mound City has long been misidentified as the Hushpuckney Shale Member of the Swope Formation (e.g., Burchett and Reed, 1967).

East Peru Limestone Member
(new name in Iowa)

The East Peru Limestone Member was named by Pope (2000) from west-facing cutbank exposures in a tributary to Clanton Creek in the NE SW NE section 12, T. 74 N., R. 27 W., about five miles (8.0 km) east of East Peru, Madison County, Iowa. The name was suggested by P.H. Heckel in 1999. At the type section it is a thin-bedded, argillaceous skeletal packstone.

The East Peru Limestone Member, where present, lies above the Ovid Coal bed of the Shale Hill Member of the Pleasanton Shale and underlies the base of the dark gray (N3) to black (N1) shale facies of the overlying Mound City Shale Member. It is represented by local limestone lenses in Kansas (e.g., east of Turkey Creek in NE NW NW section 12, T. 25 S., R. 22 E., Bourbon County: Heckel, 1992) and Missouri (roadcut along the east side of Missouri Highway 291 between Kentucky and Courtney roads at Sugar Creek, in the center S½ NE¼ section. 24, T. 50 N., R. 32W., Jackson County: Gentile, 1976; Gentile and Thompson, 2004).

A reference section was designated by Pope (2000) in the SW NE SW section 5, T. 75 N., R.

27 W., at a south-facing backslope cutbank on a private road to the Winterset waste water treatment plant. A thin limestone that occurs at the 1062.9-1063.2 foot interval in the Riverton core is also designated a reference section.

Pleasanton Formation
(new members and beds recognized)

The name Pleasanton was first used by Haworth (1895b) for rocks between the upper Pawnee limestone (Coal City) and the base of the overlying Hertha limestone. It was named from exposures near Pleasanton, Linn County, Kansas. In Kansas, Moore (1932) and in Nebraska, Condra (1935) dropped the name and used the name Bourbon Group. McQueen and Greene (1938) excluded all Desmoinesian strata from the Pleasanton, and Moore (1948) dropped the name Bourbon in favor of Pleasanton.

The Pleasanton Group, as now defined in Kansas (Heckel and Watney, 2002), overlies the Marmaton Group and underlies the Kansas City Group. In the Midcontinent it contains the newly designated Desmoinesian-Missourian Stage boundary at the base of the Exline Limestone Member of the Pleasanton Shale (Heckel, Boardman and Barrick, 2002). It is a shale-dominated succession with thin limestones and local sandstones (Heckel, 1999).

Because the Pleasanton is much thinner and contains only three major units (Hepler Shale, Exline Limestone, and Shale Hill in ascending order) and two named coal beds in Iowa, Ravn and others (1984) proposed that the Pleasanton should be reduced to formational rank and the three major units should be named as members. The author agrees and regards the Pleasanton as the basal formation of the Bronson Group.

The 1063.2-1084.0 foot interval in the Riverton core, the 62.8-84.3 foot interval in the Logan core, and the 53.0-72.6 foot interval in the CP-37 Osceola core are designated as reference sections. A reference section is also designated at a south-facing backslope cutbank on a private road to the waste water treatment plant south of Winterset, in the SW NE SW section 5, T. 75 N., R. 27 W., Madison County. At the latter outcrop the Hepler Shale is absent. See Heckel (1991) for additional descriptions of the "upper" Pleasanton unit (mostly Shale Hill Member of this report), the Exline Limestone and Hepler Shale in several other Iowa cores.

Shale Hill Member
(new name in Iowa)

The name Shale Hill was originally proposed by Howe (1982), in an open-file publication, and was revised to more correlatable boundaries by Heckel and Watney (2002) to encompass the strata of the upper Pleasanton Group, above the Hepler Formation and below the revised Mound City Shale Member of the Hertha Formation. The type section is at a complete exposure of these strata in a brick pit cut into Shale Hill at Utica, near the center of section 18, T. 57 N., R. 24 W., southwest of Chillicothe, Livingston County, Missouri.

In Iowa, the Shale Hill Formation of Missouri and Kansas, is reduced in rank to a member of the Pleasanton Formation. The Shale Hill Member overlies the Exline Limestone Member and underlies the East Peru Limestone Member (where present) or the base of the dark gray (N3) to black (N1) shale facies of the Mound City Shale Member of the Hertha Formation. In Iowa and northern Missouri the Ovid Coal bed occurs near the top of the unit.

Reference sections are designated in the 1063.2-1066.3 foot interval in the Riverton core, the 62.8-68.2 foot interval in the Logan core, and the 53.0-69.9 foot interval in the CP-37 Osceola core, at a south-facing backslope cutbank on a private road to the waste water treatment plant south of Winterset, (SW NE SW section 5, T. 75 N., R. 27 W.), and at a west-facing cutbank exposure along a tributary to Clanton Creek in the NE SW NE section 12, T. 74 N., R. 27 W., (East Peru Limestone type section). In the Omaha area of western Iowa and adjacent Nebraska, the Shale Hill has apparently been misidentified as the Ladore Formation (e.g., Burchett and Reed, 1967).

Ovid Coal bed
(new name in Iowa)

According to Hinds (1912) the Ovid Coal was named by Marbut (1898), but no type section was designated. The coal was named after the former town of Ovid that once existed in the NW section 25, T. 54 N., R. 27 W., Ray County, Missouri. The Ovid Coal probably correlates with the Chapel (No. 8) Coal of Illinois (Bergstrom, 1956; Ravn, 1986).

Reference sections are designated at a south-facing backslope cutbank on a private road to the waste water treatment plant south of Winterset, in the SW NE SW section 5, T. 75 N., R. 27 W., Madison County and at a west-facing cutbank exposure along a tributary to Clanton Creek in the NE SW NE section 12, T. 74 N., R. 27 W., Madison County, Iowa (East Peru Limestone type section).

Exline Limestone Member
(unchanged)

The Exline Limestone Member was named by Cline (1941) from exposures of dark skeletal wackestone in cutbanks of a west-flowing tributary to North Shoal Creek in the SE of section 6, T. 67 N., R. 17 W., Appanoose County, Iowa. The name was derived from the town of Exline 1.5 miles (2.4 km) to the north. The Exline Limestone Member overlies the Hepler Shale Member and underlies the Shale Hill Member. In northern Missouri, south of Appanoose County, Iowa, the Exline Limestone exhibits a facies change to a shale with abundant gastropods, the '*Trepospira sphaerulata* zone' of Hinds and Greene (1915) and Cline (1941).

In Madison County (SW NE SW section 5, T. 75 N., R. 27 W.), the Exline Limestone is possibly represented by 2.8 feet (0.84 m) of nodular, argillaceous, brecciated-looking skeletal lime wackestone that is sitting on top of the Cooper Creek Limestone, with no apparent unconformity to show that the Hepler Shale is absent (Pope, 2000). Nielson (1987) described the Exline-Cooper Creek interval in the Schildberg Stanzel core (Madison County) and the Schildberg Jefferson core (Adair County) as a single limestone unit. In the Logan core (Harrison County) the Hepler Shale separates the two units (Nielson, 1987). In the CP-37 Osceola core (Clarke County) the Exline is described as 2.5 feet (76 cm) of phosphatic, fossiliferous, argillaceous, irregularly bedded, skeletal calcilutite separated from the underlying Cooper Creek Limestone by 3.6 inches (9 cm) of mudstone, now assigned to the Hepler Shale (Swade, 1985). In areas where the Hepler Shale is absent, the Exline and Cooper Creek limestones can only be distinguished by their conodont fauna (Swade, 1985; Nielson, 1987). In a quarry northwest of Centerville (E ½ section 34, T. 70 N., R. 19 W.), Appanoose County, the Exline is about eight feet (2.4 m) of skeletal packstone with abundant calcite spar, separated from the underlying Cooper Creek Limestone by several feet of shale and mudstone.

At the type section of the East Peru Limestone (Madison County), the Exline may be represented by 2.8 feet (0.85 m) of sandstone and conodont-bearing shale above the Grain Valley Coal (Pope, 2000), but the relationship of the sandstone to the Exline elsewhere and underlying units is somewhat uncertain, even though the Cooper Creek Limestone is known to occur at a slightly lower horizon a few hundred feet to the north. The sandstone and underlying coal has only been seen in two isolated outcrops east and south of East Peru.

The 1066.3-1078.1 foot interval in the Riverton core, the 68.2-71.7 foot interval in the Logan core, and the 69.9-72.4 foot interval in the CP-37 Osceola core are designated as reference sections. See Heckel (1991) for additional descriptions of the Exline Limestone in several other Iowa cores. In the Omaha area of western Iowa and adjacent Nebraska, the Exline has apparently been misidentified as the Hertha Limestone (e.g., Burchett and Reed, 1967).

MIDDLE PENNSYLVANIAN SERIES

DESMOINESIAN STAGE

The Desmoinesian Series was derived from the Des Moines formation named by Keyes (1893) from outcrops along the Des Moines River in south-central and southeastern Iowa. Later, Keyes (1896) defined the Des Moines series (productive coal measures) as "… clearly limited above by the Bethany limestone and below by the Mississippian or earlier formations." The base of what Keyes (1896) and Broadhead (1895) called the Bethany limestone (or great limestone at Winterset) was the base of what is now called the Hertha Limestone, and was regarded as the base of the 'upper' Coal Measures. No specific type section for the Desmoinesian was ever designated. Jewett and others (1968) regarded the Desmoinesian as a stage (in Kansas) and Heckel and Watney (2002) regarded it as the Desmoinesian Stage (Figures 7, 8) of the Middle Pennsylvanian Series.

The Desmoinesian Stage comprises a succession of cyclic shales, coals, sandstones, and limestones (Heckel, 1999) in the Midcontinent. It represents the lower Coal Measures of the upper Carboniferous (Keyes, 1893), and as he defined it, the Desmoinesian was to include all strata from the base of the "great limestone of Winterset" or Bethany Limestone (now called Bethany Falls Limestone) down to the base of the Pennsylvanian (usually the top of the Mississippian) in Iowa. The Desmoinesian as previously used in Iowa, has included rocks of Morrowan and Atokan age (Ravn et al., 1984; Peppers, 1996). In Iowa, the lower (Atokan-Desmoinesian) boundary was determined on the basis of palynomorphs (Ravn, 1981; Peppers, 1996; Peppers and Brady, 2007) and conodonts (Lambert and Heckel, 1990). See section on Desmoinesian-Atokan boundary below.

Moore (1932) and Cheney and others (1945) redefined the upper Desmoinesian boundary to coincide with a widespread unconformity (base of the Chariton Conglomerate where present in Iowa) within the Pleasanton Group. Ravn and others (1984) placed the Desmoinesian-Missourian boundary at the top of the Cooper Creek Limestone (base of the Pleasanton Formation). In the Midcontinent of Kansas, the upper (Desmoinesian-Missourian) boundary was placed by Heckel (1999), Heckel and others (1999), Heckel, Boardman, and Barrick (2002), and Heckel and Watney (2002) at the base of the Exline Limestone in the Pleasanton Group of Kansas (Pleasanton Formation of Iowa), based on the first appearance of the conodont *Idiognathodus eccentricus* in the Exline.

The Desmoinesian is characterized by the presence of the foraminifer *Beedeina* (=*Fusulina*), the brachiopod *Mesolobus*, coral-like chaetetid sponges (e.g., '*Chaetetes*'), the conodont *Neognathodus*, various ammonoids, and certain arborescent lycopods, which become extinct below the present upper boundary.

The Desmoinesian is perhaps 6600 feet (2000 m) thick in the Arkoma Basin of central Oklahoma, ranging from 600-750 feet (180-225 m) along outcrop in eastern Kansas, and thinning slightly northward along outcrop into Iowa. It thickens into the subsurface in the Forest City Basin of Iowa, Nebraska, and Missouri to perhaps 950 feet (290 m). The Desmoinesian Stage overlies the Atokan Stage and underlies the Missourian Stage.

The 71.7-582.0 foot interval in the Logan core is designated as a reference core for the entire Desmoinesian Stage.

Hepler Shale Member (of Pleasanton Shale) (new name in Iowa)

The Hepler was originally named as a sandstone by Jewett (1940) from roadcut exposures of sandstone two miles (3.2 km) north of the town of Hepler in the center of section 14, T. 27 S., R. 22 E., Bourbon County, Kansas. Heckel and Watney (2002) raised the Hepler to formational rank in Kansas, and revised the definition to include all strata from the top of the underlying Lost Branch Formation to the base of the Exline Limestone Member of the overlying Shale Hill Formation. Because a number of sandstones, at various stratigraphic intervals have been called Hepler, Heckel and Watney (2002) designated a new reference exposure approximately two miles (3.2 km) northwest of the original type Hepler. In Iowa, the Hepler Shale is considered a member of the Pleasanton Formation, and contains the Grain Valley Coal bed near its top. The Hepler Shale Member overlies the Cooper Creek Limestone Member of the Lost Branch Formation and underlies the Exline Limestone Member.

In most of Madison and several other counties in south-central and southwest Iowa, the Hepler Shale is absent, and the Exline Limestone lies directly on the Cooper Creek Limestone. In the CP-37 Osceola core (Clarke County), Swade (1985) described the Hepler Shale as 3.6 inches (9 cm) of conodont-bearing mudstone. In the Logan core (Harrison County), the Hepler is represented by 13 feet (4.0 m) of sandy shale and mudstone, but by only four feet

(1.2 m) of shale in the Riverton core (Fremont County). In a quarry northwest of Centerville (E ½ section 34, T. 70 N., R. 19 W.), Appanoose County, the Hepler is about three feet (0.9 m) thick, with a thin coal (Grain Valley Coal) near the top (Cline 1941; J.P. Pope, unpublished field notes).

The 71.7-84.3 foot interval in the Logan core, the 72.4-72.7 foot interval in the CP-37 Osceola core, and the 1078.1-1084.0 foot interval in the Riverton core are designated as reference sections. See Heckel (1991) for additional descriptions of the Hepler Shale in several other Iowa cores. In the Omaha area of western Iowa and adjacent Nebraska, the Hepler has apparently been considered to represent the entire Pleasanton Formation, ranked as a group (e.g., Burchett and Reed, 1967).

Grain Valley Coal bed
(new name in Iowa)

The Grain Valley Coal bed was named by Howe (1982) from a thin coal exposed in the cutbank of a south-flowing tributary to Sni-A-Bar Creek near the west line of NW SW SW section 14, T. 49 N., R. 30 W., Jackson County, Missouri. The name was derived from the nearby town of Grain Valley. The Grain Valley Coal may correlate with the Lake Creek Coal or Athensville Coal (Upper Scottville Coal of Kosanke, 1950) of Illinois.

A reference section is designated at a west-facing cutbank exposures in a tributary to Clanton Creek in the NE SE NW section 22, T. 75 N., R. 26 W., Madison County, Iowa (East Peru Limestone type section).

MARMATON GROUP
(new members and beds recognized)

The Marmaton Group (Figure 7) was derived from the Marmaton formation named by Haworth (1895b) for the upper division of the Lower Coal Measures, even though Keyes (1896) had used the name Marmaton for the middle Henrietta shale (Labette Shale of today). The name Marmaton was derived from exposures along the Marmaton River in Kansas. This area was further defined by Jeffries (1958) to extend from Fort Scott to Uniontown, Bourbon County, Kansas. Haworth (1898) defined the Marmaton Formation to include all strata from the top of the Cherokee to the top of the Pleasanton Shale.

In Missouri, Hinds and Greene (1915) used the name Henrietta, the name being derived from Henrietta Post Office in Ray County, Missouri, first used by Marbut in a “physiographic sense” in 1896, and later defined stratigraphically by Keyes (1896). The Henrietta spanned strata from the base of the Fort Scott Limestone (base of Blackjack Creek Limestone Member) to the top of the Pawnee Limestone (top of the Coal City Limestone Member). In Missouri, McQueen and Greene (1938) and Clair (1943), used the name Henrietta Group for what is now essentially the Marmaton Group. Cline (1941) and McQueen (1943) extended the lower boundary of the Henrietta Group to include upper Cherokee strata down to the base of an unconformity (base of a sandstone between the Breezy Hill Limestone and the Bevier Coal). Cline (*in* Moore et al., 1944) dropped the name Henrietta and used the name Appanoose for the same strata. The name Appanoose had been introduced by Bain in 1896, for deposits in Appanoose County, Iowa and correlative strata in Missouri, which were essentially the same as the present day Marmaton Group.

Moore (1932) used the name Marmaton and revised the upper boundary to coincide with the top of the Holdenville Subgroup (top of the Cooper Creek Limestone Member at the top of the Lost Branch Formation) of Missouri. At a meeting of the Oklahoma, Kansas, Nebraska, Iowa, and Missouri geological surveys it was agreed to drop the names Henrietta Group and Appanoose Group in favor of the name Marmaton Group (Moore, 1948). The name Appanoose was later revived by Searight and Howe (1961) to represent a subgroup of strata of the Marmaton Group above the Fort Scott Subgroup (Labette through Holdenville), and was used by Gentile and Thompson (2004) as a subgroup in Missouri.

Ravn and others (1984) redefined the Cherokee-Marmaton boundary and placed the Excello Shale at the base of the Marmaton Group instead of at the top of the Cherokee Group. This allowed consistency with other overlying Marmaton Group formational boundaries that are placed at the base of the first demonstrably marine unit.

As now defined (Heckel, 1991, p. 9; Heckel, 1999, p. 42) the Marmaton Group overlies the Cherokee Group and underlies the Bronson Group of the Missourian Stage, encompassing strata from the base of the Excello Shale to the top of the Lost Branch Formation (top of the Cooper Creek Limestone Member, in Iowa). The Marmaton Group reflects an increasing trend toward the cyclic style of strata that is characteristic of the Late Pennsylvanian. It comprises a succession of limestone-dominated major cyclothems separated by locally thick shale formations, some of which contain local sandstones and widespread coals. In ascending order in Iowa, these formations are: Mouse Creek Formation, Morgan School Shale, Stephens Forest Formation, Labette Shale, Pawnee Limestone, Bandera Shale, Altamont Limestone, Nowata Shale, Lenapah Limestone, Memorial Shale and Lost Branch Formation.

In Kansas, the lower part of the Marmaton, from the base of the Excello Shale to the base of the Anna Shale, was placed in the Fort Scott Formation (e.g., Cline, 1941). The Fort Scott Formation was never recognized by the Iowa Geological Survey (Moore, 1948). Ravn and others (1984) recognized two complete cyclic intervals from the Excello to the Labette. For Iowa, they rejected the name "Ft. Scott" and erected three new formational subdivisions, in ascending order: Mouse Creek Formation, Morgan School Shale, and Stephens Forest Formation. The Marmaton Group varies from 125-170 feet (38-52 m) thick in southwest Iowa (Witzke et al., 2003a).

The 84.3-233.0 foot interval in the Logan core (Harrison County) and the 72.7-216.8 foot interval in the CP-37 Osceola core (Clarke County) are designated as reference cores for the entire Marmaton Group. The 117.4-188.0 foot interval in the CP-22 core (Appanoose County) is designated as a reference section, from the top of the Pawnee Formation (Coal City Limestone) to the top of the Swede Hollow Formation (top of the Mulky Coal). Ravn and others (1984, Fig. 24, p. 42) used the CP-22 core as a reference section for their newly named Mouse Creek, Morgan School and Stephens Forest formations. A reference outcrop for the middle Marmaton (Lake Neosho Shale to Mystic Coal bed), is designated at an exposure in a west-facing hill on a dirt road southwest of St. Charles, along the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County. A reference outcrop for the lower Marmaton (Myrick Station Limestone to the base of the Excello Shale), is designated in a west-facing cutbank of Preston Branch west of Madrid, at the C N line NW NE section 33, T. 82 N., R. 26 W., Boone County.

"Chariton Conglomerate"
(name not formally recognized)

The Chariton Conglomerate was named by Bain (1896) for exposures in a quarry in the east bluff of the Chariton River, near the mouth of Snort Creek, in the SW section 9, T. 69 N., R. 17 W., Appanoose County, Iowa. Bain (1896) placed the Chariton Conglomerate between the Coal City and Worland limestones, while Cline (1941) placed the Chariton Conglomerate between the Exline and Hertha limestones. Wilcox (1941) illustrated an outcrop of Chariton Conglomerate in the SE SW section 31, T. 69 N., R. 17 W., in Centerville, Appanoose County, where the top of the conglomerate is a few feet below the Hertha Limestone. Howe (1982) included the Chariton with clastics of the Warrensburg and Moberly channel-fill sequences of Missouri. Thompson (1995) thought the coarse, locally-developed, limestone-clast conglomerate, which is at the base of channel-fill deposits at some localities in Missouri, was the Chariton Conglomerate of earlier workers and also regarded it as a facies of the Warrensburg Sandstone. Gentile and Thompson (2004) recognized two horizons of "Chariton" Conglomerate that can be seen in an exposure along an abandoned road 0.5 mile east of the former site of Elko, on the common section line corner for section 19 and section 30, T. 65 N., R. 17 W., and section 25, T. 65 N., R. 18 W., Putnam County, Missouri, and concluded that the "Chariton" Conglomerate may occur at more than one stratigraphic horizon.

Landis & Van Eck (1965)				Ravn and others (1984)					Pope (this report)			
Series	Group	Formation	Member	Series	Super Group	Group	Formation	Member	Stage	Group	Formation	Member *bed*
Missouri	Pleasanton		Exline Ls Ovid C Chariton Conglomerate	Missourian	Missouri	Bronson	Pleasanton	unnamed sh Exline Ls unnamed sh	MO	Bronson	Pleasanton	Shale Hill *Ovid C* Exline Ls Hepler Sh *Grain Valley C*
Des Moines	Marmaton	Lenapah	Cooper Crk Ls	Desmoinesian	Des Moines	Marmaton	"Lost Branch"	Cooper Crk Ls unnamed sh Sni Mills Ls	Desmoinesian	Marmaton	Lost Branch	Cooper Creek Ls Nuyaka Creek Sh Sni Mills Ls
		Nowata Sh					unnamed sh Lenapah Nowata Sh				Memorial Sh	*Dawson C*
											Lenapah Ls	Norfleet Ls
											Nowata Sh	unnamed ls *unnamed c*
		Altamont	Worland Ls Lake Neosho Sh Amoret Ls				Altamont	Worland Ls Lake Neosho Sh Amoret Ls			Altamont Ls	Worland Ls Lake Neosho Sh Amoret Ls
		Bandera Sh	[Lonsdale C]				Bandera Sh				Bandera Sh	*McBride C* Farlington Ls *Mulberry C*
		Pawnee	Coal City Ls Mine Creek Sh Myrick Station Ls Anna Sh				Pawnee	Coal City Ls Mine Creek Sh Myrick Station Ls Anna Sh			Pawnee	Coal City Ls Mine Creek Sh *Imes C* Myrick Station Ls Anna Sh Childers School Ls
		Labette Sh	Mystic C Marshall C				Labette Sh	Mystic C Marshall C			Labette Sh	*Mystic C* *Marshall C*
		Fort Scott	Higginsville Ls Houx Ls				Stephens Forest	Higginsville Ls unnamed sh Houx Ls Little Osage Sh			Stephens Forest	Higginsville Ls Blackwater Crk Sh *unnamed c* Houx Ls Little Osage Sh Clanton Creek Ls
			Summit C				Morgan Sch	Summit C			Morgan Sch Sh	*Summit C*
			Blackjack Crk Ls				Mouse Crk	Blackjack Crk Ls Excello Sh			Mouse Creek	Blackjack Creek Ls Excello Sh unnamed ls
	Cherokee / Upper		Mulky C			Cherokee	Swede Hollow	Mulky C		Cherokee	Swede Hollow	*Mulky C*

Figure 7. Upper Desmoinesian Stage (Marmaton Group) stratigraphy, showing relationships to Bronson and Cherokee groups, in Iowa. Missourian Stage (MO).

In Iowa the "Chariton" Conglomerate occurs in Appanoose, Lucas, Marion, Monroe and Warren counties. Wallace (1941) had extended the "Chariton" into Marion and Lucas counties from Appanoose County, and Cline (1941) also mentioned an outcrop west of Truro in Madison County. The "Chariton" Conglomerate varies from a calcite cemented quartzose sandstone to a coarse conglomerate consisting of carbonate (some carbonate clasts are up to one foot (30 cm) across) and quartz clasts with some carbonized wood fragments (some exceed 18 inches (45 cm) in length) in a sandstone matrix. Carbonate clasts at the abandoned quarry about two miles (3.6 km) east of Moravia, in the NW section 1, T. 70 N., R. 17 W., Appanoose County, contain chaetetids and the fusulinid

Beedina megista, suggesting these clasts are from the Worland Limestone.

Pope and others (2002) provisionally placed the Chariton Conglomerate in the Marmaton Group (Nowata-Memorial interval), but the conglomerate may also occur as high as the Hepler or Shale Hill members of the Pleasanton Formation. J.P. Pope and B.J. Witzke agree that several lithologically similar conglomerates probably occur in the interval from the Shale Hill Member of the Pleasanton Formation to the lower Swede Hollow Formation of the Cherokee Group, in Iowa. The author follows the nomenclature of Ravn and others (1984) and considers the Chariton Conglomerate an informal unit, because of the uncertainty of its stratigraphic position(s) and the possibility that lithologically similar conglomerates outside of the type area may not be true Chariton Conglomerate.

Reference sections for conglomerates similar to the type Chariton Conglomerate, are designated at an abandoned quarry exposure in the NE NW SW NW section 1, T. 70 N., R. 17 W., east of Moravia in Appanoose County, and at exposures in an abandoned quarry south of Columbia in the SE SW SE section 10, T. 73 N., R. 20 W., Lucas County, Iowa.

Lost Branch Formation
(new member recognized)

The Lost Branch Formation was introduced by Heckel (1984) and formally defined by Heckel (1991) from a cutbank on the west side of Lost Branch tributary to Pumpkin Creek, near the C of the NE NE NE section 10, T. 33 S., R 18 E., just southwest of Mound Valley, Labette County, Kansas. The formation comprises three members in ascending order: Sni Mills Limestone, Nuyaka Creek Shale, and Cooper Creek Limestone. The Lost Branch overlies the Memorial Shale and underlies the Hepler Shale.

Reference sections are designated in the 84.3-90.7 foot interval in the Logan core, the 72.7-80.9 foot interval in the CP-37 Osceola core, and at a waterfall in a south-flowing ravine to North River in the SE NW SE section 9, T. 76 N., R. 28 W., about four miles (6.4 km) northwest of Winterset, Madison County.

Cooper Creek Limestone Member
(unchanged)

The Cooper Creek Limestone Member was named by Cline (1941) from exposures in pasture tributary ravines to Cooper Creek, north of Highway 2, in the SE section 26, T. 69 N., R. 18 W., Appanoose County, Iowa. Heckel (1991) located the principal reference section as, "… an outcrop in the northwest corner of the old quarry, southeast of the entrance to the Appanoose County dump, SW NW section 27, T. 68 N., R 18 W., six miles (9.7 km) south of the type area and two miles (3.2 km) north of the town of Cincinnati, Iowa…". Most of this quarry has been flooded with water.

Bain (1896) had called what is now the Cooper Creek Limestone, the 'floating rock.' The Cooper Creek Limestone is the lower limestone of Tilton and Bain's (1897) 'Fragmental Limestone' (see section on Hertha Limestone). Cline (1941) also referred to the Cooper Creek as the 'Fragmental Limestone', the name suggested by the irregular limestone nodules characteristic of the Cooper Creek Limestone at many locations. The Cooper Creek Limestone Member overlies the Nuyaka Creek Shale Member and underlies the Hepler Shale.

In Madison County, the Cooper Creek Limestone is about six feet (1.8 m) of nodular to bedded, argillaceous, brecciated-looking, skeletal lime wackestone and greenish-gray (10GY 5/2) shale, situated directly below the Exline Limestone. The Cooper Creek Limestone is correlated with the Lonsdale Limestone of Illinois (Hopkins and Simons, 1975).

Reference sections are designated in the 84.3-89.4 foot interval in the Logan core, the 72.7-80.7 foot interval in the CP-37 Osceola core, and at a waterfall in a south-flowing ravine to North River in the SE NW SE section 9, T. 76 N., R. 28 W., about four miles (6.4 km) northwest of Winterset, Madison County. In the Omaha area of western Iowa and adjacent Nebraska, the Cooper Creek also may have been misidentified (along with the Exline) as the Hertha Limestone (e.g., Burchett and Reed, 1967).

Nuyaka Creek Shale Member
(new name in Iowa)

The Nuyaka Creek Shale Member was named informally by Bennison (1981) and formally named by Heckel (1991) from exposures along Nuyaka Creek in the C of the E line of NE section 32, T. 12 N., R. 10 E., three miles (4.8 km) northeast of Okemah, Okfuskee County, Oklahoma. The Nuyaka Creek Shale Member overlies the Sni Mills Limestone Member and underlies the Cooper Creek Limestone Member. In Iowa, the Nuyaka Creek is normally greenish gray (5GY 6/1) to medium gray (N5) in color with occasionally a dark gray (N3) streak, and abundant conodonts.

Reference sections are designated in the 89.4-90.7 foot interval in the Logan core, the 80.7-80.8 foot interval in the CP-37 Osceola core, and at a waterfall in a south-flowing ravine to North River in the SE NW SE section 9, T. 76 N., R. 28 W., about four miles (6.4 km) northwest of Winterset, Madison County.

Sni Mills Limestone Member
(unchanged)

The Sni Mills Limestone Member was originally described by Greene (1936), and a type section was designated by Howe (1953) from cutbanks in a drainage in the NW section 28, T. 48 N., R. 29 W., east of the town of Sni Mills, Jackson County, Missouri. In Missouri and Iowa, the Sni Mills has historically been miscorrelated with the Cooper Creek Limestone of the Lost Branch Formation and with the Idenbro Limestone of the Lenapah Formation. The Sni Mills Limestone Member overlies the Memorial Shale and underlies the Nuyaka Creek Shale Member. In Madison County the Sni Mills Limestone is a thin skeletal wackestone.

Reference sections are designated in the 80.7-80.9 foot interval in the CP-37 Osceola core, and at a waterfall in a south-flowing ravine to North River in the SE NW SE section 9, T. 76 N., R. 28 W., about four miles (6.4 km) northwest of Winterset, Madison County.

Memorial Shale
(new name in Iowa; new bed recognized)

The name Memorial Shale was first used by Dott (1936), and later the Memorial Shale was formally named by Dott (1941), for exposures in roadcuts and in gullies in the SW section 2, T. 19 N., R. 13 E., near Tulsa, Tulsa County, Oklahoma. The name Memorial Shale is derived from nearby Memorial Park Cemetery in the NW section 36, T. 20 N., R. 13 E.

Heckel (1991) and Watney and Heckel (1994) revived the name and revised the Memorial Shale in Kansas and Missouri to include all strata between the Idenbro Limestone or the Norfleet Limestone of the Lenapah Formation and the base of the Lost Branch Formation. In Iowa, the Idenbro Limestone is absent, as it only extends northward from Oklahoma to Linn County, Kansas.

If the Norfleet Limestone is absent, the Nowata and Memorial shales cannot be separated, and this interval is known as the Nowata-Memorial Shale (see Heckel, 1991, Fig. 8, p. 16). The Dawson Coal bed lies near the top of the formation.

The 80.8-91.6 foot interval in the CP-37 Osceola core is designated as a reference section. The 90.7-117.6 foot interval in the Logan core is designated as a reference section for the Nowata-Memorial Shale. An exposure of the middle of the Nowata-Memorial Shale interval, consisting of moderate reddish brown (10R 4/6) and pale yellowish green (10GY 7/2) mudstone, about 80 feet (24 m) thick, occurs about five miles (8.0 km) north northeast of Winterset, in the S ½ NE NE NE section 5, T. 76 N., R. 27 W., Madison County.

Dawson Coal bed
(new name in Iowa)

The name Dawson Coal was used by Taff (1904) for a coal bed mined in and around the town of Dawson, Tulsa County, Oklahoma (Hemish, 1987). Dawson is in the northeastern part of the city of Tulsa, in the SE section 27, T. 21 N., R. 13 E., Tulsa County. The Laredo Coal bed (named by Howe, 1953, for exposures south of Laredo, Grundy County, Missouri) was placed in the Nowata Shale in Missouri, but Heckel (1991) identified the Nuyaka Creek

Shale above the type Laredo Coal. This means that the type Laredo Coal is the Dawson Coal, and that lower Nowata coals should be given a new name. See Nowata Shale below. The position of both the Dawson and Laredo coals is at the top of the Memorial Shale (Heckel, 1991, Fig. 8, p. 16). Gentile and Thompson (2004) recognized the Dawson Coal at the top of the Memorial Shale and the Laredo Coal at the base of the Nowata Shale.

A reference section is designated where the Dawson Coal occurs at the 90.3 foot level in the Logan core (W-26516) in Harrison County.

Lenapah Limestone
(new member recognized in Iowa)

The Lenapah Limestone was originally described by Ohern (1910), and a type section was designated by Jewett (1941) for exposures in a quarry at Bell Spur north of the town of Lenapah in the NW NE section 30, T. 28 N., R. 16 E., Nowata County, Oklahoma. He also raised the Lenapah to formation level. Gentile and Thompson (2004) restricted the Lenapah Limestone to only include a single member, the Norfleet Limestone, in Missouri. To the south in Kansas and Oklahoma (Watney and Heckel, 1994; Heckel et al., 1999; Heckel and Watney, 2002, Fig. 2, p. 6) the Lenapah Limestone includes the Norfleet Limestone, Perry Farm Shale and Idenbro Limestone members in ascending order. The Idenbro Limestone disappears northward in Linn County, Kansas (Heckel, 1991, Fig. 8, p. 16). The author follows the nomenclature of Gentile and Thompson (2004) and recognizes only the Norfleet Limestone Member in Iowa. The Lenapah Limestone overlies the Nowata Shale and underlies the Memorial Shale

The 91.6-94.8 foot interval in the CP-37 Osceola core in Clarke County is designated as a reference section.

Norfleet Limestone Member
(new name in Iowa)

The Norfleet Limestone Member was named by Jewett (1941) from exposures on the Ivy Norfleet farm along Pumpkin Creek, north of a low-water bridge, in the SE section 35, T. 32 S., R. 18 E., northeast of Mound Valley, Labette County, Kansas. The Norfleet Limestone is the only member of the Lenapah Limestone recognized in Iowa, where it consists of argillaceous skeletal wackestone overlain by calcareous gray shale, The Norfleet Limestone overlies the Nowata Shale and underlies the Memorial Shale.

The 91.6-94.8 foot interval in the CP-37 Osceola core in Clarke County is designated as a reference section.

Nowata Shale
(unchanged)

The Nowata Shale was originally described by Ohern (1910), and a type section was designated by Baars and Maples (1998) for exposures in the south bank of the Verdigris River near the town of Nowata in the SW section 10, T. 27 N., R. 16 E., Nowata County, Oklahoma. The Laredo Coal bed (named by Howe, 1953, for exposures south of Loredo, Grundy County, Missouri) occurs in the Nowata Shale in Missouri, but Heckel (1991) identified the Nuyaka Creek Shale above the type Laredo Coal. This means that the type Laredo Coal is the Dawson Coal, and that lower Nowata coals should be given a new name. In Appanoose County, Wilcox (1941) recognized a [unnamed] coal smut about 3.5 feet (1.1 m) above the Worland Limestone and 16.5 feet (5.0 m) below the Dawson Coal. L.M. Cline (unpublished manuscript) observed a two inch (5 cm) thick *Myalina* shell coquina above the [unnamed] coal near Youngstown, Adair County, Missouri. A thin limestone occurs about six feet above the Worland Limestone in the Logan core in Harrison County, Iowa. Neither the thin coal nor overlying marine unit, a few feet above the Worland Limestone, will be named at this time. Gentile and Thompson (2004) recognized the Dawson Coal at the top of the Memorial Shale and the Laredo Coal near the base of the Nowata Shale.

The Nowata Shale overlies the Altamont Limestone and underlies the Lenapah Limestone. If the Norfleet Limestone is not present, the Nowata and Memorial shales cannot be separated, and this interval is known as the Nowata-Memorial Shale.

The 94.8-98.9 foot interval in the CP-37 Osceola core is designated as a reference section. The 90.7-117.6 foot interval in the Logan core is designated as a reference section for the Nowata-Memorial Shale interval. An exposure of the middle part of the Nowata-Memorial Shale, consisting of moderate reddish brown (10R 4/6) and pale yellowish green (10GY 7/2) mudstone, about 80 feet (24 m) thick, occurs in the S ½ NE NE NE section 5, T. 76 N., R. 27 W., about five miles (8.0 km) north northeast of Winterset, Madison County.

Altamont Limestone

(unchanged)

Adams (1896) described a limestone near Altamont, Kansas, and Jewett (1941) defined it and described a more complete section in the C of the W line of section 5, T. 33 S., R. 19 E., 3.5 miles (5.6 km) west of Altamont, Labette County, Kansas. In Iowa, the Altamont Limestone comprises three members in ascending order: Amoret Limestone, Lake Neosho Shale and Worland Limestone. The Altamont Limestone overlies the Bandera Shale and underlies the Nowata Shale.

Reference sections are designated in the 117.6-121.3 foot interval in the Logan core, the 98.9-110.3 foot interval in the CP-37 Osceola core, at exposures 650 feet (198 m) north of a dirt road in a north-flowing ravine, southwest of St. Charles, in the NE SE SW NW section 26, T. 75 N., R. 26 W., Madison County, and at an exposure at the waterfall about 2.5 miles (4.0 km) north northeast of Stuart, in the NW SW NW section 21, T. 78 N., R. 30 W., Guthrie County.

Worland Limestone Member

(unchanged)

The Worland Limestone was informally known as the 'fifty-foot limestone' in reference to its stratigraphic position about fifty feet (15.2 m) above the Mystic Coal (Bain, 1896). The name Worland was first used by Greene (1933) for two thin limestones exposed in outcrops near Worland, Bates County, Missouri. Both limestones were then placed in the Bandera Shale. Cline traced the two beds northward into Iowa and found the upper limestone correlated with the 'fifty-foot limestone' of Bain (1896). By 1940, Moore, Greene, Jewett, and Cline had traced the Worland into southeastern Kansas and found that it correlated with the upper and lower Altamont limestones. Moore and Jewett suggested that the name Worland be retained for the upper limestone member of the Altamont Formation, so Cline (1941) restricted the name Worland to the upper limestone and named the lower limestone the Tina. The Tina Limestone was later renamed the Amoret Limestone by Cline and Greene (1950). See discussions below, of the Amoret Limestone, Bandera Shale and Farlington Limestone.

A type section for the Worland Limestone was designated by Jewett (1941) at exposures along the Kansas City Southern Railroad cut in the SW SW section 5, T. 39 N., R. 33 W., northeast of the town of Worland, Bates County, Missouri. The Worland Limestone Member overlies the Lake Neosho Shale Member and underlies the Nowata Shale. In Madison County, Iowa, the Worland Limestone often has abundant grayish-green (10GY 5/2) shale partings up to 0.5 inches (1.3 cm) thick. Southwest of St. Charles, Madison County, the rare terebratulid brachiopod *Cryptacanthia compacta* has been found. *Beedina* (=*Fusulina*) *megista*, *Phricodothyris perplexa*, *Antiquatonia portlockianus*, *Tetrataxis* sp., *Composita* spp., and *Cleiothyridina carbonaria* are common fossils.

Reference sections are designated in the 117.6-120.4 foot interval in the Logan core, the 98.9-108.9 foot interval in the CP-37 Osceola core, at exposures 650 feet (198 m) north of a dirt road in a north-flowing ravine, southwest of St. Charles, in the NE SE SW NW section 26, T. 75 N., R. 26 W., Madison County, and at an exposure at the waterfall about 2.5 miles (4.0 km) north northeast of Stuart, in the NW SW NW section 21, T. 78 N., R. 30 W., Guthrie County.

Lake Neosho Shale Member

(unchanged)

The Lake Neosho Shale Member was named by Jewett (1941) for exposures southeast of Lake Neosho in Neosho County State Park in the SW section 23, T. 30 S., R. 20 E., Neosho

County, Kansas. Cline (1941), Cline and Greene (1950) and Cline and Stookey (1954) included in the Lake Neosho Shale, all strata from the top of what is now Heckel and others (1999) Farlington Limestone to the base of the overlying Worland Limestone. The Lake Neosho Shale, as now defined, overlies the Amoret Limestone Member where present, the top of the McBride Coal where present, or the top of a mudstone, and underlies the Worland Limestone Member, as a member of the Altamont Formation. Southwest of St. Charles, Madison County, the Lake Neosho is 1-2 feet (30-60 cm) thick. In the NE SE section 3, T. 76 N., R. 27 W., Madison County, the Lake Neosho Shale is 1.5 feet (45 cm) of dark gray (N3) to light gray (N7) shale, and overlies a 0.7 inch (1.8 cm) thick coal, which is above 1.9 feet (58 cm) of coaly, rooted medium gray (N5) mudstone.

Reference sections are designated in the 120.4-121.1 foot interval in the Logan core, the 108.9-109.9 foot interval in the CP-37 Osceola core, at exposures 650 feet (198 m) north of a dirt road in a north-flowing ravine southwest of St. Charles, in the NE SE SW NW section 26, T. 75 N., R. 26 W., Madison County, and at an exposure at the waterfall about 2.5 miles (4.0 km) north northeast of Stuart, in the NW SW NW section 21, T. 78 N., R. 30 W., Guthrie County.

Amoret Limestone Member
(redefined for Iowa, this report)

The Tina Limestone was originally named by Cline (1941) from outcrops near the town of Tina in the W central part of section 7, T. 54 N., R. 22 W., Carroll County, Missouri, but this was rejected by Greene and Searight (1949) because the rocks for the type Tina described by Cline (1941) were proven not to be part of the Altamont. The type Tina is actually the Higginsville Limestone of what is now the Stephens Forest Formation in Iowa. Cline and Greene (1950) proposed the name Amoret be used to replace the Tina, and designated a type section in the SW section 33, T. 40 N., R. 33 W., two miles (3.2 km) south of Amoret, Bates County, Missouri. Jewett (1941) regarded the Amoret Limestone as a member of the Altamont Formation in Kansas and Oklahoma.

In unpublished manuscripts, L.M. Cline described the Amoret/Tina Limestone in a small area of north-central Madison County, Iowa, as "… two feet or less of limestone which is essentially a *Chaetetes* biostrome." and in the southeastern part of the county as "limestone; masses of *Chaetetes* embedded in a clay matrix [about 2 feet thick]". Northeast of Winterset in the C of the S line SW SE SE section 28, T. 77 N., R. 27 W., Madison County, are four feet (1.2 m) of skeletal wackestone with abundant chaetetids, just as in Cline's description of the Tina. Recent work by J.P. Pope (unpublished field notes), indicates that Cline (1941) was describing the post-Mulberry marine unit of Heckel and Pope (1992), or what is now named the Farlington Limestone by Heckel and others (1999), because the Farlington seems to be the only limestone to contain chaetetids in Madison County. Cline (1941), Cline and Greene (1950) and Cline and Stookey (1954), in unpublished cross-sections clearly show a paleosol, a lenticular coal, a thin limestone, and a phosphatic shale, in ascending order, between Cline's Tina/Amoret Limestone (Farlington of today) and the base of the overlying Worland Limestone, in sections in northern Missouri and southern Iowa.

The following summarizes the confusion due to miscorrelation of the Amoret and Farlington limestones in Iowa and Missouri in the 1940s and early 1950s. Although the type Lake Neosho Shale of Jewett (1941) overlies the unit now known as the Amoret Limestone, the Lake Neosho Shale as once used in northern Missouri and Iowa, where the Amoret Limestone is thin or absent, extended down to a unit that Heckel and Pope (1992) called the post-Mulberry marine unit, and which Heckel et al. (1999) renamed the Farlington Limestone from the Farlington quarry in southeast Kansas.

L.M. Cline (unpublished manuscript) described the McBride Limestone and designated a type section northwest of Winterset, in the C of the NE section 34, T. 77 N., R. 27 W. The McBride Limestone was named after the nearby McBride covered bridge. Recent work by J.P. Pope (unpublished field notes) indicates the McBride Limestone is actually the Farlington Limestone of Heckel and others (1999). Since the name 'McBride

Limestone' was never published, it was not used by later workers. Swade (1985) tentatively assigned a 1.5 foot (46 cm) thick zone of carbonate nodules in grayish green (10GY 5/2) shale near the top of the Bandera Shale in the CP-22 in Appanoose County, to the Amoret Limestone. This unit is probably the Farlington Limestone of Heckel and others (1999). Swade (1985) also assigned a 0.4 foot (12 cm) thick argillaceous, skeletal calcilutite, just below the Lake Neosho Shale and above a thin coal and paleosol, in the CP-37 Osceola core in Clarke County, to the Amoret Limestone. The base of the limestone is interlaminated with thin sandstones and carbonaceous green shale. This unit is probably the Amoret Limestone as it is defined today in Missouri and Iowa.

The name Amoret Limestone (Cline and Greene, 1950) was used to replace Tina in Kansas and Missouri for the limestone just below the Lake Neosho Shale. In Iowa, the Amoret Limestone is now defined as the thin [transgressive] limestone or fossiliferous shale above the McBride Coal bed (when present) at or near the top of the Bandera Shale or at the top of the paleosol in the Bandera Shale and below the dark gray (N3) to light gray (N7) shale facies of the overlying Lake Neosho Shale. In the Logan and Osceola cores the Amoret Limestone is a thin skeletal wackestone.

Reference sections are designated in the 121.1-121.3 foot interval in the Logan core, the 109.9-110.3 foot interval in the CP-37 Osceola core, and at an exposure at the waterfall about 2.5 miles (4.0 km) north northeast of Stuart, in the NW SW NW section 21, T. 78 N., R. 30 W., Guthrie County.

Bandera Shale

(new member and beds recognized)

The name Bandera Shale was originally used by Adams (1903) and was defined by Jewett (1941) from exposures near the old Bandera Railway Station in section 29, T. 25 S., R. 23 E., Bourbon County, Kansas. Greene (1933) included the Worland Limestone in the Bandera Shale, but Cline (1941) placed the Worland Limestone in the Altamont Formation, above the Bandera Shale.

L.M. Cline (unpublished manuscript) described the Worland Limestone and Lake Neosho Shale as members of the Altamont Formation, where the "Amoret" Limestone (now known to be Farlington at most places in northern Missouri and southern Iowa) was present. He also included the Lake Neosho Shale and strata equivalent to the true Amoret Limestone in the Bandera Shale where the "Amoret" Limestone (now known to be Farlington) was absent. Thus the Lake Neosho Shale and beds equivalent to the true Amoret Limestone could be in two formations at the same time.

The Bandera Shale, as now defined in Iowa, spans strata from the top of the Coal City Limestone Member of the Pawnee Formation to the base of the Amoret Limestone Member of the Altamont Formation. If the Amoret Limestone and/or McBride Coal are absent, the top of the Bandera Shale is placed at the top of the paleosol below the Lake Neosho Shale. In Iowa, the Bandera Shale includes two named beds and one named member in ascending order: Mulberry Coal bed, Farlington Limestone Member, and McBride Coal bed. In the Osceola core the Bandera Shale is mainly shale, siltstone and sandstone in the lower part, and red mudstone in the upper part. The Farlington Limestone occurs in the lower part of the Bandera Shale in the Logan core.

The 121.3-164.0 foot interval in the Logan core, the 110.3-144.2 foot interval in the CP-37 Osceola core, and an exposure in a west facing hill in a dirt road southwest of St. Charles, along the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County, are designated as reference sections.

McBride Coal bed

(newly named this report)

The McBride Coal bed is named in this report from exposures in a tributary ravine to North River about six miles (9.6 km) northeast of Winterset, in the NW NW SE section 3, T. 76 N., R. 27 W., Madison County, Iowa. The McBride Coal is lenticular and is usually only a smut below the Lake Neosho Shale or Amoret Limestone (if present). Cline (1941) and L.M. Cline (unpublished manuscripts) showed the coal in a cross-section across north-central Missouri. The name is derived from the nearby McBride covered bridge, which formerly spanned the North Branch of North River, about 1.2 miles (1.9 km) to the north of the type section. The McBride covered bridge no longer exists, but its former location is shown on the 1983 USGS St. Charles NW 7.5' topo sheet. The McBride Coal is often absent, and is seen only as carbonaceous debris in a shell "hash" or as a thin smut, in most of south-central Iowa.

At the type section the coal is 0.7 inch (1.8 cm) thick, where it underlies 1.5 feet (45 cm) of dark gray (N3) to light gray (N7) shale, and overlies 1.9 feet (58 cm) of coaly, rooted medium gray (N5) mudstone.

Farlington Limestone Member
(new name in Iowa)

The name Farlington Limestone was used by Heckel and others (1999) for exposures in a limestone quarry near the town of Farlington in the S1/2 SW section 31, T. 27 S., R. 24 E., Crawford County, Kansas.

In southeastern Madison County the Farlington Limestone is usually nodular skeletal wackestone with large chaetetids in a greenish gray (5GY 6/1) shale. Northeast of Winterset in Madison County, it is a four foot (1.2 m) thick skeletal wackestone with abundant chaetetids up to 15 inches (38 cm) across. See discussion of Amoret Limestone above.

Reference sections are designated in the 151.0-155.0 foot interval in the Logan core, at creek bank exposures along the intersection of a north-flowing and a west-flowing ravine in the NE SE SW NW section 26, T. 75 N., R. 26 W., Madison County, about 1.5 miles (2.4 km) southwest of St. Charles, and at a west-side backslope roadcut exposure 0.3 mile (0.4 km) north of the former McBride covered bridge in the SE NW NE section 34, T. 77 N., R. 27 W., Madison County. The latter is L.M. Cline's (unpublished manuscript) type section for the McBride Limestone (name never published nor used).

Mulberry Coal bed
(new name in Iowa)

A coal (Tina Coal) below Cline's (1941) Tina Limestone, and Cline and Stookey's (1954) Amoret Limestone (Amoret Coal), was originally named the Lonsdale Coal by St. John (1870) from exposures of a coal on the banks of Deer Creek at Lonsdale's mine in the NE section 20, T. 78 N., R. 30 W., Guthrie County, Iowa. The Lonsdale Coal of Iowa should not be confused with the Lonsdale Limestone (Cooper Creek Limestone of Iowa) described by Worthen (1873) near Peoria, Illinois. For this reason the name Lonsdale Coal will be dropped in Iowa.

Because of miscorrelations of the Amoret/Tina limestones by Cline, (1941) and Cline and Stookey (1954), these units in Iowa were not recognized as being equivalent to the post-Mulberry marine horizon of Kansas and Missouri, until much later (e.g., Heckel and Pope, 1992). The Mulberry Coal bed was named by Broadhead (1874) from exposures where it was mined in Bates County, Missouri. The name was derived either from exposures along Mulberry Creek (section 3, T. 40 N., R. 33 W.) or from the town of Mulberry (C W½ W½ section 10, T. 40 N., R. 33 W.), and probably was described from exposures in the highwalls of strip pits mining the Mulberry Coal in section 33 and/or section 34, T. 41 N., R. 33 W.

In Madison County, southwest of St. Charles, the Mulberry Coal varies from a smut to a few inches of coaly shale (J.P. Pope, unpublished field notes). The Mulberry Coal probably correlates with the Allenby Coal of southeastern Illinois (Ravn, 1986).

A reference section is designated at exposures in a tributary stream west-side cutbank to the Middle Raccoon River southwest of Redfield, in the SW NE SE NE section 4, T. 78 N., R. 30 W., southeastern Guthrie County. Here strata consist of, in ascending order: three feet (0.9 m) of light gray (N7), rooted, blocky mudstone, a 4-5 inch (10-12.5 cm) coal, 4-12 inches (10-30 cm) of light gray (N7) shale, ten inches of dark gray (N3) to black (N1) shale with compressed *Calamites*, a 14-16 inch (36-40 cm) coal, and four feet (1.2 m) of medium gray (N5) shale.

Pawnee Formation

(new member and bed recognized)

The name Pawnee was first used by Swallow (1866), and Moore (1936) described the type section along Pawnee Creek near the village of Pawnee (now called Anna) southwest of Fort Scott, Kansas. Keyes (1941) raised it to formation rank. The Pawnee was later defined by Jewett (1941) from roadcuts along Kansas Highway 7, just N of the C section 7, T. 27 S., R. 24 E., and also the middle of the E line of section 2, T. 27 S., R. 24 E., Bourbon County, Kansas.

In Iowa, the formation comprises five members and one bed in ascending order: Childers School Limestone, Anna Shale, Myrick Station Limestone, Mine Creek Shale, Imes Coal bed and Coal City Limestone (= Laberdie Limestone of Jewett, 1941). The Pawnee Formation overlies the Labette Shale and underlies the Bandera Shale.

Reference sections are designated in the 164.1-197.8 foot interval in the Logan core and in the 144.2-166.7 foot interval in the CP-37 Osceola core. Reference outcrop sections, which extend from the Coal City Limestone Member to strata below the Anna Shale Member are designated at a north-facing cutbank of the South Raccoon River about five miles (8.0 km) north northeast of Stuart, in the NW SE SW section 4, T. 78 N., R. 30 W., Guthrie County, and at an exposure in a west facing hill in a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County.

Coal City Limestone Member

(unchanged)

The Coal City Limestone was named by Cline (1941) from exposures in the east bluff of the Chariton River east of the now abandoned town of Coal City, in the S½ SW section 16, T. 67 N., R. 16 W., Appanoose County, Iowa. The location was erroneously reported by Cline (1941) as the SE quarter of section 16. The Coal City is correlated with the Laberdie Limestone of Kansas and Oologah Limestone in Oklahoma (Watney and Heckel, 1994; Heckel, 2002a). The Coal City Limestone Member overlies the Mine Creek Shale Member and underlies the Bandera Shale.

The Coal City Limestone was informally known as the ‘water rock’ in Putnam County, Missouri. In other areas of southern Iowa and northern Missouri, it was called the ‘seventeen foot limestone’, ‘eighteen foot limestone’ or ‘nineteen-foot limestone’ in reference to its stratigraphic position, approximately eighteen feet (5.5 m) above the Mystic Coal. In most of southern Iowa the Coal City Limestone is a single bed of skeletal wackestone to packstone, ranging from 1.0-4.5 feet (0.3-1.4 m) thick. In Appanoose County it contains fusulinids and chaetetids, but chaetetids have not been seen in the unit in Madison County.

The 164.1-168.5 foot interval in the Logan core, the 144.2-144.9 foot interval in the CP-37 Osceola core, an exposure in a west facing hill in a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County, and an exposure in a west-facing backslope roadcut about four miles (6.4 km) west northwest of Redfield, in the SW NE NE section 31, T. 79 N., R. 29 W., Dallas County, are designated as reference sections.

Mine Creek Shale Member

(new bed recognized)

The Mine Creek Shale was named by Jewett (1941) from exposures in a tributary to Mine Creek in the middle of the S line section 23, T. 21 S., R. 25 E., Linn County, Kansas. The Mine Creek Shale Member overlies the Myrick Station Limestone Member and underlies the Coal City Limestone Member. In Iowa, the Imes Coal bed occurs near the top of the shale, several inches below the Coal City Limestone. Thin sandy limestones and sandstone beds often occur in the Mine Creek Shale of Iowa and northern Missouri (Price, 1984; see Bisnett and Heckel, 1996, Fig. 5).

The 168.5-192.4 foot interval in the Logan core, the 144.9-163.3 foot interval in the CP-37 Osceola core, and an exposure in a west facing hill in a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County, are designated as reference sections.

Imes Coal bed
(newly named this report)

The Imes Coal bed is named in this report from an exposure in a north-side roadcut in a west facing hill on a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County. The name is derived from the Imes covered bridge that once sat on Clanton Creek about 0.5 mile (0.8 km) to the west northwest of the type section. The bridge is now situated on a ravine at the east edge of St. Charles. At the type section, the unit is about three inches (8.0 cm) of coal and black (N1) coaly shale, sitting on a rooted, blocky mudstone, and occurring about 18 inches (45 cm) below the Coal City Limestone.

The 172.0-172.5 foot interval in the Logan core and exposures in a west-facing backslope roadcut about four miles (6.4 km) west northwest of Redfield, in the SW NE NE section 31, T. 79 N., R. 29 W., Dallas County, where the coal is about 0.5-1 in (1.3-2.5 cm) thick, are designated as reference sections.

Myrick Station Limestone Member
(unchanged)

The Myrick Station Limestone was named by Cline (1941) from exposures in a ravine in the south bluff of the Missouri River valley, 0.25 mile (0.4 km) west of the Myrick railroad station just southwest of Lexington in the NW NE NW section 5, T. 50 N., R. 27 W., Lafayette County, Missouri. The Myrick Station Limestone Member overlies the Anna Shale Member and underlies the Mine Creek Shale Member.

The Myrick Station, in Iowa, was called the 'Mystic Caprock' in reference to its stratigraphic position a few feet above the Mystic Coal, and was called the Lexington Caprock in Missouri. In southern Iowa, the Myrick Station Limestone ranges from 0.5-2.0 feet (30.0-60.0 cm) of bioturbated skeletal wackestone to packstone. At a roadcut backslope northwest of Van Meter, in the W ½ SW NW SW section 21, T. 78 N., R. 27 W., Dallas County a large nautiloid and ammonoid were found in the Myrick Station (Wolf, et al., 1990).

Reference sections are designated in the 192.4-194.9 foot interval in the Logan core, the 163.3-164.5 foot interval in the CP-37 Osceola core, at a south side creek cutbank exposure north northwest of Stuart, in the SW NE NE NE section 7, T. 78 N., R. 30 W., Guthrie County, at an exposure in a west facing hill in a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Anna Shale Member
(unchanged)

The Anna Shale was named by Jewett (1941) from exposures "a little north of the C of section 7, T. 27 S., R. 24 E., Bourbon County, Kansas." P.H. Heckel in a 2003 personal communication with R. Gentile, had located the type section in the N½ S½ section 7, "… just south of the center of section 7, …" (Gentile and Thompson, 2004). Jewett (1941) redefined the base of the Pawnee so that it included in descending order: a black shale (Anna Shale), a thin lenticular limestone (more recently named the Childers School Limestone bed in Oklahoma) and a coal (Mystic Coal of Iowa or Lexington Coal of Missouri), all originally included in the underlying Labette Shale. He included all three units in the Anna Shale Member of the Pawnee Formation. Alcock (1942) excluded the limestone bed from the Anna Shale, and named it the Childers School Limestone. L.M. Cline (unpublished manuscript) placed the Anna Shale in the Labette Shale, because the Childers School Limestone is absent in most of northern Missouri and Iowa. In Iowa, the Anna Shale Member overlies the Mystic Coal of the Labette Shale or the Childers School Limestone bed (where present), and underlies the Myrick Station Limestone Member. Hinds (1909) reported that the Anna Shale in Appanoose County, Iowa, was sometimes bituminous [and fissile] and known as "slate," soft and clay-like and known as "clod," or heavy, homogenous, nonfissile and known as "black bat." In most of southern Iowa the Anna Shale is black (N1), fissile, phosphatic, and is rich in conodonts.

Reference sections are designated in the 194.9-198.7 foot interval in the Logan core, the 164.5-165.1foot interval in the CP-37 Osceola core, at south side creek cutbank exposures north northwest of Stuart, in the SW NE NE NE section 7, T. 78 N., R. 30 W., Guthrie County, at an exposure in a west facing hill in a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Childers School Limestone Member
(new name in Iowa)

The name Childers School Limestone was originally used by Alcock (1942) who designated a type section at a roadcut in the SE corner section 6, T. 26 N., R. 17 E. The actually location is in the SE corner section 1, T. 26 N., R. 16 E. (Price, 1981). Because the Childers School Limestone is well developed in northern Oklahoma, Alcock (1942) excluded the limestone bed below the black shale from the Anna Shale, where it was placed by Jewett (1941). The Childers School Limestone was extended from northern Oklahoma into Kansas by Price (1981, 1984). Jewett (1945) reported a thin limestone at the base of the Anna Shale, which extends from Missouri to Oklahoma. Jefferies (1958) also recognized this limestone in Bates County, Missouri, and placed the base of the Anna Shale at the base of the limestone. In Iowa, the Childers School Limestone and equivalents will include strata from the top of the underlying Mystic Coal to the base of the black fissile facies of the overlying Anna Shale.

A reference section is designated in the 138.2-138.6 foot interval in the CP-22 core in Appanoose County, above the Mystic Coal and below the black fissile Anna Shale, where there is 0.5 feet (15 cm) of dark gray (N3) calcareous, fossiliferous (chaetetids, ostracodes, brachiopods) shale with argillaceous, lenticular calcarenite near the base (Swade, 1985).

A reference section is also designated in the 165.1-166.7 foot interval in the CP-37 Osceola core in Clarke County. This interval consists of 1.5 feet (45 cm) of brownish black (5YR 2/1) to black (N1) shale with carbonaceous debris. A thin zone of fossil debris (linguloid and calcareous brachiopods, pyritized clams, and ostracodes) is present near the base. Four inches (10 cm) above the base is echinoderm debris and thin lenticular limestones, including a whole-shell gastropod-rich calcilutite and an argillaceous skeletal calcarenite near the top of the unit (O'Brien, 1977; Swade, 1985). L.M. Cline (unpublished manuscript) reported a brachiopod-rich shale below the black fissile facies of the Anna Shale, in Iowa.

Labette Shale
(unchanged)

The Labette Shale was named by Haworth (1898) from exposures near the town of Labette, Labette County, Kansas. A type section was formally designated by Jewett (1941) at exposures eastward from the C of the N line to the NE corner of section 22, T. 33 S., R. 20 E. Keyes (1897) had used the name Marmaton, for what is now the Labette. Originally the Labette Shale included all strata between the top of the upper Fort Scott Limestone (Higginsville) and the base of the lower Pawnee Limestone (Myrick Station). Jewett (1941) redefined the base of the Pawnee so that it included a black shale, a thin lenticular limestone and coal originally included in the Labette, and named this interval the Anna Shale. The Labette Shale, as defined in Iowa, includes all strata above the top of underlying Higginsville Limestone in the Stephens Forest Formation and below the base of the overlying Anna Shale or base of the Childers School Limestone (where present) in the Pawnee Formation.

In Iowa, the Labette Shale is variable in thickness and composition, and often contains blocky mudstones and thin sandstones as well as shale and coal. In Iowa, the Labette usually contains two named coals, the stratigraphically lower Marshall Coal and the Mystic Coal at the top of the formation, but north of Stuart in the SW NE NE NE section 7, T. 78 N., R. 30 W., Guthrie County, it contains three coals. The Labette Shale thickens to the south, and in Missouri, Kansas, and Oklahoma may contain more than two coals, sandstone units, and several thin limestones below the Mystic Coal.

Reference sections are designated in the 138.6-142.5 foot interval in the CP-22 core, the 166.7-181.8 foot interval in the CP-37 Osceola core, at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County, and at south side creek cutbank exposures north northwest of Stuart, in the SW NE NE NE section 7, T. 78 N., R. 30 W., Guthrie County.

Mystic Coal bed
(reduced in rank)

The Mystic Coal was named by Keyes (1894) from exposures near the town of Mystic, northwest of Centerville along Walnut Creek in the NE SW section 17, T. 69 N., R. 18 W., Appanoose County, Iowa. The Mystic Coal in Appanoose County is split by two clay seams, and the lower Labette (Marshall Coal) does not seem to be present, but it may correlate with the lower and/or middle coal of the three beds of the Mystic Coal (Hinds, 1909). The Mystic Coal is correlated with the Lexington Coal of Missouri (Peppers, 1970), and the Herrin (No. 6) Coal of Illinois (Hopkins and Simon, 1975; Ravn, 1986). A section given by Bain (1896) for Appanoose County, shows in ascending order: 1-6 feet of fireclay, 2-3 inch coal, 0.5 inch clay parting (the “Dutchman”), 8-10 inch coal (lower bench), 2-3 inch clay parting (“mud band”), one foot 10 inch coal (upper bench).

Reference sections are designated in the 138.6-141.0 foot interval in the CP-22 core, the 166.7-167.1 foot interval in the CP-37 Osceola core, at south side creek cutbank exposures north northwest of Stuart, in the SW NE NE NE section 7, T. 78 N., R. 30 W., Guthrie County, at an exposure in a west facing hill in a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Marshall Coal bed
(reduced in rank)

The Marshall Coal was named by St John (1870) for a coal at Marshall’s Mine in the NW section 24, T. 78 N., R. 30 W., Guthrie County, Iowa. The Marshall Coal has also been called the Lower Mystic Coal. L.M. Cline (unpublished manuscripts on Guthrie County) correlated the type Marshall Coal with the Albia (Bevier of today’s use) Coal of the stratigraphically lower Swede Hollow Formation. The author follows the nomenclature of Hershey and others (1960) and later workers (e.g., Ravn et al., 1984) and uses the name Marshall for the lower coal, until the type Marshall Coal is restudied. The Marshall Coal may be the equivalent of the Alvis Coal of Missouri and probably correlates with the Briar Hill (No. 5A) Coal of southeastern Illinois (Ravn, 1986). Near the type Clanton Creek Limestone southwest of St. Charles, the Marshall Coal is about one foot (30 cm) thick, and is overlain by three inches (7.6 cm) of ostracode-rich shale and cone-in-cone calcite (see Heckel and Pope, 1992).

Reference sections are designated at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County, at south side creek cutbank exposures north northwest of Stuart, in the SW NE NE NE section 7, T. 78 N., R. 30 W., Guthrie County, and at a creek bank exposure southwest of St. Charles, in the SW SW SW SW section 23, T. 75 N., R. 26 W., Madison County.

Stephens Forest Formation
(new member recognized)

The Stephens Forest Formation was named by Ravn and others (1984) from exposures along the C of the E line [NW SW NE] of NW section 18, T. 72 N., R. 22 W., Lucas County, Iowa. It was named after Stephens State Forest, with nearby tracts found south of the town of Lucas about 1.5 miles (2.4 km) to the southwest of the type section. At the type section the Stephens Forest Formation consists of 2.5 feet (0.75 m) of black (N1), fissile, phosphatic, conodont-rich Little Osage Shale, overlain by 8.6 feet (2.58 m) of greenish gray (5GY 6/1) to light gray (N7) fossiliferous shale and 4.8 inches (12 cm) of light gray (N7) Higginsville Limestone. The Houx Limestone is not present, so the boundary between the Little Osage Shale and the overlying Blackwater Creek Shale is placed at the top of the black (N1) fissile shale. The Stephens Forest Formation overlies the Morgan School Shale and underlies the Labette Shale.

In Iowa, the Stephens Forest Formation comprises five members in ascending order: Clanton Creek Limestone, Little Osage Shale, Houx Limestone, Blackwater Creek Shale, and Higginsville Limestone.

Reference sections are designated in the 142.5-165.7 foot interval in the CP-22 core, the 181.8-209.0 foot interval in the CP-37 Osceola core, at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County, and at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C NE NE section 31, T. 79 N., R. 29 W., Dallas County.

Higginsville Limestone Member
(unchanged)

The Higginsville Limestone was proposed by F.C. Greene (in a personal communication to L.M. Cline in 1940) for the upper limestone of the Ft. Scott Formation. The Higginsville was formally named by Cline (1941) from exposures east of the town of Higginsville, Lafayette County, Missouri, but a type section was never designated. Thompson (2001) designated a type section at exposures four miles (6.4 km) southwest of Higginsville, in a ravine north of a gravel road near the C of the NW SW SE section 15, T. 49 N., R. 26 W. Gentile and Thompson (2004) designated a principal reference section at an exposure in a ravine in the south bluff of the Missouri River Valley, 0.75 mile (1.2 km) west of Lexington, in the vicinity of the former location of Myrick railroad station NE NW NE section 5, T. 50 N., R. 27 W., Lafayette County, Missouri.

The Higginsville Limestone Member overlies the Blackwater Creek Shale Member and underlies the Labette Shale. The Higginsville Limestone was sometimes called the ‘Mystic sump rock’ or ‘Mystic bottom-rock’ by early workers and miners in Iowa and ‘Lexington sump rock’ or ‘Lexington bottom-rock’ by those in Missouri. In Iowa, the Higginsville Limestone varies from an argillaceous skeletal wackestone with brachiopods and fusulinids to calcareous nodules in a fossiliferous shale.

Reference sections are designated in the 142.5-146.8 foot interval in the CP-22 core, the 181.8-191.0 foot interval in the CP-37 Osceola core, at a roadcut backslope northwest of Van Meter, in the W ½ SW NW SW section 21, T. 78 N., R. 27 W., Dallas County, at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C NE NE section 31, T. 79 N., R. 29 W., Dallas County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Blackwater Creek Shale Member
(new name in Iowa)

The Blackwater Creek Shale (misprinted as Backwater Creek Shale in some of L.M. Cline’s unpublished manuscripts) was named by Clair (1943) on a stratigraphic column, but he did not designate a type section or region from which the name was derived. The name was probably derived from the South Fork Blackwater River in Johnson or Cass counties, Missouri. Greene and Searight (1949) defined the Blackwater Creek Shale as shale overlying the Houx Limestone and underlying the Flint Hill Sandstone (just below the Higginville Limestone). The name was last used in Missouri by Howe and Searight (1953), but was resurrected and used by Heckel and Pope (1992) in Iowa. Gentile and Thomson (2004) designated a type section in a stream cutbank tributary to Rocky Fork Creek on the east side of U.S. Highway 63 at the western edge of Fingers Lake State Park, Boone County, Missouri. In Iowa, the Blackwater Creek Shale includes all strata overlying the Houx Limestone Member, or Little Osage Shale Member where the Houx Limestone Member is absent, and underlying the Higginsville Limestone Member.

Cline (1941) described a carbonaceous zone (coal and shale) below the Higginsville Limestone in northern Appanoose, Dallas, Guthrie, and Polk counties in Iowa and Adair County, Missouri. A dark carbonaceous streak at the type Clanton Creek Limestone section southwest of St. Charles in Madison County (J.P. Pope, unpublished field notes), may correlate with this coal. The coal will not be named at this time. In Madison County the Blackwater Creek Shale is mainly a greenish gray (5GY 6/1) to grayish red (10R 4/2) mottled, blocky mudstone below the unnamed coal, with light gray (N7) shale above.

Reference sections are designated in the 146.8-161.1 foot interval in the CP-22 core, the 191.0-204.5 foot interval in the CP-37 Osceola core, at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C NE NE section 31, T. 79 N., R. 29 W., Dallas County, at a west-facing cutbank of Preston Branch west of Madrid, at the SW NE NE section 33, T. 82 N., R. 26 W., Boone County, and at a south-side cutbank exposure in a tributary ravine to Clanton Creek near Hanley, in the NE SE NW section 22, T. 75 N., R. 26 W., Madison County.

Houx Limestone Member
(unchanged)

The Houx Limestone Member was proposed by F.C. Greene (in a letter to L.M. Cline in 1940) and formally named by Cline (1941) from exposures in the backslope of a gravel driveway at Houx Ranch northwest of Centerview, in the NE section 15, T. 46 N., R. 27 W., Johnson County, Missouri. In Iowa, the Houx Limestone Member is lenticular, and where present is generally only about 0.3 feet (9.1 cm) thick, but increases to almost one foot (30 cm) in the CP-22 core in Appanoose County. The Houx Limestone Member was called the 'Rhomboidal limestone' by early workers (e.g., Broadhead, 1874, Missouri Geological Survey) in reference to the way it broke along joint planes. At the Clanton Creek Limestone type section in Madison County, the Houx is 1.2 feet (36.6 cm) of limestone nodules in fossiliferous shale. At a roadcut backslope northwest of Van Meter, in the SE SE section 20, and SW SW section 21, T. 78 N., R. 27 W., Dallas County, the Houx is represented by six inches (15 cm) of lenticular skeletal wackestone. In Iowa, the Houx is defined as limestone or calcareous, fossiliferous shale lying between the black facies of the Little Osage Shale Member and the blocky mudstone of the Blackwater Creek Shale Member.

Reference sections are designated in the 161.1-162.1 foot interval in the CP-22 core, the 204.5-204.9 foot interval in the CP-37 Osceola core, at a roadcut backslope northwest of Van Meter, in the W ½ SW NW SW section 21, T. 78 N., R. 27 W., Dallas County, and at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C NE NE section 31, T. 79 N., R. 29 W., Dallas County.

Little Osage Shale Member
(unchanged)

The Little Osage Shale was named by Jewett (1941) from exposures along the Little Osage River in the NE SE section 2, T. 24 S., R. 25 E., Bourbon County, Kansas. The Little Osage originally encompassed all strata from the top of the Blackjack Creek Limestone to the base of the Higginsville Limestone (e.g., Cline and Stookey, unpublished strat-section). This definition is still used for the Little Osage Formation by Gentile and Thompson (2004) in Missouri. In Iowa, Ravn et al. (1984) restricted the name 'Little Osage Shale' to the dark gray (N3) to black (N1) phosphatic shale above the Summit Coal or Clanton Creek Limestone (where present) to the base of the Houx Limestone (where present) or Blackwater Creek Shale.

In Iowa, the Little Osage Shale Member overlies the Clanton Creek Limestone Member or the Morgan School Shale where the Clanton Creek Limestone is absent. It underlies the Houx Limestone Member or the Blackwater Creek Shale Member where the Houx Limestone Member is absent. The author follows the restricted usage of the Little Osage Shale used by Ravn and others (1984).

The Little Osage Shale of Iowa, correlates with the Binkley Shale of Missouri (Gentile and Thompson, 2004). At a roadcut backslope northwest of Van Meter, in the SE SE section 20, and SW SW section 21, T. 78 N., R. 27 W., Dallas County, it is black (N1) and phosphatic in the bottom part and light gray (N7) in the upper part, and contains cartilaginous fish material, mainly the dermal denticle, *Petrodus patelliformis,* and abundant conodonts.

Reference sections are designated in the 162.1-165.2 foot interval in the CP-22 core, the 204.9-206.4 foot interval in the CP-37 Osceola core, at a roadcut backslope northwest of Van Meter, in the W ½ SW NW SW section 21, T. 78 N., R. 27 W., Dallas County, at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C of the NE NE section 31, T. 79 N., R. 29 W., Dallas County, at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County, and at a south-side cutbank exposure in a tributary ravine to Clanton Creek south of Hanley, in the NE SE NW section 22, T. 75 N., R. 26 W., Madison County (Clanton Creek Limestone type section).

Clanton Creek Limestone Member
(new name in Iowa)

The Clanton Creek Limestone Member was named by Heckel and Pope (1992) from south-side cutbank exposures in a tributary ravine to Clanton Creek in the NE SE NW section 22, T. 75 N., R. 26 W., near the town of Hanley, Madison County, Iowa.

The limestone is lenticular, but occurs in wells and outcrops from Iowa to Kansas. At the type section, the Clanton Creek is about one foot (30 cm) of skeletal packstone overlain by four inches (5 cm) of nodular skeletal wackestone. At a roadcut backslope northwest of Van Meter, in the SE SE section 20, and SW SW section 21, T. 78 N., R. 27 W., Dallas County, it is represented by a 1.2 inch (3 cm) fossil hash (mainly the brachiopods *Desmoinesia muricata*, *Mesolobus mesolobus*, and *Linoproductus* sp.) and limestone lenses. In the CP-37 Osceola core in Clarke County, this interval is about three feet (0.91 m) of fossiliferous, calcareous shale. In the CP-22 core in Appanoose County, it is six inches (15.2 cm) of interbedded medium gray (N5) argillaceous skeletal wackestones to packstones and medium dark gray (N3) shale with carbonaceous debris in the lower portion. The Clanton Creek Limestone Member overlies the Morgan School Shale and underlies the Little Osage Shale Member.

Reference sections are designated in the 165.2-165.8 foot interval in the CP-22 core, the 206.4-207.6 foot interval in the CP-37 Osceola core, at a roadcut backslope northwest of Van Meter, in the W ½ SW NW SW section 21, T. 78 N., R. 27 W., Dallas County, at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C NE NE section 31, T. 79 N., R. 29 W., Dallas County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

MORGAN SCHOOL SHALE
(unchanged)

The Morgan School Shale was named by Ravn and others (1984) from exposures along the C of the E line of NW [NW SW NE] section 18, T. 72 N., R. 22 W., Lucas County, Iowa. The Morgan School Shale was named after the former site of the Morgan School about one mile (1.6 km) to the southeast of the type section. The Morgan School Shale overlies the Mouse Creek Formation and underlies the Stephens Forest Formation. The Summit Coal bed occurs at the top of the shale where the Clanton Creek Limestone Member of the Stephens Forest Formation is absent. If both the Summit Coal bed and Clanton Creek Limestone Member are absent, the top of the formation is placed at the position of the Summit Coal (top of the paleosol) or the base of the black (N1) fissile facies of the Little Osage Shale if the top of the paleosol is not obvious. At the type section, the Morgan School Shale consists of 5.6 feet (1.68 m) of moderate olive brown (5Y 4/4) shale and mudstone, overlain by 1.2 inches (3.0 cm) of Summit Coal.

Reference sections are designated in the 165.8-182.0 foot interval in the CP-22 core, the 207.6-209.7 foot interval in the CP-37 Osceola core, at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C of the NE NE section 31, T. 79 N., R. 29 W., Dallas County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Summit Coal bed
(reduced in rank)

The Summit Coal bed was named by McGee (1888), probably from exposures in a coal strip pit in the area of T. 56 N., R. 14 W. (no specific type section was ever designated), in Macon County, Missouri (Gentile and Thompson, 2004). The Summit Coal in Iowa, is usually no more than one inch (2.5 cm) thick, but in the IGS CP-37 Osceola core (W-27337) in Clarke County, there is an eight inch (20 cm) zone (209.0-209.7 foot interval) of interbedded black (N1) carbonaceous shale and coal with calcareous fossil debris. The Summit Coal bed lies at or near the top of the Morgan School Shale. The Summit Coal correlates with the Springfield (No. 5) Coal (northern) and Harrisburg (No. 5) Coal (southeastern) of Illinois (Peppers, 1970; Ravn, 1986).

Reference sections are designated in the 0.5 inch (1.3 cm) thick coal just below the 165.8 foot horizon in the CP-22 core, at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C of the NE NE section 31, T. 79 N., R. 29 W., Dallas County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Mouse Creek Formation
(unchanged)

The Mouse Creek Formation was named by Ravn and others (1984) from exposures in a gully along Whitebreast Creek in the NW NE NE section 8, T. 73 N., R. 22 W., Lucas County, Iowa. The actual location is just south of a gravel road in the NW NE NE section 8, T. 72 N., R. 22 W. (M. Howes, 2002, personal communication). The Mouse Creek Formation is named after Mouse Creek about five miles (8 km) to the west-northwest of the type section. At the type section of the Mouse Creek, the formation overlies the 1.2 inch (3 cm) thick Mulky Coal and 14.2 feet (4.26 m) of light green gray (5G 8/1) Swede Hollow Formation shale and mudstone. The type Mouse Creek consists of 2.0 feet (0.6 m) of dark gray (N7) phosphatic, conodont-rich shale, overlain by 2.9 feet (0.87 m) of light olive brown (5Y 5/6) calcareous mudstone (Excello Shale). The Blackjack Creek Limestone is only present as float blocks.

Since the Blackjack Creek Limestone Member is not present at the Mouse Creek type section of Ravn and others (1984) and it is difficult to access, a new type section (neostratotype) is designated for the Mouse Creek Formation at exposures in a south-facing roadcut backslope east of Booneville, in the S½ NW NE section 29, T. 78 N., R. 26 W., Dallas County, Iowa.

The Mouse Creek Formation overlies the Swede Hollow Formation (Cherokee Group) and underlies the Morgan School Shale. The Mouse Creek comprises two named members in ascending order: Excello Shale and Blackjack Creek Limestone.

Reference sections are designated in the 182.0-187.9 foot interval in the CP-22 core, the 209.7-216.9 foot interval in the CP-37 Osceola core, at a west-side cutbank of the Middle Raccoon River northwest of Redfield, in the C of the NE NE section 31, T. 79 N., R. 29 W., Dallas County, at an exposure in the north ditch of a dirt road northwest of Liberty Center, in the SW section 8, T. 74 N., R. 23 W., Warren County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Blackjack Creek Limestone Member
(unchanged)

The Blackjack Creek Limestone Member was proposed by F.C. Greene (in a letter to L.M. Cline in 1940) for the lower limestone of the Ft. Scott Formation, and was formally named by Cline (1941) from outcrops (mentioned by Hinds in 1912) along Blackjack Creek, four miles (6.4 km) southeast of Fayetteville, in T. 47 N., R. 25 W., Johnson County, Missouri. Since no type section was formally designated, Gentile and Thompson (2004) designated a section described by Cline (1941), as the type section. This outcrop is 0.5 mile (0.8 km) west of the U.S. Highway 50 bridge over the South Fork of the Blackwater River, in the backslope of a driveway leading to the Houx Ranch, in the NW NE NE section 15, T. 46 N., R. 27 W., Johnson County, Missouri. Early geologists in Iowa and Missouri, called the Blackjack Creek Limestone the ‘Mulky cap-rock’ (e.g., Hinds, 1912), and in Kansas it was called the lower Fort Scott Limestone. The Blackjack Creek Limestone Member overlies the Excello Shale Member and underlies the Morgan School Shale.

In Dallas County the limestone is an argillaceous skeletal wackestone to packstone with shaly zones, and is very fossiliferous, containing a diverse open marine invertebrate fauna, including the triangular bryozoan *Prismopora* sp. and the fusulinid foraminifer *Beedina* (=*Fusulina*) *girtyi*.

Reference sections are designated in the 182.0-185.1 foot interval in the CP-22 core, the 209.7-214.0 foot interval in the CP-37 Osceola core, at exposures in a south-facing roadcut backslope east of Booneville, in the S½ NW NE section 29, T. 78 N., R. 26 W., Dallas County (neostratotype of the Mouse Creek Formation), at an exposure in the north ditch of a dirt road northwest of Liberty Center, in the SW section 8, T. 74 N., R. 23 W., Warren County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Excello Shale Member
(unchanged)

The Excello formation (equivalent to Excello Shale Member in Iowa) was named by Searight and others (1953) from exposures of black shale in the highwall of a coal mine strip pit 2.6 miles (4.2 km) west of the town of Excello, in the NW section 30, T. 56 N., R. 14 W., Macon County, Missouri. Since the Excello is no longer exposed at the type section, Gentile and Thompson (2004) proposed a new type section (neostratotype), 2.5 miles (4.0 km) northeast of Blairstown, in the west cutbank of Morris Creek, 100 ft (30 m) south of SW JC road in the NW NE NW NW section 33, T. 44., R. 27 W., Henry County, Missouri. Prior to O'Brien (1977) the Excello Shale was not officially recognized in Iowa, but its distinctive black shale facies was considered the top of the Cherokee Group.

Northeast of Medora (Warren County) and east of Booneville (Dallas County) the black fissile facies is conodont-rich and contains numerous well-preserved radiolarians in phosphate nodules and large dark gray (N3) to black (N1) calcilutite concretions (Pope, 2006; Pope, Nestell and Nestell, 2010; Nestell, Pope, and Nestell, ms in press). These concretions, often with pyritic rinds, have also been reported in Missouri, Kansas, Oklahoma and Illinois (e.g., James, 1970; J.P. Pope, unpublished field notes), and do not represent a transgressive limestone, but instead they seem to be early diagenetic features within the black facies of the shale (Pope, 2006; Pope, Nestell and Nestell, 2010). The Excello Shale Member overlies the Mulky Coal of the Swede Hollow Formation and underlies the Blackjack Creek Limestone Member.

Ravn and others (1984) designated a reference section in the NW NE NE section 8, T. 73 N., R. 22 W., at an outcrop along a west flowing ravine to Whitebreast Creek, Lucas County, Iowa. The actual location is just south of a gravel road in the NW NE NE section 8, T. 72 N., R. 22 W. The author is designating reference sections in the 185.1-187.9 foot interval in the CP-22 core, the 214.0-216.9 foot interval in the CP-37 Osceola core, at exposures in a south-facing roadcut backslope east of Booneville, in the S ½ NW NE section 29, T. 78 N., R. 26 W., Dallas County (neostratotype of the Mouse Creek Formation), at an exposure in the north ditch of a dirt road northwest of Liberty Center, in the NE SW SW section 8, T. 74 N., R. 23 W., Warren County, and at a west-facing cutbank of Preston Branch west of Madrid in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Unnamed limestone below Excello Shale
(not named in this report)

Searight and Howe (1961) mentioned a thin lenticular limestone between the base of the black (N1) fissile shale facies of the Excello Shale and the underlying Mulky Coal, at some localities in Missouri. J.P. Pope (unpublished field notes) recognized calcareous lenses at this horizon, at the Excello Shale neostratotype in Henry County, Missouri. James (1970) noted a thin, four inch (10 cm) thick, basal shell coquina in the Excello Shale in outcrops and cores from Oklahoma to the Illinois Basin. A thin limestone and fossiliferous shale is described in the CP-37 Osceola core in Clarke County, Iowa (O'Brien, 1977; Swade, 1985), and was seen (J.P. Pope, unpublished field notes) at an exposure in the north ditch of a dirt road northwest of Liberty Center, in the NE SW SW section 8, T. 74 N., R. 23 W., Warren County. The lenticular limestone seen at this horizon at the Excello Shale neostratotype outcrop in Henry County, Missouri, is currently under study by J.P. Pope and B.S. Hunter. No name is proposed for this interval at this time, and it is currently included in the Excello Shale.

CHEROKEE GROUP
(new formations, members, beds recognized)

The Cherokee Group (Figure 8) was named by Haworth and Kirk (1894) from exposures in Cherokee County in southeastern Kansas. In most of Iowa and the northern Midcontinent shelf, the Cherokee Group represents the basal major Pennsylvanian unit, lying above Mississippian and locally older strata and underlying the Marmaton Group. In Iowa, the Cherokee Group encompasses strata of the Desmoinesian and Atokan stages, with a possibility of Morrowan strata at its base. The Morrowan has not been recognized in the Forest City Basin in southwest Iowa, but may possibly be found in coal project cores in southeast Iowa, pending further conodont studies (personal communication, T.R. Marshall and B.J. Witzke, 2009).

In 1953, Searight and others adopted the Krebs and Cabaniss groups to replace the Cherokee Group, at a conference of several state geological surveys (Iowa, Kansas, Missouri, Nebraska, and Oklahoma), but Iowa did not fully agree with the classification. Despite ratification of the Krebs and Cabaniss groups, the Cherokee Group continued to be used in Iowa and throughout the Midcontinent. The Krebs and Cabaniss are still used as subgroups in Missouri and Oklahoma, but as formations in Kansas.

The Iowa Geological Survey Coal Division Coal Project, which ended in 1979, provided the first practical means of correlating beds in the Cherokee Group in Iowa. Ravn (1979), Ravn and others (1984), and Ravn (1986) established a biostratigraphic zonation for the group, based on palynology.

Prior to 1984 (e.g., Landis and Van Eck, 1965) the Cherokee-Marmaton boundary was placed at the base of the Blackjack Creek Limestone. Ravn and others (1984) placed the boundary at the base of the Excello Shale, the lowest recognized marine unit in the Marmaton. This was more consistent with other Marmaton Group and younger Pennsylvanian formations (especially in the Missourian Stage), which are divided on the basis of the cyclic nature of their sedimentation. These sedimentary cycles are usually divided into two formations: 1) a marine formation dominated by limestones and marine shales and 2) a nonmarine formation dominated by nonmarine to marginal marine clastics.

The Cherokee Group has been divided into a number of cyclothemic successions in Missouri (Gentile and Thompson, 2004), but Ravn and others (1984) designated only four formations within the Cherokee Group of Iowa, similar in scale to the divisions designated by the Kansas and Oklahoma surveys. At this time, pending further study of the strata below the Verdigris Formation, The author proposes five formations for the Cherokee of Iowa, in ascending order: Kilbourn, Kalo, Floris, Verdigris and Swede Hollow, of which the Verdigris is newly recognized in Iowa as a separate formation.

The Cherokee Group averages about 400 feet (122 m) thick in its type region in Kansas to about 500 feet (152 m) in south-central Iowa, and about 750 feet (320 m) thick in southwest Iowa. It thickens to over 800 feet (244 m) near the Iowa-Missouri-Nebraska border region in the Forest City Basin, north of the Bourbon Arch and east of the Nemaha Uplift. It also thickens south of the Bourbon Arch to at least 2500 feet (762 m) in northeastern Oklahoma near the Arkoma Basin (Heckel, 1999).

The Verdigris cyclothem (including the Ardmore Limestone) is the only easily recognized major marine cyclothem within the group, and is traceable from Iowa to Oklahoma. The Carruthers is another major marine cycle, but not all of the cyclothem members are well-developed or are seen at any one location. Several other minor and intermediate cyclothems (e.g. Bevier, Wheeler, Thousand Acre) contain conodont-rich zones and thin (often lenticular) limestones.

The Cherokee Group contains most of the coal resources of Iowa (Landis and Van Eck, 1965; Ravn, 1979) and the Midcontinent region. Major Cherokee Group coals in Iowa include the Blackoak, Cliffland, 'Laddsdale', Carruthers, Whitebreast, Wheeler, Bevier and Mulky, in ascending order.

In order to understand and adequately describe the Cherokee Group, I have described a series of unnamed shale, mudstone, and sandstone intervals between the named units, in the Swede Hollow and Floris formations. The

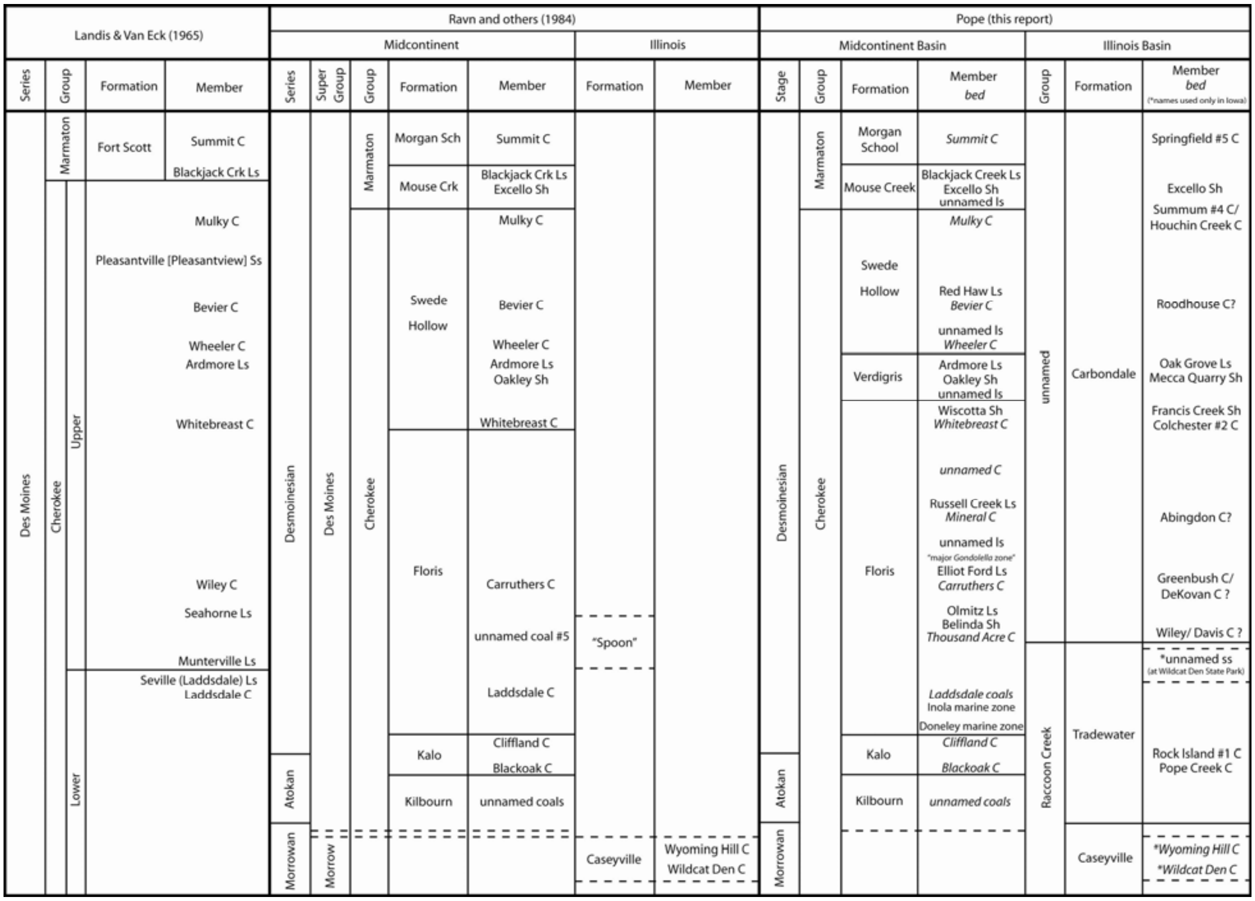

Figure 8. Lower Desmoinesian Stage (Cherokee Group and lower Marmaton Group) stratigraphy in Iowa, with Illinois basin correlations.

author has also described and designated reference sections for these unnamed intervals. See sections on Swede Hollow and Floris formations below.

The 233.0-582.0 foot interval in the Logan core in Harrison County is designated as a reference core for the entire Cherokee Group. Other partial cores are used to reference specific units in the Cherokee Group (see formation descriptions below). It should be noted that the identities of certain units and their horizons (mainly below the Oakley Shale) in many of the Iowa Geological Survey (IGS) Coal Project cores and other cores are uncertain, pending study of associated marine units and their conodont faunas. Most of these early stratigraphic "picks" were based on palynology and counting of coal beds above or below relatively recognizable units. In many cases the palynology did not give enough resolution, and the lenticular nature of units made counting coal beds uncertain.

Below the Oakley Shale, only cores that have been studied using conodont data (e.g., the Logan core in Harrison County, the CP-78 core in Wayne County, and the CP-79 core in Lucas County) can be used with any certainty.

Swede Hollow Formation

(revised; restricted; new member recognized)

The Swede Hollow Formation was named by Ravn and others (1984) from a series of streamcut exposures along a tributary (Swede Hollow) to Whitebreast Creek south of Oakley, in sections 33 and 34, T. 73 N., R. 22 W., and section 3, T. 72 N., R 22 W., Lucas County, Iowa. The original definition of the Swede Hollow was all strata between the base of the

Whitebreast Coal at the bottom, and the base of the Excello Shale at the top (Ravn et al., 1984). The Swede Hollow (as defined in this report) spans strata from the top of the Ardmore Limestone to the base of the Excello Shale, after placing the Oakley Shale and Ardmore Limestone in the newly erected Verdigris Formation (this report). The Swede Hollow Formation overlies the Verdigris Formation, and underlies the Mouse Creek Formation of the Marmaton Group.

At this time only relatively continuous limestone and coal units within the Swede Hollow Formation will be named. In descending order these are the: Mulky Coal bed, Red Haw Limestone Member, Bevier Coal bed, and Wheeler Coal bed. These units are important in developing a cyclothemic framework for the Pennsylvanian upper Cherokee Group of Iowa, and for purposes of mapping, most of these units are relatively continuous into other states. Because of the uncertainty involved in correlating laterally discontinuous and highly variable sandstone bodies and shales, the thicker detrital units between the above named members and beds will not be formally named.

Ravn and others (1984, Fig. 22, p. 36) used three cores as reference cores for the Swede Hollow. Intervals for these units in these cores are: the 216.8-307.8 foot interval in the CP-37 Osceola core in Clarke County, the ~117.4-205 foot interval in the CP-76 core in Appanoose County, and the 228.5-309.8 foot interval in the CP-78 core in Wayne County. The author has also designated outcrop reference sections for the intervals between the named units. See unnamed units below.

Unnamed detrital strata between base of Excello Shale Member of Mouse Creek Formation and base of Red Haw Limestone or top of Bevier Coal bed (no name proposed at this time)

No names are proposed at this time for the various shale, mudstone and sandstone units, averaging 50-60 feet (15-18 m) thick, below the Excello Shale and above the top of the Red Haw Limestone Member or above the Bevier Coal bed if the Red Haw Limestone is absent. The Mulky Coal bed occurs near or at the top of the unit.

Cline (1941) placed the lower boundary of the Marmaton Group (upper boundary of the Cherokee Group) at an unconformity at the base of a sandstone that occurs below the Mulky Coal and above the Bevier Coal. Locally a sandstone (and probably several sandstones), below the Mulky Coal, cut down thru strata as low as the Bevier and Wheeler coals (Cline, 1941). In the abandoned Redfield clay pit in the northwest corner of the town of Redfield, Dallas County, a sandstone cuts down through the Ardmore Limestone and underlying Whitebreast Coal. The top of this sandstone is assumed to be above the Bevier Coal.

These sandstones have been known locally by the names ‘Albia’, ’Panora’, ‘Andys Branch’ and ‘Lagonda’ from various exposures in Iowa and Missouri. In Oklahoma (Greene, 1933) and Missouri, drillers have informally called these sandstones the ‘Squirrel sand [Sandstone]’ in reference to the way the sandstones ‘tend to jump around’ or appear at different stratigraphic horizons in different drill holes (Pierce and Courtier, 1938; Cargo, 1982; see Gentile and Thompson, 2004). These sandstones were also known as the ‘Prue’ sandstone in Missouri. There may be three or more sandstones in the interval between the Bevier Coal and the Mulky Coal at several different stratigraphic horizons in Iowa and northern Missouri. Most of these sandstones are inferred to have been deposited in river channels and paleovalleys.

In Iowa the sandstone(s) in this interval were usually called the ‘Pleasantview’ (Weller et al., 1942), a name applied by Ekblaw (1931) for a sandstone occupying a similar stratigraphic position near the town of Pleasantview, Schuyler County, Illinois. Landis and Van Eck (1965, Fig. 4, p. 19) also used the name Pleasantview, but it was misprinted as Pleasantville in their stratigraphic column. In Iowa and Missouri, the Pleasantview was normally considered the first sandstone below the Mulky Coal or sometimes below the Breezy Hill Limestone of Missouri. Other workers (e.g., L.M. Cline and D.G. Stookey, unpublished strat-section) have used the name Pleasantview for sandstones occurring below the Bevier Coal (Bevier Coal of today’s definition) and possibly below the Wheeler

Coal. Ravn and others (1984) dropped the name Pleasantview from Iowa nomenclature, because of the uncertainty involved in correlating laterally discontinuous sandstone bodies, especially from basin to basin (Illinois Basin to Midcontinent Basin).

The Breezy Hill Limestone and underlying Iron Post Coal, which occur in Missouri, Oklahoma and Kansas just below the Mulky Coal, are not recognized in Iowa. At the exposures in the north ditch of a dirt road northwest of Liberty Center, in the SW section 8, T. 74 N., R. 23 W., Warren County, a thin, dark, carbonaceous shale and a 0.5 inch (1.3 cm) thick layer of fibrous calcite occur, a few feet below the Mulky Coal. It is not known at this time if this zone is related to the Breezy Hill cyclothem. IGS Coal Project cores and unpublished notes of L.M. Cline suggest that one or more cycles of deposition may occur between the Bevier Coal and the overlying Mulky Coal.

A reference section for the entire interval, is designated at exposures in the north ditch of a dirt road northwest of Liberty Center, in the NE SW SW section 8, T. 74 N., R. 23 W., Warren County. Ravn and others (1984, Fig. 22, p. 36) used three cores as reference cores for the Swede Hollow. Intervals for these units in these cores are: the 216.8-274.0 foot interval in the CP-37 Osceola core, the 117.4-174.0 foot interval in the CP-76 core, and the 228.5-281.7 foot interval in the CP-78 core.

Mulky (Mulkey) Coal bed
(reduced in rank)

The Mulky 'Creek' Coal was named by Broadhead (1873) from exposures of a coal on the land of Ennis and Cundiff, at the railroad near Mulky [Mulkey] Creek in Johnson County, Missouri, but no specific type section was ever designated. It is unclear, but from his descriptions it appears Broadhead was describing an exposure in either the SE section 34, T. 49 N., R. 25 W., or the SW section 35, T. 49 N., R. 25 W., which are in Lafayette County. The USGS topographic sheet (Knob Noster NW, 1961) shows a north-flowing Mulkey Creek about three miles (4.8 km) west of Concordia, Lafayette County, that is crossed by a railroad about 0.25 mile (0.4 km) north of Interstate Highway 70. This location is about 4.25 miles (6.8 km) north of the Lafayette-Johnson county line.

Searight (1955) stated the coal was named after Mulky [Mulkey] Creek in Johnson County. There is also a southeast-flowing Mulkey Creek about six miles (9.6 km) southwest of Concordia. Most of this creek is in northeastern Johnson County, but it is not crossed by a railroad on modern maps.

According to Schoewe (1959), the Mulky Coal was named after the town of Mulky, Lafayette County, Missouri. Mulkey (Mulkey's) Grove was a location near the center of the east line section 2, T. 48 N., R. 25 W., about one mile (1.6 km) southeast of where the railroad crosses Mulkey Creek, near Mulkey Station Road, Lafayette County. The reason for the change in spelling 'Mulky' for the coal and 'Mulkey' for the creeks and Mulkey Grove on the Knob Noster NW 1961 topo sheet is unknown.

The Mulky Coal varies from a smut to six inches (15 cm) thick along roadcuts east of Otter Creek northeast of Medora in Warren County. The Mulky correlates with the Summum (No. 4) Coal of Illinois, the Houchin Creek (IVa) Coal of Indiana and the Upper Well (No. 8b) Coal of western Kentucky (Peppers, 1970). In Kansas, it was known by early geologists and miners as the Osage or Fort Scott Coal (Schoewe, 1959).

Reference sections are designated at exposures in a south-facing roadcut backslope east of Booneville, in the S ½ NW NE section 29, T. 78 N., R. 26 W., Dallas County, at exposures in the north ditch of a dirt road northwest of Liberty Center, in the NE SW SW section 8, T. 74 N., R. 23 W., Warren County, and at a west-facing cutbank of Preston Branch west of Madrid, in the SW NE NE section 33, T. 82 N., R. 26 W., Boone County.

Red Haw Limestone Member
(newly named unit this report)

The Red Haw Limestone Member is named in this report from exposures about three miles (4.8 km) northeast of Chariton, just south of the C of the N line SW section 4, T. 72 N., R. 21 W., Lucas County, Iowa. The type section is in a roadcut and pasture on the south side of a gravel road, just east of Little White Breast Creek. The name is derived from Red Haw Lake and Red Haw State Park about 4.5 miles (7.2 km) to the south of the type section.

The Red Haw Limestone is lenticular and in many places is represented by a conodont-bearing (*Idiognathodus* spp., *Neognathodus* spp., *Adetognathus* sp., *Diplognathodus iowensis, D. coloradoensis* and *Hindeodus* sp.) fossiliferous, light gray (N7) shale. At the type section, the Red Haw Limestone is about 1.5 feet (45 cm) of skeletal packstone with abundant conodonts, carbonized wood fragments, macrospores, brachiopods and crinoids. It occurs from 0.5-6.0 inches (1.3-15 cm) above the Bevier Coal bed. The type Red Haw Limestone is currently under study by J.P. Pope and L. Treese.

The 271.9-274.0 foot interval in the CP-37 Osceola core is designated as a reference section.

Unnamed detrital strata between base of Red Haw Limestone or top of the Bevier Coal bed and top of Wheeler Coal bed
(no name proposed at this time)

No names are proposed at this time for the various shales and sandstone units below the Red Haw Limestone above the Bevier Coal bed and the lenticular limestone or fossiliferous shales above the Wheeler Coal bed. One or more sandstones may occur in the interval below the Bevier Coal, and some workers have used the names Pleasantview Sandstone or Squirrel sand for these sandstones (e.g., Cline and Stookey, unpublished stratigraphic-section). The tops of some of the sandstones found in this interval may be above the Bevier Coal. The Bevier Coal bed occurs near or at the top of the unit. The interval ranges from about 2-28 feet (0.6-8.4 m) thick.

The Wheeler-Bevier interval tends to thicken to the southwest, into the deeper parts of the Forest City Basin (Ravn et al., 1984). In some cores (e.g., CP-77 in Lucas County) three coals are present in this interval. In south-central Iowa the interval between the two coals can reach 25 feet (7.6 m) or more (e.g., CP-37 Osceola core in Clarke County; CP-78 core in Wayne County; Swede Hollow type section), but is usually less than 20 feet (6.1 m), and as in Missouri they tend to be separated by only a thin shale parting in some areas (e.g., CP-76 core in Appanoose County; SE corner SE section 15, T. 71 N., R. 17 W., Monroe County).

A reference section is designated for the middle and bottom part of this interval, exposed east of Medora, just south of the bridge over Otter Creek, on County road G76 in the NW NE NE section 30, T. 74 N., R. 23 W., Warren County. The upper 15 feet (4.6 m) of this interval is exposed along the north ditch of a dirt road northwest of Liberty Center, in the NE SW SW section 8, T. 74 N., R. 23 W., Warren County. Ravn and others (1984, Fig. 22, p. 36) used three cores as reference cores for the Swede Hollow. Intervals for these units in these cores are: the 274.0-302.2 foot interval in the CP-37 Osceola core in Clarke County, the 174.0-176.6 foot interval in the CP-76 core in Appanoose County, and the 281.7-306.3 foot interval in the CP-78 core in Wayne County.

Bevier Coal bed
(lowered in rank)

In Iowa and much of Missouri there are at least two coals present above the underlying Ardmore Limestone and the overlying Mulky Coal. Early workers in Missouri called both coals the Bevier, or upper and lower Bevier coals. The name Bevier Coal was first used by McGee (1888) and was defined by Gordon (1896) for a coal in strip pits in the vicinity of the town of Bevier, Macon County, Missouri, but no specific type section was ever designated (Gentile and Thompson, 2004). In Adair County, Missouri, where the coal is about four feet (1.2 m) thick, it is split into three seams by clay partings (Cline, 1941). In Macon County, Missouri the coal averages 4.3 feet (1.3 m) thick, and is divided into two seams by a thin clay parting (Robertson, 1971). Hinds and Greene (1915) reported that in Linn and Chariton counties in Missouri, the two coals virtually form one bed.

In Adair, Johnson, Lafayette, Livingston, and Putnam counties in Missouri, the two coals are some distance apart (15 feet or more) and the upper coal was called the Bedford (Hinds, 1912) while the lower coal was called the Bevier. The Bedford Coal was named from Bedford, Livingston County, Missouri. Weller and others (1942), following Missouri nomenclature, also called the upper coal the Bedford and the lower coal the Bevier (Stookey, 1935), until Cline (unpublished reports) used O.H. St. John's name, Wheeler (*in* White, 1870) for the lower coal and named the upper coal the Albia, because he did not think the name Bedford was appropriate (Bedford was a preoccupied name for a limestone in Indiana). The Albia Coal was named for roadcuts near Albia, in the C of the W line NW section 28, T. 72 N., R. 17 W., Monroe County, Iowa. In Missouri, Habib (1960) and Searight and Howe (1961) called the upper coal the Bevier and the lower coal the Wheeler, based on palynological studies. Later workers in Iowa and Missouri (e.g., Landis and Van Eck, 1965; Robertson, 1971), also used the name Bevier for the upper coal and Wheeler for the lower coal.

In south-central Iowa the interval between the two coals can reach 25 feet (7.6 m) or more (e.g., CP-37 Osceola core in Clarke County, CP-78 core in Wayne County, Swede Hollow type section), but is usually less than 20 feet (6.1 m). Eastward in Iowa and in north-central Missouri, the two coals tend to be separated by only a thin shale parting in some areas (e.g., CP-76 core in Appanoose County and about five miles (8.0 km) south of Albia in the SE corner SE section 15, T. 71 N., R. 17 W., Monroe County). The Wheeler-Bevier interval tends to thicken to the southwest, into the deeper parts of the Forest City Basin (Ravn et al., 1984). In some cores (e.g., CP-77 core in Lucas County) three coals are present in this interval. The Bevier Coal varies from a smut to 18 inches (45 cm) thick, west of Madrid near the Des Moines River. The Bevier Coal correlates with the Kerton Creek Coal (northwestern) and Roodhouse Coal (southwestern) of Illinois (Ravn, 1986).

Reference sections are designated at exposures about three miles (4.8 km) northeast of Chariton, just south of the C of the N line SW section 4, T. 72 N., R. 21 W., Lucas County, Iowa (Red Haw Limestone Member type section), and along the north ditch of a dirt road northwest of Liberty Center, in the NE SW SW section 8, T. 74 N., R. 23 W., Warren County.

Unnamed limestone above Wheeler Coal bed (not named in this report)

There is no marine unit above the Wheeler Coal where the interval between the Wheeler and Bevier coals is thin, but fossiliferous shale has been reported in several IGS Coal Survey Project cores where the interval is thicker: CP-28 core in Wapello County, CP-37 core in Clarke County, CP-41 core in Marion County, CP-77 core in Lucas County, CP-78 core in Wayne County, CP-79 core in Lucas County, and CP-80 core in Lucas County. There is a thin zone of lenticular pyrite and marcasite with marine fossils (e.g., orthoconic nautiloids, brachiopods *Desmoinesia* and *Mesolobus*, clams and gastropods), just above the Wheeler Coal at the bridge over Otter Creek east of Medora on County road G76, Warren County (J.P. Pope, unpublished field notes). Searight (1958) mentioned a limestone in Henry County, Missouri, and Gentile (1968) mentioned a capping limestone in Bates County, Missouri. Gentile and Thompson (2004) illustrate several feet of limestone and shale (Wheeler cap limestone) in their section 33 above the Wheeler Coal, in Bates County, Missouri. No name is proposed for this unit at this time.

Unnamed detrital strata between top of Wheeler Coal bed and top of the Ardmore Limestone Member of Verdigris Formation (no name proposed at this time)

No names are proposed at this time for the various shale, mudstone, and sandstone units below the unnamed fossiliferous zone above the Wheeler Coal bed down to the top of the Ardmore Limestone Member of the Verdigris Formation. The Wheeler Coal bed occurs near or at the top of the unit. This interval ranges from about 3.5-28 feet (1.1-8.4 m) thick. One or more sandstones may occur in the interval below the Wheeler Coal and some workers have used the name Pleasantview Sandstone for these sandstones (e.g., Blair, 1993). The tops of some of the sandstones found in this interval may be above the Bevier Coal.

Reference sections for these units are designated at Woodland Mounds State Preserve southeast of Ackworth, in the N ½ NW NE section 31, T. 76 N., R. 22 W., Warren County; east of Medora, just south of the bridge over Otter Creek, on County road G76 in the NW NE NE section 30, T. 74 N., R. 23 W., Warren County; and at the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County. Ravn and others (1984, Fig. 22, p. 36) used three cores as reference cores for the Swede Hollow. Intervals for these units in these cores are: the 302.2-307.8 foot interval in the CP-37 Osceola core in Clarke County, the 176.6-205.0 foot interval in the CP-76 core in Appanoose County, and the 306.3-309.8 foot interval in the CP-78 core in Wayne County.

Wheeler Coal bed
(lowered in rank)

In Iowa the lower of the two coals above the Ardmore Limestone, was called the Wheeler Coal by O.H. St. John (*in* White, 1870), but the name was essentially unused by later workers. Weller and others (1942), following Missouri nomenclature, called the upper coal the Bedford and the lower coal the Bevier, until L.M. Cline (unpublished reports) used St. John's name Wheeler for the lower coal and named the upper coal the Albia, because he did not think the preoccupied name Bedford was appropriate. The Albia Coal was named for roadcuts near Albia in the C of the W line NW section 28, T. 72 N., R. 17 W., Monroe County, Iowa. In Missouri, Habib (1960) and Searight and Howe (1961) called the upper coal the Bevier and the lower coal the Wheeler, based on palynological studies. Later workers in Iowa and Missouri (e.g., Landis and Van Eck, 1965; Robertson, 1971), also used the name Wheeler for the lower coal and Bevier for the upper coal. See discussion of Bevier Coal bed. Ravn and others (1984) followed the nomenclature of Landis and Van Eck (1965) for the coal bed names, and placed the Wheeler and Bevier coals in their newly named Swede Hollow Formation.

The Wheeler Coal was named by O.H. St. John (*in* White, 1870), from exposures measured in 1868, near the Swede Hollow type section southwest of Oakley, in the NE section 33, T. 73 N., R. 22 W., Lucas County, Iowa, in the immediate vicinity of Wheeler's mill, which no longer exists. Hall (1969) relocated O.H. St. John's type section in the NW NW NE section 33, T. 33N., R. 22 W. Ravn and others (1984) redescribed the Wheeler Coal at exposures in a series of streamcuts, at their Swede Hollow type section, in sections 33 and 34, T. 73 N., R. 22 W. and section 3, T. 72 N., R 22 W., Lucas County, Iowa.

The Wheeler correlates with the Lowell/Cardiff Coal (northwestern) and Shawneetown Coal (southeastern) of Illinois, the Survant (IV) Coal of Indiana, and the No. 8 Coal of western Kentucky (Peppers, 1970).

The Wheeler Coal varies from no coal in some cores (e.g., Logan core in Harrison County); to a one foot (30 cm) thick coal at the 210.0-211.0 foot interval in the CP-79 core in Lucas County) to three feet (0.91 m) at Woodland Mounds State Preserve (Warren County). The coal is four inches (10.2 cm) thick in the Redfield clay pit (Dallas County) and over 1.5 feet (45 cm) thick east of Medora on Otter Creek (Warren County).

Reference sections are designated in the 306.2-307.1 foot interval in the CP-78 core in Wayne County, the 210.0-211.0 foot interval in the CP-79 core in Lucas County, at Woodland Mounds State Preserve southeast of Ackworth, in the N ½ NW NE section 31, T. 76 N., R. 22 W., Warren County, and east of Medora, just south of the bridge over Otter Creek, on County road G76 in the NW NE NE section 30, T. 74 N., R. 23 W., Warren County. In the CP-79 core (Lucas County) the Wheeler Coal (210.0-211.0 foot interval) was previously misidentified as the stratigraphically lower Whitebreast Coal (Hanley, 2008). This led to misidentification of coals below this unit in the core.

Verdigris Formation
(new name in Iowa)

The Verdigris limestone was originally named on a published geologic map from exposures along the Verdigris River in southern Rogers County, Oklahoma (Smith, 1928), and was essentially equivalent to what is now called the Ardmore Limestone. The Verdigris formation of Searight and others (1953), Searight (1955), Searight and Howe (1961) and

Thompson (1995) lay between the Croweburg and Bevier formations, and included an unnamed basal shale, the Ardmore Limestone, the Wheeler Coal bed and an unnamed upper member, in ascending order. Gentile and Thompson (2004), in Missouri, used the same units, naming the lower shale the Oakley of Ravn and others (1984), with the upper shale an unnamed member of the Wheeler Formation.

The author proposes restricting the Verdigris Formation in Iowa, to include only an unnamed lower marine carbonate unit (where present), the Oakley Shale Member, and the overlying Ardmore Limestone Member, as used by Ravn and others (1984). The author also proposes placing the underlying Wiscotta Shale Member (of this report) and the Whitebreast Coal bed (Croweburg Coal of Missouri) in the top of the underlying Floris Formation. In Iowa, the Verdigris Formation overlies the Floris Formation and underlies the Swede Hollow Formation.

An excellent reference section for the Verdigris Formation is designated at exposures in the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County. The three Swede Hollow Formation reference cores of Ravn and others (1984, Fig. 22, p. 36) are also used. Intervals for these units in these cores are: the 307.8-316.8 foot interval in the CP-37 Osceola core in Clarke County, the 205-216.8 foot interval in the CP-76 core in Appanoose County, and the 309.8-331.1 foot interval in the CP-78 core in Wayne County. The entire Verdigris Formation is presently exposed in the Glen-Gerry Redfield clay pit in the NW NW section 3, T. 78 N., R 29 W., Dallas County.

Ardmore Limestone Member (reclassified)

The name Ardmore Limestone was used by Gordon in 1893 (but Gordon did not formally publish the name until 1896), in the same area where he [Gordon] had named the Lower Ardmore Coal. Cline (1941) redefined the Ardmore to include all of the limestone and shale beds from the base of the 'Whitebreast caprock' upward to the top of the highest marine limestone below the Wheeler Coal. McQueen (1943) designated a type section for roadcuts near the town of Ardmore immediately W of the C of the E line section 24, T. 56 N., R. 15 W., Macon County, Missouri. Abernathy (1936, 1937) redefined the Ardmore as the "Ardmore cyclothem" with the Ardmore limestone as one of the more characteristic units within the cyclothem. Searight and others (1953) formally proposed that Abernathy's "cyclothem" be called the Verdigris formation, identifying the prominent limestone member as the Verdigris limestone member. Since two rock units (Ardmore formation and member), should not have the same name, Searight and Howe (1961) proposed the present nomenclature; Ardmore Limestone Member of the Verdigris Formation. The Ardmore was called the Rich Hill Limestone in western Missouri, by Greene and Pond (1926). The Ardmore Limestone Member overlies the Oakley Shale Member and underlies the Swede Hollow Formation.

The lower Ardmore (the single limestone just above the Oakley Shale) was often called the 'diamond rock' (in reference to its rhombic joint pattern) and 'Whitebreast caprock' by early miners. It is a skeletal wackestone that ranges from 0-18 inches (0-46 cm) in thickness and averages six inches (15 cm) thick. In some core and outcrop it is not present or only occurs as a layer of limestone nodules in shale.

The shale between the lower and upper limestone beds averages about six feet (1.8 m) in thickness, but may exceed 15 feet (4.6 m). It varies from medium dark gray (N4) to dark gray (N3) to black (N1) in color, and often contains pyrite-filled burrows and selenite crystals on weathered surfaces.

The upper Ardmore in Iowa often occurs as two layers of argillaceous limestone separated by a thin, black (N1) *Crurithyris planoconvexa*-bearing, phosphatic, conodont-rich shale. Hence it was called the 'Two-Layer Limestone' by Lugn (1927) for exposures at the type section of the Whitebreast Coal, and was called the 'Bevier Sump Rock' by early miners in northern Missouri. In some outcrops in Dallas County, the upper Ardmore is represented by up to eight feet (2.4 m) of thin argillaceous limestones separated by shale. In the Glen-Gerry Redfield clay pit in the NW NW section 8, T. 78 N., R. 29 W., Dallas County, the upper Ardmore is represented by 2.5 feet (0.76 m) of light-gray (N6) fossiliferous shale overlain by six inches (15 cm) of algal-coated, abraded-grain, skeletal grainstone.

Moore (1936) recognized that the Ardmore Limestone is essentially the equivalent of the Verdigris Limestone of Oklahoma, which was named from exposures along the Verdigris River in Rogers County, Oklahoma (Smith, 1928). The Ardmore has also been correlated with the Oak Grove Limestone of Illinois (Wanless, 1955; Hopkins and Simon, 1975; Heckel and Weibel, 1991).

Reference sections are designated in the 309.8-328.1 foot interval in the CP-78 core in Wayne County, the 215.9-230.9 foot interval in the CP-79 core in Lucas County, and at exposures at the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County.

Oakley Shale Member (reclassified)

The Oakley Shale was named by Ravn and others (1984) for exposures in a series of streamcuts at the Swede Hollow type section in sections 33 and 34, T. 73 N., R. 22 W., and section 3, T. 72 N., R 22 W., Lucas County, Iowa. It is named for the nearby town of Oakley in northern Lucas County. The Oakley Shale underlies the Ardmore Limestone Member and overlies the Whitebreast Coal or lighter-colored shale and sandstone (Wiscotta Shale bed of this report) above the Whitebreast Coal.

The Oakley Shale averages about 1.5 feet (46 cm) in thickness. In CP-76 in Appanoose County it is 8.5 feet (2.6 m) thick, but only one foot (30 cm) thick in CP-80 in Lucas County. In many places there is a thin light-gray (N7) shale above the Whitebreast Coal, but usually the black (N1) fissile facies rests directly on the coal, and contains carbonized wood debris in its lower part. The black fissile phosphatic facies may be separated from the Whitebreast Coal by several feet of shale and sandstone (see Wiscotta Shale bed below). The black (N1) fissile shale also usually contains numerous spherical non-skeletal phosphorite nodules less than one inch (2.5 cm) in diameter and locally 6-15 inch (15-38 cm) diameter, light gray (N7) to medium gray (N5) concretions of lime mudstone. These limestone concretions are not a transgressive limestone, but seem to be early diagenetic features within the black facies of the shale. At the Saylorville Dam Emergency Spillway, many of the phosphorite nodules and limestone concretions contain abundant poorly- to moderately- preserved pseudoalbaillellid and spherical (e.g., entactinid) radiolarians replaced by dolomite and pyrite (Fisher and Pope, 2009; Pope and Marshall, 2009; Pope, Nestell and Nestell, 2010). The author does not recommend naming the black fissile facies in Iowa, the “Mecca Quarry” shale bed, as Gentile and Thompson (2004) did informally in Missouri, although this facies of the Oakley Shale Member appears to be the equivalent of the Mecca Quarry Shale in northern Illinois (Ravn et al., 1984; Hopkins and Simon, 1975; Heckel 1994, 1999; Gentile and Thompson, 2004). Above the black (N1) phosphatic facies is usually 2-6 inches (5-15 cm) of bioturbated light-gray (N7) shale. Where the Wiscotta Shale is present the base of the Oakley Shale is placed at the base of the black (N1) phosphatic facies.

Reference sections are designated at exposures at the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County, in the 328.1-331.1 foot interval in the CP-78 core in Wayne County and in the 230.9-234.8 foot interval in the CP-79 core in Lucas County.

Unnamed limestone below Oakley Shale (not named in this report)

At the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County, several skeletal wackestone to packstone nodules occur between the black, fissile, phosphatic facies of the Oakley Shale and the underlying Whitebreast Coal. These nodules are up to 3.3 feet (1 m) across, and contain abundant pyrite replaced gastropods and clams, as well as carbonized wood fragments (Fisher and Pope, 2009; Pope and Marshall, 2009). Searight (1958, Plate II) shows a limestone in this position in Henry and Johnson counties in Missouri, on a cross-section. No name is proposed for this interval at this time, and it is currently included in the Oakley Shale Member.

Floris Formation

(revised; new members, beds recognized)

The Floris Formation includes strata from the base of the Laddsdale Coal, just above the top of the Kalo Formation, to the base of the Oakley Shale Member of the Verdigris Formation. The type area for the Floris consists of a number of backslope cuts along a north-south road on the east edge of section 29, T. 72 N., R. 13 W., east of Ottumwa, Wapello County, but does not include the upper part of the Floris, from the Carruthers Coal upward. Most of the outcrops at the type section are now covered. The Floris Formation is named from the nearby town of Floris, in northeastern Davis County.

Ravn and others (1984) named two members in the Floris Formation in ascending order, the "Laddsdale Coal" at the base and the Carruthers Coal above the middle. The "Laddsdale [Coal] Member" was defined by Ravn and others (1984) to include one or more lenticular coals that are palynologically distinct from other Cherokee coals. The Carruthers is a single thin coal also originally distinguished by palynomorphs. The Whitebreast Coal bed, formerly included in the Swede Hollow Formation, is now included at or near the top of the Floris Formation (Figure 8). One or more coals occur above the Carruthers Coal (e.g., Mineral Coal and an unnamed coal of this report) and between the Carruthers Coal and the "Laddsdale Member" (e.g., Thousand Acre Coal of this report). Many of these coals have lenticular marine limestones and shales associated with them (Cline, 1941, Pope and Chantooni, 1996; Hanley, 2008; Pope and Marshall, 2009; Marshall, 2010). The CP-7 core in Wapello County, encountered eight Floris coals, the most noted in any of the 85 IGS Coal Survey Project cores.

At the type section, the Floris is about 100 feet (30.5 m) thick, and includes seven coals, but the Carruthers Coal and overlying strata are not present. The lower six coals are assigned to the Laddsdale Member, while the upper coal is palynologically distinct from the Laddsdale, but was left unnamed by Ravn and others (1984). The various Laddsdale coals at the type section range from one inch (2.5 cm) to 2.2 feet (70 cm) thick.

In IGS Coal Survey Project cores, the Floris ranges from 65 feet (20 m) to 196 feet (60 m) thick. In the CP-53 core in Monroe County, the lower 140 feet (42 m) is composed of sandstone. These thick Floris sections are the result of successions of sandstones (interpreted as having been deposited in river channels, as paleovalley fills, or as bay-head delta deposits), which locally cut down into underlying Kalo and Kilbourn strata and occasionally into the Mississippian (e.g., CP-18 core in Wapello County; CP-53 core in Monroe County; CP-76 core in Appanoose County). Some of these thick sandstones have not been named (e.g., an unnamed sandstone in Ledges State Park, Boone County and an unnamed sandstone in Dolliver State Park, Webster County) and others have been only informally named (e.g., "Redrock Sandstone" of Keyes, 1891 for a series of sandstones that seem to occur at different stratigraphic horizons, around what is now Red Rock Reservoir, Marion County; "Cliffland Sandstone" of Leonard (1902) near the town of Cliffland in Wapello County; "Redfield Sandstone" or "Hanging Rock Sandstone" near the town of Redfield, Dallas County. There are several other similar subsurface sandstones known from cores and well logs in southeast, south-central and southwest Iowa. These sandstones may have depositional histories similar to those of the upper Tradewater (formerly Spoon) Formation sandstones in Scott and Muscatine counties.

In the CP-41 core in Marion County, the Floris contains five coals ranging in thickness from 7-19 inches (17.8-50 cm). In the CP-7 core in Wapello County, the Floris is 140 feet (42 m) thick and contains eight coals, which range in thickness from eight inches (20 cm) to five feet (1.5 m). The lower six coals are all assigned to the Laddsdale Member (Ravn et al., 1984), and three of the six coals are associated with marine limestones and shales. The Floris Formation underlies the Verdigris Formation and in most places in Iowa overlies the Kalo Formation, but may lie unconformably on the Kilbourn Formation or Mississippian strata.

In the CP-78 core (Wayne County), the CP-79 core (Lucas County) and at the old claypit in Redfield (Dallas County) a thick shale lies between the top of the Whitebreast Coal and the base of the black (N1) phosphatic facies of the overlying Oakley Shale. This lenticular unit has been named the Wiscotta Shale in this report.

Marshall (2010) identified the Inola cyclothem between two coals within the type Laddsdale Member (Davis County) in the CP-78 core (Wayne County) and in the CP-79 core (Lucas County). Pending further study of many named units (at their type sections in Oklahoma, Kansas, and Missouri), below the Croweburg Coal (= Whitebreast Coal bed of Iowa), and their relationship to units in Iowa, there is still a great deal of controversy on how to correlate the units in Iowa with those in states to the south. Therefore, the author has suggested Iowa names for some of these units, until more positive correlations can be made. The author has also included the most recent tentative correlations from Hanley (2008), Fisher and Pope (2010), and Marshall (2010).

At this time, the author uses the three cores of Ravn and others (1984, Fig. 17, p. 29) as reference cores for the Floris Formation. The intervals for these units in these cores are: the 110.1-253.9 foot interval in the CP-7 core in Wapello County, the 120.9-226.7 foot interval in the CP-41 core in Monroe County, and the 170.9-364.4 foot interval in the CP-53 core in Monroe County. The upper 50 feet (15 m) of the Floris is presently exposed above the angular unconformity in the Glen-Gerry Redfield claypit in the NW NW section 3, T. 78 N., R. 29 W., Dallas County.

Wiscotta Shale Member
(newly named unit this report)

The Wiscotta Shale Member is named in this report from exposures in the abandoned claypit (behind the old brick kilns) in the northwest corner of Redfield, Dallas County, in the NE SE NW section 4, T. 78 N., R. 29 W. The name (suggested by P.H. Heckel, 2011) is derived from the nearby town of Wiscotta, about 0.5 miles (0.8 km) to the south. At the type section, the Wiscotta Shale Member consists of up to about 15 feet of lenticular light gray (N7) to medium gray (N5) shale with abundant siderite and clay-iron concretions. The shale, although poorly exposed, also outcrops in an abandoned clay pit just south of the center of the west line of section 4, T. 78, N., R. 29 W. This clay pit is in both sections 4 and 5, just west of the Middle Raccoon River.

In the CP-78 core in Wayne County the black (N1) fissile phosphatic facies of the Oakley Shale Member becomes very dark gray (N2) and is three feet (0.91 m) thick (328.1-331.1 foot interval). It is separated from the Whitebreast Coal by carbonaceous grayish brown (5YR 3/2) to medium gray (N5) shale and siltstone up to 22 feet (6.7 m) thick (331.1-353.2 foot interval). In CP-79 in Lucas County, Hanley (2008) recognized that the black (N1) fissile phosphatic facies of the Oakley Shale Member is separated from the probable position of the Whitebreast Coal by 5.2 feet (1.6 m) of light gray (N7) to greenish gray (5G 6/1), sideritic, rooted shale. She inferred that the Whitebreast Coal should occur at the top (241.2 foot depth) of a light gray (N7) blocky, rooted mudstone, just below the shale unit.

L.M. Cline (unpublished manuscripts) correlated the lower medium-gray (N5) shale facies (between the overlying black fissile phosphatic facies of the Oakley Shale and the underlying Whitebreast Coal) with the Francis Creek Shale of Illinois from which the remarkable Mazon Creek fossils were described. A similar fauna of fern leaves and a xiphosuran (*Euproöps danae*) in siderite and clay-iron concretions, have been described from this facies at the old Redfield clay pit, Dallas County (Case, 1982).

Reference sections are designated in the 331.1-353.2 foot interval in the CP-78 core in Wayne County and in the 234.8-241.2 foot interval in the CP-79 core in Lucas County,

Unnamed detrital strata between base of
Wiscotta Shale (where present) or Oakley
Shale and base of Russell Creek Limestone
or top of Mineral Coal bed
(no name proposed at this time)

No names are proposed at this time for most of the various shale, mudstone, and sandstone units below the Wiscotta Shale Member where it is present, or below the Oakley Shale Member of the Verdigris Formation where the Wiscotta Shale is absent, and the top of the underlying Russell Creek Limestone or the top of the Mineral Coal (where the Russell Creek Limestone is absent). The Whitebreast Coal bed occurs at or near the top of this unit, above an unnamed coal (Fleming Coal of Hanley, 2008). Known thickness of this unit ranges from about 15-37 feet (4.6-11.3 m).

Reference sections for these units are designated at exposures in the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County, in the 331.1-367.8 foot interval in the CP-78 core (Wayne County) and in the 234.8-272.1 foot interval in the CP-79 core (Lucas County), where the Russell Creek Limestone occurs.

Whitebreast Coal bed
(reduced in rank; reclassified)

Before 1870, O. H. St. John referred to what is now known as the Whitebreast Coal, as the 'A' coal. Later, St. John (1870) named a coal the Panora Coal, for outcrops at Panora Mills on the Raccoon River, near the town of Panora in section 31, T. 80 N., R. 30 W., Guthrie County. Another one of St. John's (1870) sections contained both the Panora and Wheeler coals, and was described as being in "the immediate vicinity of Wheeler's Mill" on Whitebreast Creek in the NE section 33, T. 73 N., R. 22 W., Lucas County. Lugn (1927) described a section about 0.5 mile (0.8 km) south of St. John's section, south of Wheeler's bridge near the middle of the same section [33], and renamed the Panora Coal the 'White Breast' [Whitebreast] Coal. The name was derived from White Breast (Whitebreast of some maps) Creek. Hall (1969) relocated Lugn's type section about 400 yards (366 m) south of the bridge over White Breast Creek in the SW SW NE section 33, T. 73 N., R. 22 W.

Ravn and others (1984) redescribed the Whitebreast Coal at exposures in a series of streamcuts, at their Swede Hollow type section southwest of Oakley, in sections 33 and 34, T. 73 N., R. 22 W. and section 3, T. 72 N., R 22 W., Lucas County, Iowa. The Whitebreast Coal Member occurs at or near the top of the Floris Formation and underlies the Oakley Shale Member of the Verdigris Formation or the Wiscotta Shale Member of the Floris Formation, where present. The Whitebreast Coal varies from a smut to 13 inches (32 cm) thick, but is absent in the CP-79 core (Hanley, 2008).

The Whitebreast Coal has been correlated with the Lower Ardmore Coal (Hinds, 1912); probably incorrectly with the Tebo Coal of Missouri (Stookey, 1935); but correctly with the Colchester (No. 2) Coal of Illinois (Hopkins and Simon, 1975); Croweburg Coal, Pioneer Coal, and Williams Coal of southeastern Kansas and southwestern Missouri (Howe, 1956; Gentile and Thompson, 2004); Croweburg Coal of Oklahoma (Wilson and Hoffmeister, 1956); Colchester (IIIa) Coal of Indiana (Peppers, 1970); and the Schultztown Coal of western Kentucky (Peppers, 1970). The name Panora has priority over the Whitebreast (Cline, 1938), but the name Whitebreast has been firmly entrenched in the literature and will be retained.

Reference sections for the Whitebreast Coal are designated in the 353.1-354.1 foot interval in the CP-78 core (Wayne County) and at exposures in the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County. In the CP-79 core (Lucas County) the stratigraphically higher Wheeler Coal (210.0-211.0 foot interval) was previously misidentified as the Whitebreast Coal (see Hanley, 2008). The Whitebreast Coal is absent in the CP-79 core, but Hanley (2008) placed the probable position of the Whitebreast Coal at the top of the mudstone paleosol at the 241.2 foot depth.

Unnamed coal bed
(no name proposed at this time)

Hanley (2008) recognized at the 258.77-259.25 foot interval in CP-79 core in Lucas County, a coal bed that she tentatively referred to as the Fleming Coal bed in Iowa, by its stratigraphic position as the second coal above the Carruthers Coal bed. The Fleming Coal is also associated with an overlying marine interval, containing a "minor *Gondolella* zone" with mainly *Gondolella pohli,* in correlative positions in cores southward in Kansas (Hanley, 2008). The Fleming Coal was named by Pierce and Courtier (1938) from exposures in a strip pit north of the town of Fleming, southern Crawford County, Kansas. Pierce and Courtier (1937) had called this coal the Mineral Rider Coal, in reference to its position above the Mineral Coal, and Abernathy (1936, 1937) had called it the Lightning Creek Coal in Kansas. At the Saylorville Dam Emergency Spillway, in the C of the NW section 31, T. 80 N., R. 24 W., Polk County, the unnamed coal horizon may be represented by a thin light gray (N7) shale 13 feet (4.0 m) below the base of the Oakley Shale, and above a moderate red (5R 4/6) shale above the Russell Creek Limestone. A lenticular 6-8 inch (15-18 cm) thick lime mudstone to skeletal wackestone also occurs at this horizon at the Saylorville Dam Emergency Spillway section.

Until the relationship of this coal and associated marine unit to underlying beds is firmly established, the author recommends that the coal remain unnamed.

Russell Creek Limestone Member
(new name in Iowa)

The Russell Creek Limestone Member occurs in exposures 17 feet (5.2 m) below the base of the Oakley Shale, at the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County. Here the Russell Creek Limestone is lenticular and consists of, in ascending order, a 0-10 inch (0-25 cm) fossiliferous lime mudstone to skeletal wackestone, a 0.5-1 inch (1.25-2.5 cm) conodont-rich shale, and another 0-3 inch (0-7.5 cm) fossiliferous lime mudstone to skeletal wackestone. It overlies 0.5-1 inch (1.25-2.5 cm) of shale, the Mineral Coal bed and 1.5 feet (0.46 m) of dark gray (N7) mudstone, in descending order. The Russell Creek Limestone is overlain by about 16 feet (4.9 m) of mudstone and shale (Pope and Chantooni, 1996; Pope and Marshall, 2009). The Russell Creek Limestone was named by Branson (1952) from exposures along Russell Creek in NE SW section 15, T. 29 N., R. 20 E., Craig County, Oklahoma.

Hanley (2008) correlated marine units in Iowa (e.g., the 271.8-272.1 foot interval in the CP-79 core in Lucas County), which are equivalent to the Russell Creek Limestone of this report, with the Russell Creek Limestone of Missouri and Oklahoma. J.P. Pope (unpublished manuscript for the IGS), Pope and Marshall (2009) and Fisher and Pope (2010) used the name Camp Dodge Limestone in Iowa, for the Russell Creek Limestone.

A reference section is designated in the 271.8-272.1 foot interval in the CP-79 core in Lucas County.

Unnamed detrital strata between base of Russell Creek Limestone or top of Mineral Coal bed and base of Elliot Ford Limestone or top of Carruthers Coal bed
(no name proposed at this time)

A series of shales, mudstones, and sandstones ranging from 8-12 feet (2.4-3.7 m) thick, occur below the Russell Creek Limestone or the top of the Mineral Coal where the Russell Creek Limestone is absent and above the Elliot Ford Limestone or top of the Carruthers Coal where the Elliot Ford Limestone is absent. The Mineral Coal bed occurs near or at the top of this unit.

At the Saylorville Dam Emergency Spillway, a phosphatic, conodont-rich shale zone occurs about 5-8 feet (1.5-2.4 m) above the Carruthers Coal bed and about 4.5 feet (1.4 m) below the Mineral Coal bed (Pope and Chantooni, 1996; Pope and Marshall, 2009; Fisher and Pope, 2010). The conodont-rich shale has an abundance of about 2,300 P elements per kilogram, and is the “major *Gondolella* zone” of Hanley (2008), which is dominated by *Gondolella* aff. *pohli* and includes *G. laevis.* This shale has been traced through cores in Iowa, Kansas and Missouri and correlated with a *Gondolella* zone just above the type Tiawah Limestone, as the upper Tiawah cyclothem of Oklahoma (Boardman et al., 2004; Hanley, 2008). This fauna has also been discovered in a black, fissile, phosphatic shale above the type Tebo Coal of Missouri (Fisher and Pope, 2010).

A reference section for these units is designated at exposures at the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County, where the *Gondolella*-rich shale is about 26 feet (7.9 m) below the Oakley Shale.

Mineral Coal bed
(new name in Iowa)

The Mineral Coal bed occurs at exposures in the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County. At the Saylorville Spillway the Mineral Coal bed overlies 1.5 feet (0.46 m) of dark gray (N7) mudstone. It is overlain by 0.5-1 inch (1.25-2.5 cm) of shale, a 0-10 inch (0-25 cm) lime mudstone to skeletal wackestone, a 0.5-1 inch (1.25-2.5 cm) conodont-rich shale, and another 0-3 inch (0-7.5 cm) lime mudstone to skeletal wackestone, in ascending order (Pope and Chantooni, 1996; Pope and Marshall, 2009). The Mineral Coal was named by Abernathy (1936, 1937) from exposures in a strip-pit highwall in SE NW section 24, T. 28 S., R. 25 E., Crawford County, Kansas.

The Mineral Coal may be the same as the unnamed persistent coal that lies 8-17 feet (2.4-5.2 m) above the Carruthers Coal bed, and may correlate with the Abingdon Coal of northwestern Illinois (L.M. Cline, and L.M. Cline and D.G. Stookey, unpublished manuscripts; Ravn, 1986).

Hanley (2008) correlated units in Iowa (e.g., the 367.8-368.5 foot interval in the CP-78 core in Wayne County and the 274.0-274.6 foot interval in the CP-79 core in Lucas County), which are equivalent to the Mineral Coal of this report, with the Mineral Coal of Missouri, Kansas and Oklahoma. J.P. Pope (unpublished manuscript for IGS), Pope and Marshall (2009) and Fisher and Pope (2010) used the name Saylorville Coal in Iowa, for the Mineral Coal.

Reference sections are designated in the 367.8-368.5 foot interval in the CP-78 core in Wayne County and in the 274.0-274.5 foot interval in the CP-79 core in Lucas County.

Unnamed limestone associated with "major *Gondolella* aff. *pohli* zone"
(no name proposed at this time)

In some cores (e.g., the 281.2-281.8 foot interval in the CP-79 core in Lucas County, the 365.4-366.5 foot interval in the Logan core in Harrison County), and possibly some outcrops, a thin limestone or series of interbedded limestones and shales occur above the conodont-rich shale horizon containing the "major *Gondolella* aff. *pohli* zone" above the Elliot Ford Limestone and below the Mineral Coal bed. No name is proposed for these limestone units at this time.

The limestone at the 376.2-376.9 foot interval in the CP-78 core (W-27377) in Wayne County and the 365.4-366.5 foot interval in the Logan core are designated as reference sections.

Elliot Ford Limestone Member
(newly named unit this report)

A relatively persistent, lenticular limestone occurs above the Carruthers Coal, and below the "major *Gondolella* aff. *pohli* zone" of Hanley (2008), at outcrops around Saylorville Lake and other locations in south-central and southeast Iowa. The Elliot Ford Limestone is named in this report from exposures at Elliot Ford along the west side of Saylorville Lake in the NW NW section 14, T. 80 N., R. 25 W., Polk County, Iowa. At the type section it is a thin bedded, 2.5 foot (76 cm) thick, argillaceous, brachiopod/gastropod-rich packstone, with abundant carbonized wood fragments. At the Saylorville Dam Emergency Spillway it varies from brachiopod-rich, fossiliferous shale to six inches (15 cm) of dense lime mudstone to skeletal wackestone, with abundant white and red dolomite and calcite spar filled fractures.

Based on the widespread "major *Gondolella* zone', Hanley (2008) correlated marine units in Iowa that are equivalent to the Elliot Ford Limestone of this paper, with the upper part of the Tiawah Limestone (the upper Tiawah cyclothem) at the Tiawah Limestone type section in Oklahoma. The name Tiawah was first used by Lowman (1932) for a limestone that is well developed in the hills near the town of Tiawah (southeast of Claremore) in eastern Oklahoma. The type section was selected by Tillman (1952), and formally established by Branson (1954) for an exposure in the north road cut on Oklahoma Highway 20 on the west side of the hill in the SW section 12, T. 21 N., R. 16 E., Rogers County, Oklahoma. At the type section the Tiawah Limestone is a single carbonate unit with an intraformational conglomerate near the middle of the unit. North of the type section, in Kansas, Missouri and Iowa, the Tiawah apparently splits into an upper and lower carbonate unit with shale, mudstone, sandstone and coal ("Scammon Coal" of Kansas, Carruthers Coal of Iowa, type Tebo Coal of Missouri) in between (updated from Hanley, 2008). The type section of the Tiawah Limestone needs to be restudied before detailed correlations with the lithostratigraphic units in Iowa can be confidently made.

A reference section for the Elliot Ford Limestone is designated at exposures 30 feet (9.1 m) below the Oakley Shale in the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County. The limestone at the 285.4-286.5 foot interval in the CP-79 core in Lucas County is probably equivalent to the Elliot Ford Limestone of this report (see Hanley, 2008).

Unnamed detrital strata between top of Carruthers Coal bed and top of Thousand Acre Coal bed
(no name proposed at this time)

About 7.6 feet (1.4 m) of shale, sandstone and mudstone at the Carruthers Coal type section, separate the underlying Olmitz Limestone Member from the overlying Carruthers Coal bed (Ravn et al., 1984). The Carruthers Coal bed occurs near or at the top of the unit. A conodont-rich shale and argillaceous skeletal wackestone occurs in the Glen-Gerry Redfield claypit (Dallas County), about 18 feet (5.5 m) below the Carruthers Coal. This limestone has been tentatively assigned to the Olmitz Limestone pending evaluation of the conodont fauna (J.P. Pope, unpublished field notes). The Olmitz Limestone and Belinda Shale members occur near the base of this unit.

A reference section is designated at exposures south of Columbia, in the east backslope along a gravel road in NW NW SE section 3, T. 73 N., R. 20 W., Lucas County, Iowa, at the type section of the Carruthers Coal.

Carruthers Coal bed
(reduced in rank)

The Carruthers Coal was named by Ravn and others (1984) for exposures south of Columbia, in the east backslope along a gravel road in NW NW SE section 3, T. 73 N., R. 20 W., Lucas County, Iowa. The author (this report) placed it in the SE SW NE section 3, T. 73 N., R. 20 W. The name is derived from Carruthers Creek, about one mile (1.6 km) to the southeast.

At the type section, the Carruthers Coal sits on about 1.2 feet (37 cm) of gray-brown (5YR 4/1) silty mudstone with common carbonaceous debris. The Carruthers is 1.4 feet (43 cm) thick and is overlain by 0.7 feet (21 cm) of dark gray (N3) clay shale with linguloid brachiopods and pelecypods. Above this is six feet (1.83 m) of slightly silty, medium gray (N5) shale with dusky red (5R 3/4) mottling and moderate red (5R 4/6) to moderate reddish brown (10R 4/6) ironstone concretions. This is overlain by a 0.5 foot (15 cm) thick light gray (N7) to dark gray (N3) shale with abundant phosphorite nodules and laminae. It also contains abundant conodonts, including the smooth platformed species *Gondolella* aff. *pohli*, along with *G. laevis*. Above this, a 10.8 foot (3.29 m) light brownish-gray (5YR 4/1) siltstone, grades upward to a pale-brown (5YR 5/2), very fine-grained, sandstone. This in turn grades upward into light brownish-gray (5YR 6/1) silty, rooted mudstone with a 0.6 inch (1.5 cm) thick coal smut at the top (possibly the Mineral Coal of this report). The Oakley Shale occurs at the top of the exposure.

At Saylorville Lake north of Des Moines, in the CP-53 core in Monroe County, and a few other locations, a light-gray (N7), lenticular, argillaceous, brachiopod-rich (*Desmoinesia muricata* and *Mesolobus* sp.) skeletal packstone with abundant carbonaceous debris lies just above the coal. This limestone may reach 2.5-4.0 feet (0.76-1.2 m) in thickness. The zone of abundant conodonts (with *Gondolella* aff. *pohli* and *G. laevis*) and phosphorite nodules ranges from six inches (15 cm) to eight feet (2.4 m) above the Carruthers Coal. In the CP-24 core in Davis County, the Logan core in Harrison County and in the CP-79 core in Lucas County, a thin fossiliferous limestone occurs above the conodont-rich phosphatic shale (Hanley, 2008).

The Carruthers Coal is relatively persistent in Iowa and ranges from a smut in the CP-37 Osceola core in Clarke County and the CP-44 core in Warren County to 2.8 feet (0.85 m) in the CP-24 core in Davis County. The Carruthers has also been known in Iowa, by the local names 'Dudley', 'Milo', and 'Crouch.'

Based on its position below the major *Gondolella* zone, Hanley (2008) correlated the coal at the 286.4-286.9 foot section in the CP-79 core in Lucas County, with the type Carruthers Coal of Iowa and with the “Scammon Coal” of Kansas and Missouri. The latter correlation was based on the apparent miscorrelation of the type Tebo Coal with an older coal at the Montrose section in southwestern Henry County, Missouri, by Gentile and Thompson (2004). Discovery of the major *Gondolella* zone above the type Tebo Coal 21 miles (34 km) northeast of Montrose (Fisher and Pope, 2010), suggests that the “Scammon Coal” of the Kansas outcrop is the Tebo Coal of the Kansas subsurface as Howe (1956) suspected might be the case. Abernathy (1936, 1937) named the "Scammon Coal” and cyclothem from exposures along [Little] Cherry Creek, northwest of Scammon, Cherokee County, Kansas. Howe (1956) described a section exposed along [Little] Cherry Creek, east of bridge on State Highway 7, in the NW section 7, T. 32 S., R. 24 E., Cherokee County, Kansas, as “near Abernathy's type section of the Scammon coal.”

Fisher and Pope (2010) tentatively correlated the type Tebo Coal of Missouri with the type Carruthers Coal of Iowa, based on the occurrence of a major *Gondolella*-bearing zone above the type Tebo Coal in Henry County, Missouri, and the “major *Gondolella* aff. *pohli* zone” above the type Carruthers Coal in Lucas County, Iowa.

The Tebo Coal was named by Marbut (1898) who described a coal present in several mines located about the Tebo Creek area in T. 42 N., R. 25 W., Henry County, Missouri. Restudy of the strata and conodont faunas needs to be done at the type section of the Tebo Coal in Missouri, the type section of the Tiawah Limestone and the stratigraphically lower Wainwright cyclothem in Oklahoma, and the type section of the Scammon Coal in Kansas before definite correlations with these units can be made into Iowa. See discussion under Thousand Acre Coal below.

Historically the Carruthers Coal has been correlated with the Wiley Coal of Illinois (Weller et al., 1942). L.M. Cline (unpublished reports) and Landis and Van Eck (1965) used the name Wiley for the Carruthers Coal in Iowa. However Ravn (1986), using palynology, has shown that the unnamed coal below the Carruthers is probably equivalent to the Wiley Coal of Illinois. The Carruthers thus may be correlative with the Greenbush Coal (northwestern) and Dekovan Coal (southern) of Illinois (Hopkins and Simon, 1975; Peppers, 1996).

Reference sections for the Carruthers Coal are designated at exposures 31 feet (9.4 m) below the Oakley Shale, at the Saylorville Dam Emergency Spillway in the C of the NW section 31, T. 80 N., R. 24 W., Polk County, and at an exposure along the west side of Saylorville Lake, the Elliot Ford Limestone type section, in the NW NW section 14, T. 80 N., R. 25 W., Polk County. Hanley (2008) recognized the Carruthers Coal at the 380.0-380.1 foot interval in the CP-78 core in Wayne County and the 368.9-369.3 foot interval in the Logan core in Harrison County.

Olmitz Limestone Member
(newly named unit this report)

The Olmitz Limestone Member is named in this report from exposures south of Columbia, at the type Carruthers Coal outcrop, in the east backslope along a gravel road in SE SW NE section 3, T. 73 N., R. 20 W., Lucas County. Here it consists of seven inches (18 cm) of light brownish gray (5YR 6/1), fossiliferous limestone that weathers to a brownish gray (5YR 4/1). The limestone overlies 1.1 feet (33 cm) of olive gray (5Y 4/1) shale with phosphorite nodules and abundant conodonts (Belinda Shale Member) and the Thousand Acre Coal bed. The limestone is overlain by 7.6 feet (1.4 m) of shale, sandstone and mudstone. The name is derived from the town of Olmitz, about 4.5 miles (7.2 km) to the southwest of the type section. The Olmitz Limestone may correlate with the ‘Seahorne’ Limestone of L.M. Cline, and L.M. Cline and D.G. Stookey (unpublished manuscripts) or the Upper County Line Limestone of D.G. Stookey (unpublished manuscript before 1935) and other early Iowa workers. Hanley (2008) correlated marine units equivalent to the Olmitz Limestone of this paper, with the lower Tiawah cyclothem at the

Tiawah Limestone type section in Oklahoma. See discussion under Elliot Ford Limestone.

The 378.0-379.1 foot interval in the Logan core in Harrison County is designated as a reference section.

Belinda Shale Member
(newly named unit this report)

The Belinda Shale Member is named in this report from exposures south of Columbia, at the type Carruthers Coal outcrop, in the east backslope along a gravel road in SE SW NE section 3, T. 73 N., R. 20 W., Lucas County. Here the Belinda Shale is 1.1 feet (33 cm) of olive gray (5Y 4/1) shale with phosphorite nodules and abundant conodonts (*Idiognathodus* and *Neognathodus*) in a dark gray (N3) zone about two inches (5 cm) above the Thousand Acre Coal bed and just below the Olmitz Limestone. The name is derived from the town of Belinda, about three miles (4.8 km) to the west southwest of the type section.

The 379.1-380.1 foot interval in the Logan core in Harrison County is designated as a reference section.

Unnamed detrital strata between top of Thousand Acre Coal bed and top of Laddsdale Coal beds
(no name proposed at this time)

A series of shales, mudstones and sandstones occur between the Belinda Shale and the Laddsdale Coal beds. It is difficult to estimate the thickness of these strata in Iowa, due to the uncertainty of the position of the Belinda Shale and named units in the "Laddsdale Coal beds" interval. No name is proposed for these units at this time. The Thousand Acre Coal bed occurs at the top of this unit. In most cores, it is probably coal # 5 of Ravn and others (1984), who considered this coal as palynologically distinct from the overlying Carruthers Coal and the underlying Laddsdale coals.

Thousand Acre Coal bed
(newly named unit this report)

The Thousand Acre Coal bed is named in this report from exposures south of Columbia, at the type Carruthers Coal outcrop, in an east backslope along a gravel road in SE SW NE section 3, T. 73 N., R. 20 W., Lucas County. This is the unnamed coal # 5 of Ravn and others (1984), in most cores. The Thousand Acre Coal ranges from a 0.6 inch (1 cm) smut at the type Carruthers Coal section to 1.2 feet (36 cm) at the type Floris Formation section to 1.6 feet (48 cm) in the CP-22 core in Appanoose County.

At the type section the Thousand Acre Coal is underlain by 7.2 feet (2.16 m) of medium gray (N5) to grayish green (10G 4/2) silty shale and mudstone. The name is derived from the Thousand Acre Unit of the Stephens State Forest Wildlife Management Area, about four miles (7.2 km) to the southeast of the type section. The Thousand Acre Coal is correlated with the Wiley Coal (northwestern) and Davis Coal (southeastern) Illinois (Ravn, 1986).

Hanley (2008) correlated a unit equivalent to the Thousand Acre Coal of this paper, with the Tebo Coal of Missouri, based on a previous misidentification of the Tebo Coal below the coal that underlies the major *Gondolella* zone at the exposure northwest of Montrose, Missouri, and the use of the name Tebo Coal for the coal below the Tiawah Limestone (at the base of the lower Tiawah cyclothem in Oklahoma. Fisher and Pope (2010) tentatively correlated the type Tebo Coal of Missouri with the type Carruthers Coal of Iowa, based on presence of the major *Gondolella* zone above the type Tebo Coal and above the type Carruthers Coal.

T.R. Marshall (personal communication, 2010) tentatively assigns the units above, and including the Thousand Acre Coal, to most likely the intermediate Wainwright cyclothem or possibly the lower Tiawah cyclothem, based on the morphotypes of *Idiognathodus* that are present. Thus the coal could then be equivalent to the Wainwright Coal or "Tebo" Coal below the lower Tiawah limestone of Hanley (2008) in Oklahoma. The coal at the 410.0-411.5 foot interval in the CP-78 core in Wayne County, the 299.1-300.8 foot interval in the CP-79 core in Lucas County, and the 380.1 foot level in the Logan core are probably equivalent to the Wainwright Coal of Oklahoma (see Marshall, 2010). See discussion about Carruthers Coal above.

The 380.1 foot level in the Logan core in Harrison County is designated as a reference section.

Unnamed shales, mudstones, limestones, and sandstones in "Laddsdale Member" at base of Floris Formation and above Kalo Formation
(no names proposed at this time)

A series of shales, mudstones, limestones, sandstones, and coals are included in what Ravn and others (1984) called the Laddsdale [Coal] Member, based on palynological similarities of the coals. It is difficult to estimate the thickness of these strata in Iowa, due to the uncertainty of the position of the Belinda Shale and named units in the "Laddsdale Coal beds" interval. The section containing the Laddsdale coals contains one to six coal beds, and appears to range from 13 feet (4 m) thick in the CP-9 core in Davis County to 91 feet (28 m) thick in the CP-47 core in Polk County. Ravn and others (1984) illustrated at least five coals, some associated with marine units, occurring at the Laddsdale type section along Soap Creek in Davis County. One of these marine units at the type Laddsdale section has been tentatively correlated with the Inola cyclothem of Oklahoma, by its conodont fauna (Marshall, 2010). This means that the Laddsdale coals and marine limestones should eventually be split into separate beds and members, and if the name Laddsdale is retained for a coal, it should be restricted to a single coal bed. Pending further study of conodont faunas in marine units above some of the coals in the Coal Project cores, and other cores/outcrops in Iowa and states to the south, the author will informally retain the name "Laddsdale" for this interval of coals and associated strata.

"Laddsdale coal beds"
(informal name)
(no changes proposed at this time)

The Laddsdale Coal was formally named by Hinds (1909) for exposures near the Wapello-Davis county line, although the name Laddsdale had existed since the 1800s for a coal or coals mined in the area of Laddsdale. Ravn and others (1984) designated a type section on Soap Creek in the SE SE NW section 17, T. 70 N., R. 12 W., Davis County. The section is actually in the SE SE NW section 7, T. 70 N., R. 12 W., Davis County (M. Howes personal communication, 1999; J.P. Pope, unpublished field notes). The name is derived from the Laddsdale Mines near the abandoned mining town of Laddsdale which once existed near the NW section 5 or the NE section 6, T. 70 N., R. 12 W., Davis County, Iowa.

A coal, locally called the Laddsdale, over 6.8 feet (2.1 m) thick (Howes and Lambert, 1988), occurs below a 5.1 foot (1.6 m) fossiliferous calcareous shale and a 6.7 foot (2.0 m) limestone ("Laddsdale Limestone," an informal name used by coal miners near Laddsdale) in a roadcut, along County Highway J15, in the SE NW NE section 6, T. 70 N., R. 12 W., Davis County. It is not known if this thick coal represents the entire Laddsdale interval where it consists of several coals, as at the type Laddsdale (five coal beds) about one mile (1.6 km) to the south-southwest, or if it is a very thick facies of a single coal. Although the "Laddsdale Limestone" was correlated with the Seville Limestone of Illinois by Landis and Van Eck (1965), this correlation is unlikely because the type Seville directly overlies the Rock Island (#1) Coal, which is probably older than the Cliffland Coal of Iowa (see below and Figure 9).

Ravn and others (1984) redefined the Laddsdale Member to encompass the stratigraphic interval containing all coals considered palynologically as Laddsdale. This interval is at the base of the Floris Formation, just above the Kalo Formation. At the type section, the Laddsdale coals consist of five coal beds ranging in thickness from 3.6 inches (9 cm) to 2.8 feet (0.8 m), distributed through 30 feet (9.1 m) of light gray (N7) to dark gray (N3) shales, mudstones and sandstones. About 2.4 inches (6 cm) above the third coal, is a 3.6 inch (9 cm) thick, medium gray (N5), limestone with marine fossils. This is overlain by 4.8 feet (1.4 m) of dark gray (N3), silty, micaceous, fossiliferous shale, which is overlain by 1.5 feet (45 cm) of medium gray (N5) fossiliferous, septarian limestone. This marine interval may be the same as the Munterville Limestone of L.M. Cline (unpublished manuscripts).

Marshall (2010) correlated the marine interval (limestones and dark conodont-rich shales) above the third coal at the type Laddsdale section, with the Inola cyclothem of Oklahoma, based on conodonts. Marshall (2010) reported sparse *Gondolella* in the Inola cyclothem in Kansas and Oklahoma. The limestone would be equivalent to the Inola Limestone in Oklahoma and the Hackberry Branch Limestone of Gentile and Thompson (2004), in Missouri. The third coal or possibly all three coals directly below the Inola marine interval would then be equivalent to the Bluejacket Coal of Oklahoma. The coal at the 438.5-439.8 foot interval in the CP-78 core in Wayne County, the 307.9-312.8 foot interval in the CP-79 core in Lucas County, and the ~398.0 foot level in the Logan core in Harrison County are probably equivalent to the Bluejacket Coal of Oklahoma, based on their position below the Inola marine unit (see Marshall, 2010). Lowman (1932) named the Inola Limestone from Inola Hill about 0.5 mile (0.8 km) east of Inola in section 10, T. 19 N., R.17 E., Rogers County, Oklahoma. The Hackberry Branch Limestone was named by Gentile and Thompson (2004) from exposures on Hackberry Branch in NE NE NW section 29, T. 35 N., R. 32 W., Vernon County, Missouri. The Bluejacket Coal was named by Searight and others (1953) because of its proximity to the underlying Bluejacket Sandstone.

The Laddsdale coals are correlated with the Brush Coal (Peppers, 1970) of northern and western Illinois. In Polk County, Keyes (1894), Bain (1897) and Hinds (1909) used the name 'first vein' for what appears to correlate with the 'Laddsdale Coal' (L.M. Cline, unpublished manuscripts; Howes, Culp and Greenburg, 1989), but the correlation is not definitely established as to which Laddsdale coal they referred to.

The Laddsdale interval probably represents several cyclic sequences of deposition, which have not yet been differentiated in Iowa. Later work may allow these units to be correlated into Missouri, Kansas and Oklahoma. The author will not name any new units in the Laddsdale interval or below, pending further biostratigraphic (conodonts, foraminifers etc.) study of the marine units that are associated with some of the coals.

Kalo Formation

(no changes proposed at this time)

The Kalo Formation was named by Ravn and others (1984) from the town of Kalo, Webster County, Iowa. The type section is in bluffs along the Des Moines River in the SE NW SW section 17, T. 88 N., R. 28 W., Webster County. The Kalo includes two named beds in ascending order: Blackoak Coal and Cliffland Coal. The Kalo Formation overlies the Kilbourn Formation, with the boundary at the base of the Blackoak Coal (of the Kalo Formation), and underlies the Floris Formation, with the boundary at the base of the Laddsdale Coal (of the Floris Formation).

At the type section of the Kalo, a lower coal that varies from a few inches (few cm) to 2.8 feet (0.9 m) has been identified as the Blackoak Coal (Ravn et al., 1984). This is overlain by 30.8 feet (9.4 m) of coarsening upward interlaminated sandstone, siltstone and shale. Above this another coal, 3-5 feet (0.9-1.5 m) thick, is also palynologically identified as the Blackoak. Above the upper coal is about 19 feet (6 m) of dark gray (N3) to black (N1) shale and siltstone. The boundary with the Floris Formation is tentatively placed at the base of the overlying sandstone. The Cliffland Coal is not present at the type section.

In IGS Coal Survey Project cores the Kalo, varies from a minimum of 17 feet (5.1 m) in the CP-40A core in Mahaska County, to a maximum of 120 feet (36 m) in the CP-41 core in Marion County, based on the palynology of coals. In the CP-28 core in Wapello County, the Blackoak Coal is split into two beds by a thin mudstone. It is separated from the Cliffland Coal by about 12 feet (3.7 m) of shale and sandstone. The Cliffland Coal in the core is 6.3 feet (2 m) thick, the thickest of any coal observed in the IGS coring project. In southeastern Iowa the Kalo is usually less than 60 feet (18 m) thick and the Blackoak and Cliffland coals occur as single beds. The separation between the two coals ranges from 2-20 feet (0.6-6.0 m). In the CP-37 Osceola core in Clarke County, the separation is 58 feet (17.6 m). Six coals are present in the Kalo in the CP-10 core in Appanoose County, with the lower four assigned to the Blackoak and the upper two coals to the Cliffland (Ravn et al., 1984). Palynology (Ravn et al., 1984) and conodont studies (Lambert and Heckel, 1990) show that the upper part (Cliffland Coal and above) of the Kalo Formation is Desmoinesian in age and the lower part (below Cliffland Coal) is Atokan in age. See discussion of Atokan and Atokan-Desmoinesian boundary below. No new units will be named in the Kalo Formation at this time, pending further study of the strata.

Marshall (2010) tentatively correlated units above the coal at the 604.0-504.8 foot interval in the CP-78 core in Wayne County, and units above the coal at the 401.1-405.6 foot interval (or due to lack of conodont data, as low as the coal at the 429.0-430.0 foot interval) in the CP-79 core in Lucas County, with the Doneley cyclothem. If this correlation is correct, the coal could be equivalent to the Rowe Coal in Oklahoma and the limestone at the 396.9-400.1 foot interval in the CP-79 core in Lucas County could be equivalent to the Doneley Limestone of Oklahoma. The Rowe Coal was named by Pierce and Courtier (1937) for the Rowe School in section 34, T. 30 S., R. 25 E., Cherokee County, Kansas. The Doneley Limestone was named by Branson (1952) from the Doneley School four miles (6.4 km) north of Vinita, in NW Section 16, T. 26 N., R. 20 E., Craig County, Oklahoma.

At this time, the author will use the three Kalo Formation reference cores designated by Ravn and others (1984; Fig. 12, p. 21). Intervals in these cores are: the 184.4-231.2 foot interval in the CP-28 core in Wapello County; the 439.9-546.9 foot interval in the CP-37 Osceola core in Clarke County; and the 32.6-81.6 foot interval in the CP-40 core in Mahaska County. A limestone above the Cliffland Coal and the stratigraphically lower Blackoak Coal, are presently exposed in a strip pit 0.8 miles (1.3 km) southwest of Lakonta (Truax) in the SW NW Section 29, T. 74 N., R. 16 W., Mahaska County.

Cliffland Coal bed
(reduced in rank)
(no other changes proposed at this time)

The Cliffland Coal was named by Landis and Van Eck (1965) for exposures near the town of Cliffland southeast of Ottumwa. The type section was established by Ravn and others (1984) at an abandoned railroad cut two miles (3.2 km) southeast of Cliffland, in the NE NE SE section 18, T. 71 N., R. 12 W., Wapello County.

At the type section, the Cliffland Coal consists of two beds. The lower bed varies from 1.8-3.4 feet (0.45-1.6 m) thick. The upper bed is 1.4 feet (40 cm) thick and is separated from the lower bed by a 3.2 foot (1.0 m) thick, light gray (N7) to light brown (5YR 6/4) mudstone and silty shale. The lower Cliffland is underlain by 15 feet (4.4 m) of shale and sandstone, and the upper Cliffland is overlain by 27 feet (8.1 m) of shale and sandstone.

In the CP-44 core in Warren County, the lower bed is 2.3 feet (0.7 m) thick and the upper bed is 4.3 feet (1.3 m) thick. The two beds are separated by 18 feet (5.5 m) of shale. The two beds are palynologically the same, and it is not known at this time if they are splits of the Cliffland or represent two separate cycles of deposition.

Where the Cliffland is a single bed it ranges from two inches (5 cm) thick in the CP-77 core in Lucas County, to 6.3 feet (1.9 m) thick in the CP-28 core in Wapello County. Hopkins and Simon (1975) and Lambert and Heckel (1990) correlated the Cliffland Coal with the Rock Island (No. 1) Coal of Illinois, and considered it Desmoinesian in age. Peppers (1996, p. 52) stated “the Cliffland Coal may be a little younger, however, than the Rock Island Coal.” The Cliffland may be equivalent to the Hastie Plus Coal (Landis and Van Eck, 1965) or ‘second vein’ (Keyes, 1894, Bain, 1897, Hinds, 1909) of Polk County, but the correlations have not been definitely established (Ravn et al., 1984; Howes, Culp and Greenburg, 1989). Marshall (2010) tentatively correlated the Rowe Coal of Oklahoma, Kansas, and Missouri, at the base of the Doneley cyclothem, with the Cliffland Coal of Iowa. In Iowa, the Atokan-Desmoinesian boundary is placed at the base of the Cliffland Coal.

ATOKAN STAGE

The Atokan was proposed as a stage (Atokan Stage of the little used Oklan middle Pennsylvanian series) by Moore and Thompson

(1949). It was also regarded as a stage by Cheney and Goss (1952), but was not used in this sense by most workers until Jewett and others (1968) used it as a stage in Kansas. Later workers (e.g., Gentile and Thompson, 2004) used the Atokan as a stage of the Middle Pennsylvanian Series (Figure 7, 8). Historically, four names have been applied to the post-Morrowan, pre-Desmoinesian interval. These are the: Bendian, Lampasan, Derryan, and Atokan series (Sutherland and Manger, 1984). Bendian and Lampasan were names derived from Texas, while the Derryan came from New Mexico. Because of problems with fusulinid foraminifer zonation in the Bendian, Lampasan and Derryan, a different name was needed for the post-Morrowan (post-*Millerella*), pre-Desmoinesian (pre-*Fusulina*-*Wedekindellina*) interval (Sutherland and Manger, 1984). Thus, the Atokan Series was proposed from the Midcontinent region.

The Atoka formation was named by Taff and Adams (1900) for exposures in the Choctaw Coal Field near Atoka, Atoka County, Oklahoma, and was later redefined as the Atokan Series by Spivey and Roberts (1946), specifically to describe a pre-Desmoinesian, post-Morrowan interval. Taff and Adams (1900) did not designate a specific type section, and the reference area for the Atokan Stage is still poorly defined, both biostratigraphically and lithostratigraphically. Branson (1962c) proposed another type area in northwestern Atoka County, but this was rejected by Sutherland and Manger (1984) because the rocks are so poorly exposed. A region, extending for 6-12 miles (10-20 km) northwest of the town of Clarita in Coal County, was proposed by Strimple and Watkins (1969) and endorsed by Sutherland and Manger (1983) as the best type area.

The Atoka is nearly 1300 feet (396 m) thick in the type area. Both the upper and lower boundaries of the Atokan, over the last 100 years, have been placed at various stratigraphic horizons, based on fusulinid foraminifers, palynology, ammonoids, brachiopods and conodonts.

In Iowa, Ravn (1979, 1981) placed the Atokan-Desmoinesian boundary at the top of the Blackoak Coal, based on the last occurrence of *Dictyotriletes bireticulatus*. Peppers (1996, pp. 34 & 52) states, "the Blackoak Coal of Iowa correlates approximately with the Pope Creek Coal of Illinois." The Pope Creek Coal is regarded as Atokan in age (Hopkins and Simon, 1975; Peppers, 1996, p. 45; Jacobson, 2002). In Illinois *D. bireticulatus* last occurs in the Rock Island Coal, which appears to be slightly older than the Cliffland Coal of Iowa (Peppers, 1996), and Shaver and others (1986) indicated that *D. bireticulatus* ranged up to the base of the Cliffland Coal in Iowa. Peppers (1996, p. 52) correlated the boundary in Iowa with the base of the Cliffland Coal, based on *D. bireticulatus* and other palynological data. In Illinois (Peppers, 1996), placed the Atokan-Desmoinesian boundary at the top of the Curlew/Seville Limestone, above the Rock Island Coal. Jacobson (2002) placed the boundary at the top of the Murray Bluff Sandstone, which underlies both the Seville Limestone and Rock Island Coal, but overlies the Pope Creek Coal (Figure 9).

Lambert (1990, 1992) and Lambert and Heckel (1990) also placed the boundary at the base of the Cliffland Coal (Figures 8, 9) in Iowa, based on the occurrence of the conodonts *Idiognathodus obliquus* and *Neognathodus caudatus* (Desmoinesian species) found above the Cliffland Coal. The conodonts *Idiognathoides* spp. and *Declinognathodus* spp., which are considered to be Atokan species, were found only below the Cliffland Coal.

At this time, all of the strata below the Cliffland Coal, in south-central and southwest Iowa are placed in the Atokan Stage, and this is supported also by conodont work in Marshall (2010). Future work may reveal that Morrowan strata exist in these areas.

The Atokan Stage overlies the Morrowan Stage and underlies the Desmoinesian Stage.

Blackoak Coal bed
(reduced in rank)
(no other changes proposed at this time)

The Blackoak Coal was named by Ravn and others (1984) for exposures along an intermittent tributary to Cedar Creek in an abandoned quarry in the NW SE section 31, T. 75 N., R. 17 W., northwest of Oskaloosa, Mahaska County, Iowa. The name is derived from nearby Black Oak

Township. The Blackoak Coal correlates approximately with the Pope Creek Coal of the lower Tradewater Formation (formerly Abbott Formation) of Illinois, which is upper Atokan in age (Peppers, 1996; Jacobson, 2002). Ravn and others (1984) placed the base of the Kalo Formation at the base of the Black Oak Coal.

At its type section the Black Oak Coal is about 4.5 inches (11.4 cm) thick, and is overlain by six feet (1.8 m) of shale. It is underlain by 6.1 feet (1.8 m) of light gray (N7) to dark gray (N3) shale of the top of Kilbourn Formation, which unconformably overlies Mississippian limestone at this locality.

The Blackoak Coal ranges from a smut in some cores to 5.7 feet (1.7 m) thick in the CP-19 core in Wapello County (Ravn et al., 1984). At the type section of the Kalo Formation in Webster County and in some cores, two palynologically similar coals are referred to as the Blackoak.

The name 'third vein' (Keyes, 1894; Bain, 1897; Hinds, 1909) and names Hastie and Manbeck coals (Landis and Van Eck, 1965; Howes, Culp and Greenburg, 1989) were used by miners in Polk County, and they may refer in part to the Blackoak Coal, but these correlations have not been definitely established.

Kilbourn Formation

(no changes proposed at this time)

The Kilbourn Formation was named by Ravn and others (1984) for the town of Kilbourn in Van Buren County. The type section is in an abandoned quarry just north of Kilbourn, in NW SE section 36, T. 70 N., R. 10 W. The Kilbourn Formation, in most places in Iowa, underlies the Kalo Formation, and unconformably overlies the Mississippian Subsystem.

At the type section, the Kilbourn Formation consists of 19 feet (5.7 m) of interbedded light gray (N7) to dark gray (N3) silty shale, which lie unconformably on Mississippian St. Louis Limestone. It is overlain by 18 inches (45 cm) of the Blackoak Coal and shale of the Kalo Formation.

The Kilbourn in IGS Coal Survey Project cores ranges from one foot (30 cm) in the CP-25 core in Davis County, to a maximum known thickness of 218 feet (66 m) in the CP-45 core in Polk County. In the CP-10 core in Appanoose County, the 43 foot (13 m) thick Kilbourn section contains four unnamed coals, the greatest number seen in any core. In the CP-18 core in Wapello County, and the CP-76 core in Appanoose County, Floris Formation sandstones overlie the Mississippian, and apparently represent erosional removal of the Kilbourn. In the CP-80 core in Lucas County, and some other cores, the Kilbourn may never have been deposited over highs on the Mississippian bedrock surface (Ravn et al., 1984).

Strata of the Kilbourn Formation consist mainly of shale, siltstone, sandstone, conglomerate, and thin discontinuous coals. Marine units, consisting of limestones and fossiliferous shales, are rare. Kilbourn coals are usually thin and discontinuous, but palynological evidence indicates that these coals are similar to the Reynoldsburg, Manley, and Tarter coals of the lower Tradewater Formation (formerly Abbott), in the Atokan Stage of the Illinois Basin (Ravn et al., 1984). The author proposes that no new units should be named in the Kilbourn Formation at this time, pending further study of the strata.

At this time, the author will use the three reference cores designated by Ravn and others (1984; Figure 8, p. 16). They are: the 418.9-469.2 foot interval in the CP-10 core in Appanoose County; the 445.7-508.9 foot interval in the CP-22 core in Appanoose County; and the 174.0-237.5 foot interval in the CP-27 core in Wapello County.

PART II: ILLINOIS BASIN STRATIGRAPHY

MIDDLE PENNSYLVANIAN SERIES (of SE Iowa only)

DESMOINESIAN STAGE

RACCOON CREEK GROUP

The name Raccoon Creek Group (Figure 8, 9) was first used by Wier (1961) who designated a type area from exposures along Raccoon Creek in T. 14 N., R. 6, 7, 8 W., and T. 15 N., R. 8 W., southern Parke County, Indiana. It is the basal Pennsylvanian group in Illinois, with a major unconformity between it and underlying older Paleozoic rocks, and includes strata that are Morrowan, Atokan and lower Desmoinesian in age. The Raccoon Creek Group includes the Caseyville Formation, the abandoned Abbott Formation and the lower part of the abandoned Spoon Formation of the abandoned Kewanee Group of Illinois (Greb et al., 1992; Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin, 2001; Jacobson, 2002). The Raccoon Creek Group comprises two formations in ascending order: Caseyville and Tradewater (in Illinois and Kentucky), and is overlain by a group (consisting of upper Spoon and most of the Carbondale formations, of older stratigraphic nomenclature) that is unnamed at this time in Illinois and Kentucky.

Tradewater Formation

The Tradewater Formation was named by Glenn (1912) for exposures along the Tradewater River, east of Battery Rock, Union County, Kentucky. Lee (1916) designated a type section in Union County, Kentucky. The name was dropped in Illinois by Kosanke and others (1960), but was continued to be used by the Kentucky Geological Survey. Jacobson (1991) and Weibel and others (1993), reintroduced the use of the name Tradewater in Illinois, abandoning the use of the Spoon and Abbott Formations, because of problems of recognition of the two formations and miscorrelations at the type Abbott (Jacobson, 1992). The Tradewater Formation is defined as strata between the top of the Caseyville Formation and the base of the Seelyville Coal Member (Davis Coal Member/bed), in Illinois and Kentucky.

The unnamed sandstone that lies unconformably above the Caseyville Formation in Scott and Muscatine counties in Iowa, was correlated with the abandoned Spoon Formation (now upper Tradewater Formation) of Illinois by Fitzgerald (1977). He based this on a petrologic study of the sandstones and determined they were more similar to Spoon Formation (now upper Tradewater Formation) sandstones than they were to underlying Abbott (now lower Tradewater Formation) or Caseyville sandstones of Illinois. Sandstones in the upper Tradewater (Spoon) generally tend to be very fine to coarse grained, have more argillaceous matrix, feldspar grains, lithic grains, and mica. Potter and Glass (1958) classified upper Tradewater (Spoon) sandstones as lithic arenites and lower Tradewater (Abbott) sandstones as transitional between Caseyville and upper Tradewater sandstones. Most Caseyville sandstones are quartz arenites with little or no clay matrix, feldspar, lithic fragments or mica, and tend to have quartz granules and pebbles (Hopkins and Simon, 1975; Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin, 2001). Since it was uncertain, because there is no biostratigraphic evidence, if the sandstones in Iowa were correctly correlated with the Spoon Formation (now upper Tradewater) of Illinois, the assignment was tentative. If Fitzgerald’s correlation is correct, it means these sandstones are time-equivalent to the lower part of the Floris Formation of the Cherokee Group in the Midcontinent (Western Interior) Basin. Ravn and others (1984) did not positively recognize lower Tradewater (former Abbott Formation) Formation strata in Scott and Muscatine counties, but B.J. Witzke (personal communication, 2008; unpublished cross sections) has recognized lower Tradewater units there.

The unnamed sandstone assigned to the upper Tradewater Formation (former lower Spoon Formation) at Wildcat Den State Park consists of 70 feet (21.3 m) of moderate brown (5YR) to yellow brown (10YR) poorly sorted, fine- to medium-grained quartz sandstone, with mica and minor feldspar and rock fragments (P.H. Heckel, personal communication, 2011). The exact stratigraphic horizons of the sandstone(s) are not known at this time in relationship to Midcontinent strata, but they are tentatively placed below the Thousand Acre Coal of this report (coal # 5 of Ravn et al. (1984), in most cores) and above the top of the underlying Laddsdale coals.

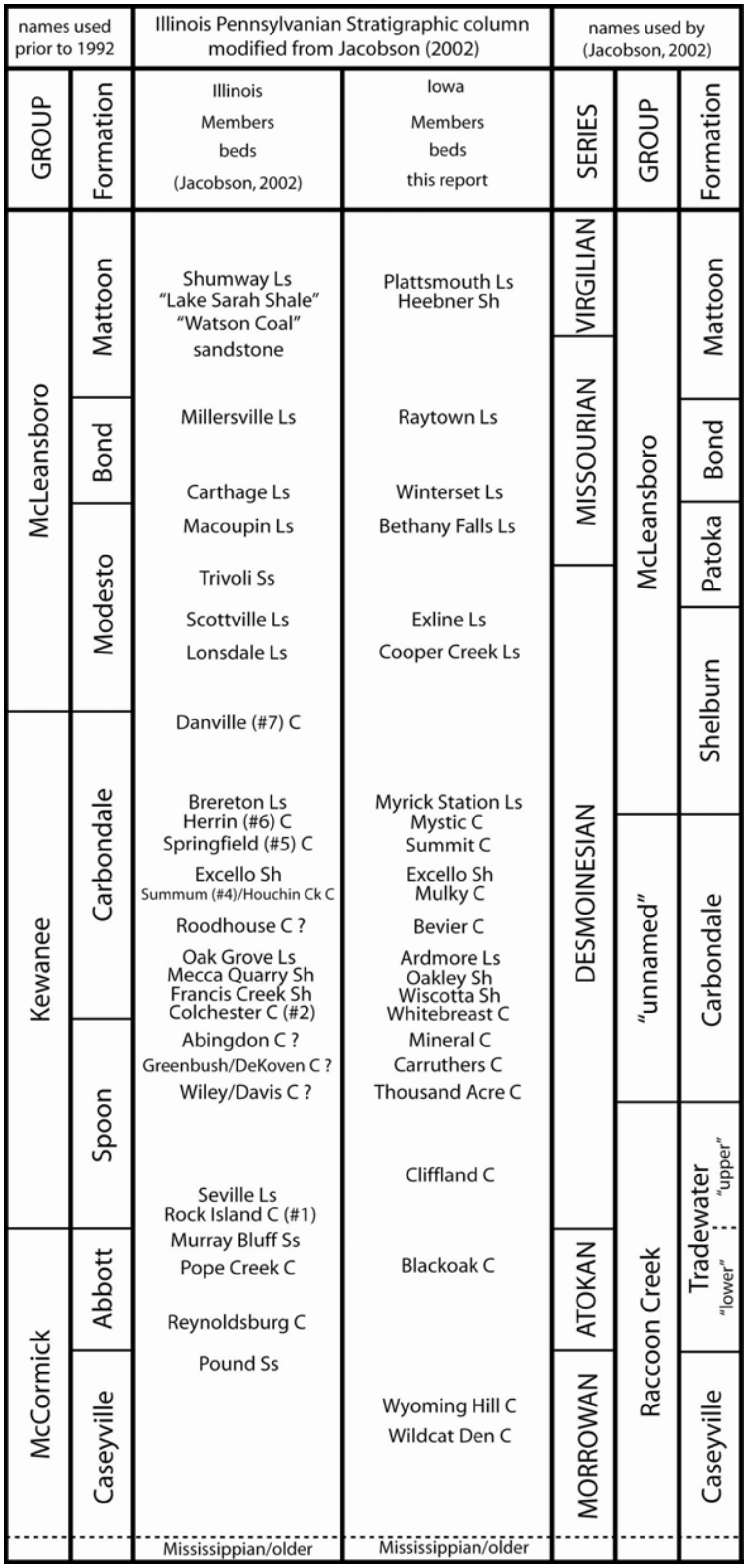

Figure 9. Recent and older Illinois Basin stratigraphy, showing main units at group and formational boundaries, with Iowa correlations mentioned in this report. Highly modified from Jacobson (2002). Not to scale.

Lower Pennsylvanian Series (of SE Iowa only)

MORROWAN STAGE

The Morrow group was named by Adams and Ulrich (1905) from exposures near the town of Morrow, Washington County, Arkansas, and they designated an area on and near Hale Mountain as the type section. Moore (1932) considered the Morrowan as a series, Jewett and others (1968) used it as a stage name (in Kansas), and later workers (e.g., Gentile and Thompson, 2004) regarded it as a stage of the Lower Pennsylvanian Series.

In Illinois (Figure 8, 9) and Kentucky the Morrowan comprises the lower part of the Raccoon Creek Group (formerly McCormick Group) and one formation, the Caseyville. The Tradewater Formation, in Illinois and Kentucky, replaces the abandoned Abbott Formation (Atokan) of the abandoned McCormick Group and lower part of the abandoned Spoon Formation (Desmoinesian) (Figure 9). The Pennsylvanian of Illinois was once (e.g., Wanless, 1929) divided into the Pottsville, Carbondale and McLeansboro formations, which corresponded roughly to the Pottsville, Allegheny and Conemaugh formations of the Appalachian Basin. The Pottsville formation included all strata below the Colchester (No. 2) Coal (Whitebreast Coal of Iowa). This would include lower Desmoinesian, Atokan, and Morrowan rocks, now assigned to the lower part of an unnamed group above the Tradewater Formation (lower Carbondale Formation) and the Raccoon Creek Group, Tradewater and Caseyville formations, in the Illinois Basin.

In Iowa, Morrowan strata are known to occur only in Scott and Muscatine counties in the southeastern part of the state, where they overlie Devonian rocks.

RACCOON CREEK GROUP

Caseyville Formation

The Caseyville Formation was named by Owen (1856) for the town of Caseyville, near the type locality on the Ohio River, in Union County, Kentucky. Lee (1916) designated a type section for exposures between Gentry ('s) Landing and the Saline River along the Ohio River in Hardin County, Illinois. In the Illinois-Kentucky region the Caseyville basal contact lies directly on rocks of Ordovician to Upper Mississippian age, but the upper boundary of the Caseyville is poorly defined in this region. In places it is at the top of the cliff-forming pebbly sandstone laterally equivalent to the Pounds Sandstone Member, but in other areas it is placed at the base of the Bell Coal that occurs just above the uppermost conglomeratic sandstone. Many Caseyville deposits are considered to fill paleovalleys in the older Paleozoic surface and vary from sandstones to shales. Caseyville sandstones are quartz arenites with little or no clay matrix, feldspar, lithic fragments or mica, and tend to have quartz granules and pebbles (Hopkins and Simon, 1975; Tri-State Committee on Correlation of the Pennsylvanian System in the Illinois Basin, 2001).

Across the Mississippi River from Scott and Muscatine counties of Iowa, in Mercer and Rock Island counties in Illinois, the Caseyville locally exceeds 100 feet (30 m) in thickness. In Iowa, the Caseyville is primarily sandstone, siltstone and shale, with a few coals (see Ravn et al., 1984). Searight and Smith (1969) recognized at least seven coals in Mercer and Rock Island counties in Illinois, and at least four coals are known in Iowa. In most areas of Iowa where it occurs, the Caseyville Formation unconformably overlies Devonian strata and unconformably underlies sandstone of the upper Tradewater Formation.

Wyoming Hill Coal bed
(reduced in rank)

The Wyoming Hill Coal was named by Ravn and others (1984) for exposures at the Wyoming Hill section along Iowa State Highway 22 in the NE section 34, T. 77 N., R. 1 W., Muscatine County, Iowa, where four coals are exposed. The upper two coals, separated by 1.3 feet (40 cm) of white (N9), very fine grained sandstone, were both assigned to the Wyoming Hill Coal, on palynological evidence, (Ravn et al., 1984). Two lower coals, separated from the Wyoming Hill Coal by 12.8 feet (2.9 m) of light gray (N7), argillaceous, sandy, laminated siltstone, are assigned to the Wildcat Den Coal. Combined, both beds of the Wyoming Hill Coal are 2.3 feet (0.7 m) thick at the type section.

Wildcat Den Coal bed
(reduced in rank)

The Wildcat Den Coal was named by Ravn and others (1984) for the lowermost coal in the Caseyville sections in Muscatine County, Iowa. The type section was designated in SW section 17 and SE section 18, T. 77 N., R. 1 E., Wildcat Den State Park, Muscatine County, Iowa. It is 1.0-1.5 feet (30-45 cm) thick at its type section, underlain by 2.5 feet (0.76 m) of light olive gray (5Y 6/1) laminated shale, and is overlain by 17 feet (5.2 m) of very dark gray (N2) laminated shale.

The lower two coals at the Wyoming Hill section are assigned to the Wildcat Den Coal. The upper coal, 0.5 feet (15 cm) thick, is underlain by about ten feet (3.0 m) of medium gray (N5), laminated siltstone, which is underlain by another coal up to 0.5 feet (15 cm) thick. This lowest coal is in the covered interval shown in Fig. 4, p. 9 of Ravn et al., 1984, but has more recently been exposed by erosion of the outcrop. Below the lower coal is about 15-20 feet (4.6-6.1 m) of shale, slightly blocky at the top, with a dark zone in the middle. The shale is underlain by lenses of fine-grained, quartzose sandstone, and grades eastward into sandstone with complex cross-bedding, which becomes more continuous and thickens to the east along the highway. Information on the lower Wildcat Den Coal and units below it were provided by P.H. Heckel in 2010, from an unpublished field trip guide for a sedimentary geology class.

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CORE LOCATIONS

All cores used in this report are reposited in the Iowa Geological Survey Core facilities at the Oakdale Campus The University of Iowa, Coralville, Iowa

W (well-log) number following core name allows direct access to core description (striplog) in GEOSAM on the Iowa Geological Survey website http://www.igsb.uiowa.edu/webapps/geosam/

Quarter section designations are: smallest → largest.

IGS CP-7(W-27307) SE SE SE section 36, T. 71 N., R. 14 W., Wapello County

IGS CP-9 (W-27309) SW NW SE section 7, T. 67 N., R. 15 W., Davis County

IGS CP-10 (W-27310) SW SW SE section 6, T. 68 N., R. 17 W., Appanoose County

IGS CP-18 (W-27318) NW NW NW NW section 6, T. 73 N., R. 14 W., Wapello County

IGS CP-19 (W-27319) NW NW NE NE section 18, T. 73 N., R. 14 W., Wapello County

IGS CP-22 (W-27322) SE SW SE section 36, T. 70 N., R. 19 W., Appanoose County

IGS CP-24 (W-27324) NW NW NE SE section 1, T. 67 N., R. 14 W., Davis County

IGS CP-25 (W-27325) NW NE NW NW section 5, T. 67 N., R. 17 W., Davis County

IGS CP-27 (W-27327) NW NW NW section 11, T. 71 N., R. 14 W., Wapello County

IGS CP-28 (W-27328) NW SE NE section 36, T. 72 N., R. 15 W., Wapello County

IGS CP-37 Osceola core (W-27337) NE SE NE section 2, T. 72 N., R. 26 W., Clarke County

IGS CP-40 (W-27340) SE SW NW NE section 6, T. 74 N., R. 17 W., Mahaska County

IGS CP-40A (W-30737) SE SE SE SW section 31, T. 75 N., R. 17 W., Mahaska County

IGS CP-41 (W-27341) NE NE SE SW section 36, T. 75 N., R. 20 W., Marion County

IGS CP-44 (W-27344) SE SW SE section 36, T. 77 N., R. 23 W., Warren County

IGS CP-47 (W-23747) SE NE NE section 4, T. 79 N., R. 25 W., Polk County

IGS CP-53 (W-27353) NE SE NE section 1, T. 71 N., R. 18 W., Monroe County

IGS CP-76 (W-27375) SE NE NE section 2, T. 70 N., R. 17 W., Appanoose County

IGS CP-77 (W-27376) NW SW NW section 27, T. 71 N., R. 20 W., Lucas County

IGS CP-78 (W-27377) SW NE NE section 12, T. 70 N., R. 22 W., Wayne County

IGS CP-79 (W-27378) NE NE NE section 12, T. 71 N., R. 22 W., Lucas County

IGS CP-80 (W-27379) SW NW SE section 12, T. 72 N., R. 22 W., Lucas County

Bedford core (W-30816) SE section 4, T. 67 N., R. 34 W., Taylor County

C-100 core (W-30790) SW SW SW SE section 7, T. 68 N., R. 36 W., Page County

GSB SW-4 Riverton core (W-27556) SE SE SE SW section 20, T. 67 N., R. 41 W., Fremont County

IMC Malvern core (W-28868) NW SW section 5, T. 71 N., R. 41 W., Mills County

USGS R-46 core (W-19953) NW NW NW section 1, T. 69 N., R. 29 W., 2.5 miles (4.0 km) SW of Ellston, Ringgold County

Wc-22 Logan core (W-26516) NW SE NE NE section 19, T. 79 N., R. 42 W., Harrison County

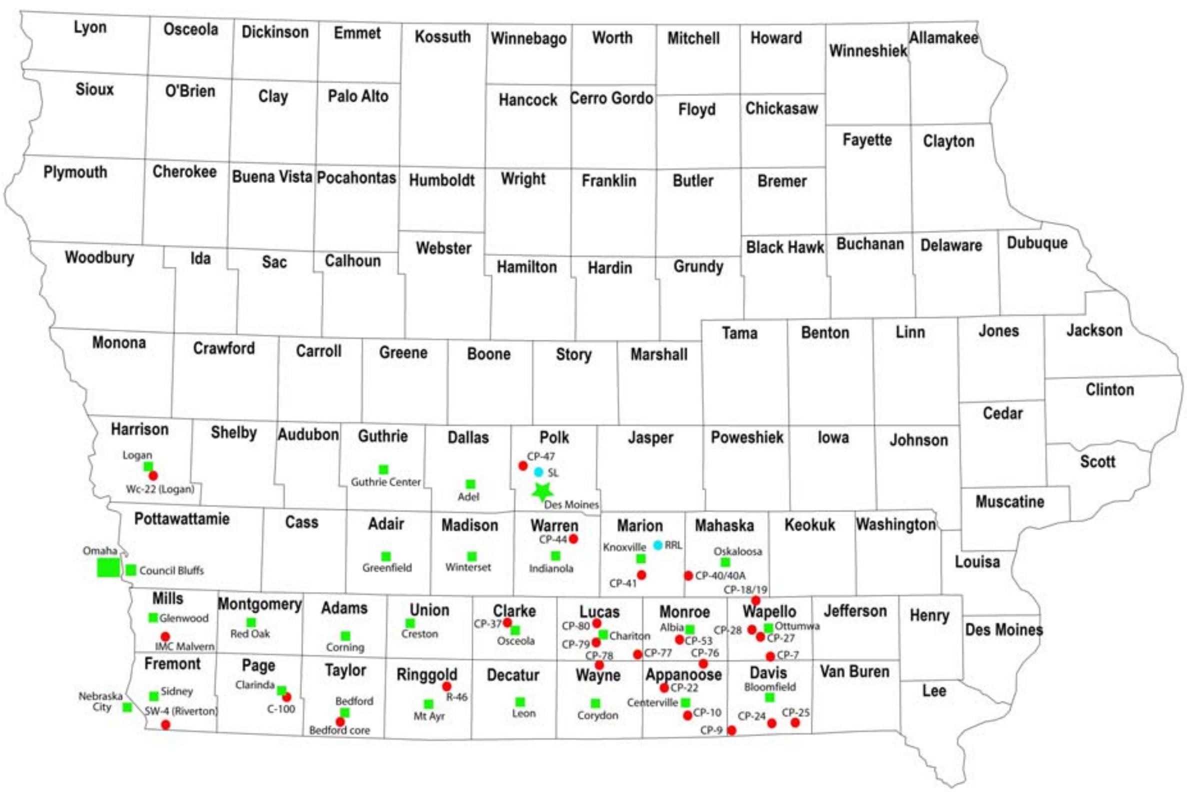

Figure 10. Map of Iowa counties, selected cities and locations of cores used in this report. SL: Saylorville Lake; RRL: Red Rock Lake

PENNSYLVANIAN TYPE SECTION LOCATIONS IN IOWA

Quarter section designations are: smallest → largest.

Arbor Hill Coal bed (AH) named from exposures along Middle River between a west-facing cutbank of Middle River in the SW SW SE SE section 22, T. 76 N., R. 30 W., west to the NE SE section 18, T. 76 N., R. 30 W., Adair County, Iowa.

Belinda Shale Member (BS) named from exposures south of Columbia, in the east backslope of a gravel road in SE SW NE section 3, T. 73 N., R. 20 W., Lucas County, Iowa.

Blackoak Coal bed (BC) named for exposures along an intermittent tributary to Cedar Creek in an abandoned quarry in the NW SE section 31, T. 75 N., R. 17 W., northwest of Oskaloosa, Mahaska County, Iowa.

Burroak Shale Member (BS) named from exposures in roadcuts and ravines in the E ½ section 21, T. 71 N., R. 43 W., near Burr Oak School, Mills County, Iowa.

Carruthers Coal bed (CC) named for exposures south of Columbia, in the east backslope of a gravel road in NW NW SE section 3, T. 73 N., R. 20 W., Lucas County, Iowa. The outcrops are actually in the SE SW NE section 3, T. 73 N., R. 20 W.

"Chariton Conglomerate" (C) named for exposures in a quarry in the east bluff of the Chariton River, near the mouth of Snort Creek, in the SW section 9, T. 69 N., R. 17 W., Appanoose County, Iowa.

Clanton Creek Limestone Member (CCr) from south-side cutbank exposures in a tributary ravine to Clanton Creek in the NE SE NW section 22, T. 75 N., R. 26 W., near the town of Hanley, Madison County, Iowa.

Cliffland Coal bed (CL) named from exposures southeast of Ottumwa, at an abandoned railroad cut two miles (3.2 km) southeast of Cliffland, in the NE NE SE section 18, T. 71 N., R. 12 W., Wapello County, Iowa.

Coal City Limestone Member (CCL) named from exposures in the east bluff of the Chariton River east of the now abandoned town of Coal City, in the S½ SW section 16, T. 67 N., R. 16 W., Appanoose County, Iowa.

Cooper Creek Limestone Member (CoC) named from exposures in pasture tributary ravines to Cooper Creek, north of Highway 2, in the SE section 26, T. 69 N., R. 18 W., Appanoose County, Iowa.

Davis City Coal bed (DCC) named from exposures in a quarry two miles (3.2 km) west of Davis City in SE NE section 4, T. 67 N., R. 26 W., Decatur County, Iowa.

East Peru Limestone Member (EPL) named from west-facing cutbank exposures in a tributary to Clanton Creek in the NE SW NE section 12, T. 74 N., R. 27 W., about five miles (8.0 km) east of East Peru, Madison County, Iowa.

Elliot Ford Limestone Member (EFL) named from exposures at Elliot Ford along the west side of Saylorville Lake in the NW NW section 14, T. 80 N., R. 25 W., Polk County, Iowa.

Exline Limestone Member (ExL) named from exposures in cutbanks of a west-flowing tributary to North Shoal Creek in the SE of section 6, T. 67 N., R. 17 W., Appanoose County, Iowa.

Floris Formation (F) named for a number of backslope cuts along a north-south road on the east edge of section 29, T. 72 N., R. 13 W., east of Ottumwa, Wapello County, Iowa.

Harmon Tunnel Coal bed (HT) named at an exposure in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County, Iowa.

Haynies Limestone Member (HL) named from exposures southeast of Haynies Railroad Station (now called Sargent's siding), Mills County, Iowa. It is unclear where the exposures were, but they may have been in section 10, T. 71 N., R. 43 W.

Imes Coal bed (IC) named from an exposure in a north-side roadcut in a west facing hill on a dirt road southwest of St. Charles, in the S line SW SW NE section 27, T. 75 N., R. 26 W., Madison County.

Kalo Formation (K) named from exposures in the bluffs along the Des Moines River in the SE NW SW section 17, T. 88 N., R. 28 W., near the town of Kalo, Webster County, Iowa.

Kilbourn Formation (KF) named for exposures in an abandoned quarry just north of Kilbourn, in the NW SE section 36, T. 70 N., R. 10 W., Van Buren County, Iowa.

"Laddsdale coal beds" (LC) named for exposures on Soap Creek in the SE SE NW section 17, T. 70 N., R. 12 W., Davis County. The section is actually in the SE SE NW section 7, T. 70 N., R. 12 W.

McBride Coal bed (McB) named from exposures in a tributary ravine to North River about six miles (9.6 km) northeast of Winterset, in the NW NW SE section 3, T. 76 N., R. 27 W., Madison County, Iowa.

Marshall Coal bed (MrC) named for a coal at Marshall's Mine in the NW section 24, T. 78 N., R. 30 W., Guthrie County, Iowa.

Morgan School Shale (MS) named from exposures along the C of the E line of NW [NW SW NE] section 18, T. 72 N., R. 22 W., Lucas County, Iowa.

Mouse Creek Formation (MCF) named from exposures in a gully along Whitebreast Creek in the NW NE NE section 8, T. 73 N., R. 22 W., Lucas County, Iowa. The actual location is just south of a gravel road in the NW NE NE section 8, T. 72 N., R. 22 W. **Mouse Creek Formation neostratotype (NMCF)** designated at exposures in a south-facing roadcut backslope east of Booneville, in the S½ NW NE section 29, T. 78 N., R. 26 W., Dallas County, Iowa.

Mystic Coal bed (M) named from exposures near the town of Mystic, northwest of Centerville along Walnut Creek in the NE SW section 17, T. 69 N., R. 18 W., Appanoose County, Iowa.

Nodaway Coal bed (NC) named from an exposure one mile (0.6 km) southeast of Clarinda, Iowa. It is unclear, but the exposures were probably at the bluff on the east side of the West Nodaway River, near the site of Shambaugh Mill, in the NW SE section 7, T. 68 N., R. 36 W., Page County, Iowa.

Nyman Coal bed (NyC) named from an exposure at a coal mine on the Charles Lindquist farm on the Middle Tarkio River in the NW NW section 24, T. 70 N., R. 38 W., about ten miles northwest of Clarinda, Page County, Iowa.

Oakley Shale Member (OS) named for exposures in a series of streamcuts at the Swede Hollow type section in sections 33 and 34, T. 73 N., R. 22 W., and section 3, T. 72 N., R 22 W., Lucas County, Iowa.

Olmitz Limestone Member (O) named from exposures south of Columbia, in the east backslope of a gravel road in SE SW NE section 3, T. 73 N., R. 20 W., Lucas County, Iowa.

Pammel Park Limestone Member (PP) named from exposures in a south-facing cutbank of Middle River, 1.1 miles (1.8 km) west of Pammel State Park in the NE NE SW section 17, T. 75 N., R. 28 W., Madison County, Iowa.

Red Haw Limestone Member (RH) named from exposures about three miles (4.8 km) northeast of Chariton, just south of the C of the N line SW section 4, T. 72 N., R. 21 W., Lucas County, Iowa.

Stephens Forest Formation (SF) named from exposures along the C of the E line [NW SW NE] of NW section 18, T. 72 N., R. 22 W., Lucas County, Iowa.

Swede Hollow Formation (SH) named from a series of streamcut exposures along a tributary (Swede Hollow) to Whitebreast Creek south of Oakley, in sections 33 and 34, T. 73 N., R. 22 W. and section 3, T. 72 N., R 22 W., Lucas County, Iowa.

Tarkio Limestone Member (TL) named from exposures in T. 68 N., R. 38 W., (Tarkio Township) along Tarkio Creek (River), north of the town of Coin, Page County, Iowa. It is not clear, but the outcrop may have been in the NE corner NW section 27, T. 68 N., R. 38 W.

Thousand Acre Coal bed (TA) named from exposures south of Columbia, in an east backslope of a gravel road in SE SW NE section 3, T. 73 N., R. 20 W., Lucas County, Iowa.

Westerville Limestone Member (WL) named exposures on Sand Creek near the town of Westerville, Decatur County, Iowa. It is unclear, but the outcrops may have been in T. 70 N., R. 27 W.

Wheeler Coal bed (W) named from exposures near the Swede Hollow type section southwest of Oakley, in the NE section 33, T. 73 N., R. 22 W., Lucas County, Iowa, in the immediate vicinity of Wheeler's mill, which no longer exists.

Whitebreast Coal bed (WBC) named for exposures about 400 yards (366 m) south of the bridge over White Breast Creek in the SW SW NE section 33, T. 73 N., R. 22 W., Lucas County, Iowa.

Wildcat Den Coal bed (WDC) named for the lowermost coal in the Caseyville sections in the SW section 17 and SE section 18, T. 77 N., R. 1 E., Wildcat Den State Park, in Muscatine County, Iowa.

Winterset Limestone Member (W) named from exposures in the vicinity of Winterset, in section 22, T. 75 N., R. 28 W., Madison County, Iowa. Also located in the old quarry in the W 1/2 section 6, T. 75 N., R. 37 [27] W., on south edge of Winterset, Madison County, Iowa.

Wiscotta Shale Member (WS) named from exposures in the NE SE NW section 4, T. 78 N., R. 29 W., in the abandoned claypit (behind the old brick kilns) in the northwest corner of Redfield, Dallas County, Iowa.

Wyoming Hill Coal bed (WHC) named for exposures at the Wyoming Hill section along Iowa State Highway 22 in the NE section 34, T. 77 N., R. 1 W., Muscatine County, Iowa.

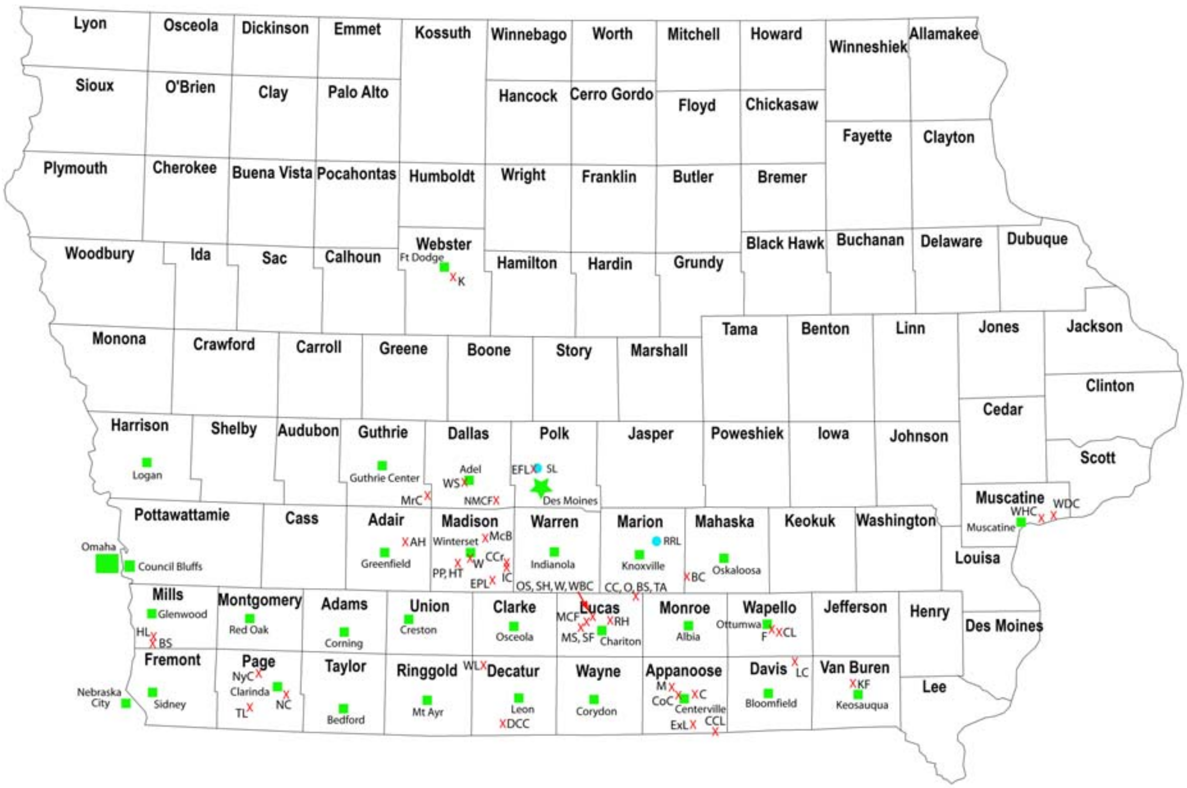

Figure 11. Map of Iowa counties, selected cities and locations of Iowa Pennsylvanian type sections. SL: Saylorville Lake; RRL: Red Rock Lake. Other abbreviations as in parentheses after rock unit names in above text.

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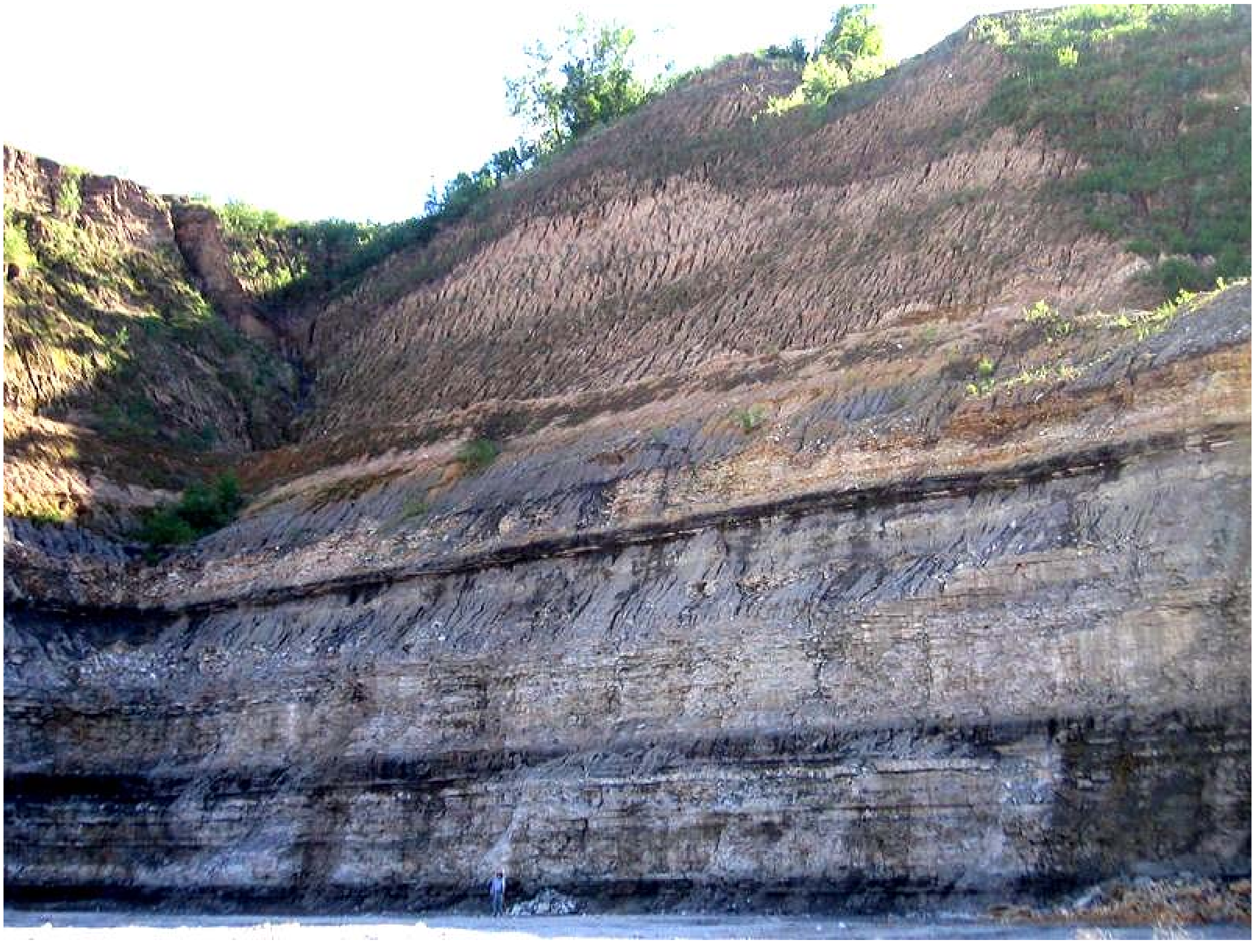

Photograph of interval from the top of the Winterset Limestone to the top of the Exline Limestone presently exposed in Schildberg's Crescent quarry, in the SE NW SW Section 26, T. 76 N., R. 44 W., Pottawattamie County, Iowa. Author John Pope is standing on the top of the Exline Limestone Member, Pleasanton Formation and is holding a staff that is 6.5 feet (2.0 m) long. Pennsylvanian strata are mantled by thick Pleistocene loess deposits. Photo by Diana Pope, June 2008