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STRATIGRAPHY OF THE CHEROKEE GROUP AND REVISION OF PENNSYLVANIAN STRATIGRAPHIC NOMENCLATURE IN IOWA

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IOWA GEOLOGICAL SURVEY

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ABSTRACT

Recent studies have revealed the need to revise and refine the stratigraphic nomenclature of the Pennsylvanian System in Iowa. Clear distinction is made between major chronostratigraphic and lithostratigraphic units in order to clarify confusion in the use of the term "Series" in previous literature. The term "Series" is restricted to its proper chronostratigraphic usage, and the term "Supergroup" is applied to strictly-defined lithostratigraphic units.

The major Pennsylvanian outlier in Scott and Muscatine counties is recognized as a structural extension of the Eastern Interior (Illinois) Basin. The Illinois formation names of Caseyville and "Spoon" are extended into Iowa for these strata. Strata of the Caseyville Formation are recognized as the oldest known Pennsylvanian (Morrowan Series) sediments in Iowa.

Systematic coring within the Des Moines Supergroup in southern Iowa has provided previously unavailable continuous sections through the Cherokee Group, and permits, for the first time, a consistent correlation through this interval. Based on major depositional episodes, four new formations are delineated within the Cherokee Group, in ascending order: Kilbourn, Kalo, Floris, and Swede Hollow. Coal bed nomenclature within the Cherokee also is formalized. The lower portion of the Cherokee Group is known to correlate with Illinois Basin strata considered to be of Atokan age. A practical chronostratigraphic boundary for the top of the Atokan Series is placed, through biostratigraphic analysis, in the middle of the Kalo Formation, between the newly-named Blackoak and redefined Cliffland Coals. The new name Carruthers is proposed to replace the name Wiley for the uppermost coal of the Floris Formation because of previous miscorrelation between this coal and the properly designated Wiley Coal of Illinois.

The boundary between the Cherokee and Marmaton Groups in Iowa is redefined as the base of the Excello Shale, rather than its top. This change results from review of the depositional interpretation of lowermost Marmaton strata. With the inclusion of the Excello Shale, the lowermost Marmaton "Fort Scott" Formation is considered to comprise two marine cyclothems, each depositionally analogous to a single formation in overlying Marmaton strata. Three new formational units are defined to accommodate these two marine cyclothems and the intervening marginal marine to non-marine shale unit. In ascending stratigraphic order, these are: Mouse Creek Formation, Morgan School Shale, Stephens Forest Formation. Depositional interpretation of the upper Marmaton Formations in Iowa are also reviewed, and two new, but yet unnamed, formations are identified.

Group nomenclature in the Missouri Supergroup is revised. The basal unit, previously designated as the Pleasanton Group, is reduced to formation status, and placed within a resurrected and newly-defined Bronson Group, to include strata from the Pleasanton upward through the Dennis Formation. The overlying Kansas City Group is redefined to include strata from the Cherryvale Formation upward through the Bonner Springs Shale. The definition of the Lansing Group is unchanged. The Westerville Limestone and Quivira Shale, previously considered formations in Iowa, are redesignated as members of the Cherryvale Formation, to bring Iowa nomenclature into conformity with that of Kansas. No changes are proposed for strata of the Virgil Supergroup.

DEDICATION

The proposals presented in this report are derived from a number of recent bio- and lithostratigraphic studies by the authors and others. Among the most important of these are the studies of John W. Swade II concerning Midcontinent Pennsylvanian conodont stratigraphy and paleoecology. John Swade was principally responsible for the stratigraphic revisions of the old Fort Scott and Lenapah Formations and a primary collaborator in the formational subdivision of the Cherokee Group, in addition to being a keen critical review through all phases of manuscript preparation.

John Swade died at the age of 31 on March 9, 1983 following a lengthy battle with cancer. He was active in his research until his death, and he left behind a great amount of data and observations, which are presently being assembled for future publication. He also left a wife and infant daughter and a long list of friends and co-workers. The sentiments of those who knew and loved John Swade have perhaps been expressed most appropriately by Steinbeck (1948) in his memorable essay on the death of a close friend, the biologist Ed Ricketts: "Everyone near him was influenced by him, deeply and permanently... He haunts the people who knew him. He is always present even in the moments when we feel his loss the most."

This paper would not have been possible without the contributions of John Swade. It is dedicated to his memory.

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KEY TO SYMBOLS AND ABBREVIATIONS USED THROUGHOUT THIS PAPER

- Sandstone (ss)
- Siltstone (slst)
- Shale (sh)
- Dark fissile shale
- Mudstone (mdst)
- Coal
- Core loss / covered interval
- Limestone (ls)
- Limestone nodule
- Phosphate nodules, laminations (phos)
- Conglomerate (cgl)
- Rooting
- Cone-in-cone structure

Note: Symbols are combined for mixed, intercalated, or gradational lithologies.

bitrb Bioturbation
zoo Zoophycus
foss Fossiliferous
brach Brachiopods
ostra Ostracodes
pelecy Pelecypods
gast Gastropods
pl deb Plant debris
xbd Cross-bedded
xlam Cross-laminated
brec Breccia, brecciated
calc Calcareous
pyr Pyrite
fest Ironstone
sid Siderite
bny Boney coal
sept Septarian structure

INTRODUCTION

The Pennsylvanian System in Iowa has confronted stratigraphers with serious correlation and nomenclatural problems for many years. Significant portions of the system have remained undifferentiated below group level. Recently, several related research projects have culminated in a more complete understanding of the age relationships and lithologic continuity of various portions of the Pennsylvanian sequence in the state. In addition, the publication of a newly-revised North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983) has illuminated certain ambiguities and inconsistencies of nomenclature as historically applied in Iowa. This paper is intended to bring the stratigraphic nomenclature for the Iowa Pennsylvanian into conformity with both the new Code and the present state of knowledge. It is designed to apply only to the geologic section as it exists in the state of Iowa, and it is not proposed as a universally applicable nomenclatural framework for other areas. We believe that these revisions will clarify understanding of the strata and depositional history of the Pennsylvanian System in Iowa, and will facilitate communication and comparison with equivalent sections elsewhere in North America.

ACKNOWLEDGMENTS

We wish to thank a number of people who have provided encouragement, technical assistance and advice, sample materials, and critical editorial review during the preparation of this study and the associated projects leading to it. Their contributions are too varied in nature to cite individually, but our grateful acknowledgements go to Donald L. Koch, State Geologist and Director of the Iowa Geological Survey (IGS); Matt Avcin, chief of the former Coal Division, IGS; Survey Geologists Bill Bunker, Greg Ludvigson, and Brian Witzke; Survey Secretary Laurie Comstock; Survey Administrative Assistant Mike Farmer; and Survey Graphic Artist Pat Lohmann; Survey Editor Sheila Baker; Philip H. Heckel and Richard G. Baker of the Department of Geology, University of Iowa; Steven R. Schutter, presently with Exxon Production Research in Houston, Texas; Russel A. Peppers, Coal Section, Illinois State Geological Survey; Wallace Howe and Thomas Thompson of the Missouri Department of Natural Resources; and collectively to the Kansas Geological Survey. Finally, we would like to thank Lynn Watney (Kansas Geological Survey) and Philip Heckel (University of Iowa) for their review of this manuscript.

LITHO- AND CHRONOSTRATIGRAPHIC TERMINOLOGY

Strata representing nearly all of Pennsylvanian time are now known to be present in Iowa. Pennsylvanian rocks are exposed, or form the pre-Pleistocene and, in some areas, pre-Cretaceous subcrop, over southwestern and south-central Iowa, extending as far north as Humboldt and Webster counties (figure 1). In addition, numerous erosional remnant outliers of Pennsylvanian strata are found in east-central and southeastern Iowa, the largest and most significant of which is located in Scott and Muscatine counties along the Mississippi River. The regional dip of the Pennsylvanian beds is generally toward the southwest. In that direction, post-Pennsylvanian erosional beveling has exposed successively younger rocks, and the thickest known Pennsylvanian sections are found in the southwestern corner of the state. Correspondingly, the oldest Pennsylvanian strata are exposed in eastern Iowa.

In Midcontinent North America, the Pennsylvanian chronostratigraphic sequence historically comprises five Series, in ascending order: Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian. Unfortunately for the interest of clarity and for more modern practices of stratigraphic nomenclature, these chronostratigraphic units, meant to represent theoretical subdivisions of geologic time measured by fossil ranges, drew upon physical rock units for their names and definition. In the past, the term "Series" was applied to both litho- and chronostratigraphic units without much consideration for the important geologic distinction between them. This has resulted in a great deal of confusion concerning the time relationships of Pennsylvanian rocks across the Midcontinent, and has been the proximate cause of some significant miscorrelations.

The newly-revised North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983, p. 859) states the problem clearly: "Although 'series' is a useful general term, it is applied formally only to a chronostratigraphic unit and should not be used for a lithostratigraphic unit. The term 'series' should no longer be employed for an assemblage of formations or an assemblage of formations and groups . . . These assemblages are groups or supergroups." Detailed discussions of the intricacies of litho- and chronostratigraphic units in general is beyond the scope of this report. Adequate summaries of these topics may be found in most modern standard stratigraphy texts (e.g., Krumbein and Sloss, 1963; Dunbar and Rodgers, 1966). The significant point is that lithostratigraphic and chronostratigraphic units are *not* synonymous. The boundaries of chronostratigraphic units, including Series, are synchronous, that is, they are time lines which commonly do *not* respect or follow the boundaries of lithostratigraphic units, defined on physical characteristics of the rocks. How frequently this fundamental stratigraphic distinction continues to be ignored in modern literature remains a source of astonishment.

We propose, therefore, to adhere strictly to the Stratigraphic Code in our definition of units in this report. Accordingly, the major lithostratigraphic subdivisions of the Pennsylvanian System in Iowa, historically called Series, are herein redesignated as Supergroups. Four are recognized, in ascending stratigraphic order: Morrow, Des Moines, Missouri, and Virgil. In order to clarify the distinction between litho- and chronostratigraphic units, we adopt the practice of Moore (1947) of adding -an or -ian suffixes to the names for the latter. This use of dual names for both kinds of units is not wholly satisfactory; its semantic clumsiness is obvious. Thoroughly sound arguments have been advanced against such a practice for many years (e.g., Kleinpell, 1938; Schenck and Muller, 1941); in many areas, as is widely recommended, completely separate systems of naming litho- and chronostratigraphic units are employed. In the North American Midcontinent, however, the major Series names have been used for so long and are so ingrained in the literature, that to reject them in favor of new names not derived from lithologic units would result in an even greater degree of confusion than presently exists. The only acceptable alternative appears to be scrupulous clarification of the use of litho- and chronostratigraphic terminology in all subsequent stratigraphic literature on the Midcontinent Pennsylvanian.

Although lithostratigraphic boundaries almost never represent true geologic time-lines (an exception being bentonites, the remains of geologically instantaneous volcanic ash falls), they may be virtually indistinguishable in practice, because of the imprecision of the fossil record upon which chronostratigraphy is based. In Iowa, for instance, the boundaries of the Missourian Series correspond, as far as we know, to the boundaries of the Missouri Supergroup. This situation is not true, however, for the Desmoinesian Series, as the Des Moines Supergroup in its type area along the Des Moines River was deposited over a deeply-eroded Mississippian surface with perhaps hundreds of feet of relief. Considerable geologic time elapsed between the initiation of sedimentation on this surface and the complete burial of the Mississippian terrane by Pennsylvanian deposits. For many years the comparative age of lower Des Moines strata remained unknown, principally because of the absence of marine units containing stratigraphically useful megafossils. Recent studies of palynomorphs from coals and conodonts from marine beds has confirmed a considerably older age for much of the lower Des Moines than previously had been believed. By comparison with accurately dated strata and the chronostratigraphic nomenclature employed in the neighboring state of Illinois (Hopkins and Simon, 1975), the lower portion of the Des Moines Supergroup in Iowa represents the Atokan Series (Ravn, in press).

Biostratigraphically determined placement of the Atokan-Desmoinesian Series boundary has been a subject of debate for years. The age of the top of the Atoka Formation, from which the Atokan Series derives its name, has never been determined satisfactorily. Its choice as a base for a chronostratigraphic unit is extremely unfortunate, as, in addition to the theoretical considerations already discussed, it is a highly faulted, unfossiliferous sandstone unit bearing none of the characteristics necessary for accurate biostratigraphic evaluation. A further complication arises from the fact that no designated type section for the formation exists (Lane and West, 1983). Despite all these inadequacies, an Atokan-Desmoinesian boundary has been projected across much of the Midcontinent, especially in Missouri and Illinois, based mainly on lithostratigraphic markers rather than on biostratigraphic correlations.

Placement of an Atokan-Desmoinesian Series boundary within the Des Moines Supergroup of Iowa, relative to the position cited in neighboring states, is useful for purposes of communication. This can be done with great precision by comparison of recently developed palynological data in Iowa to the well-documented palynostratigraphic analyses of the Pennsylvanian coals of the Illinois Basin (Kosanke, 1950; Peppers, 1964, 1970, 1979). Therefore, we propose provisional acceptance of the Atokan Series as an appropriate chronostratigraphic unit applicable to the age of strata in the lower part of the Des Moines Supergroup. Detailed discussion of the placement of this chronostratigraphic boundary may be found in the description of Cherokee Group lithostratigraphy later in this report. This usage may be subject to revision in the future if a more satisfactorily chronostratigraphic subdivision of this part of the Pennsylvanian column is agreed upon in the Midcontinent; several such suggestions (e.g., Lane and West, 1983) have been proposed or are under study. Figure 2 compares the historical Pennsylvanian lithostratigraphic nomenclature in Iowa with the nomenclature of this report, and also illustrates our current understanding of the Atokan-Desmoinesian chronostratigraphic relationship.

MORROW SUPERGROUP AND ASSOCIATED STRATA

CASEYVILLE FORMATION

A large Pennsylvanian erosional outlier exists in Scott and Muscatine counties, exposed primarily along the Mississippi River Valley (see figure 1). The current Geologic Map of Iowa (Hershey, 1969) assigns these strata to the Cherokee Group. Fitzgerald (1977) delineated two distinct units separated by a significant unconformity, and applied the Illinois formational nomenclature of Caseyville and Spoon Formations to them (figures 3 and 4), noting that they are structurally a part of the Illinois (Eastern Interior) Basin. We formally adopt this nomenclature in Iowa.

Palynological study of coals present in the lower of the two units (Ravn and Fitzgerald, 1982; Ravn, in press) has confirmed its Morrowan age and its correlation to palynologically-dated Caseyville Formation sections in southern Illinois. This unit is considerably older than other known Pennsylvanian strata that crop out in the Western Interior Basin in Iowa, where no confirmed Morrowan sediments have yet been found.

Caseyville Formation Coals--The new names Wildcat Den Coal and Wyoming Hill Coal (figures 3, 4, and 5) are proposed for two principal coal beds in the Caseyville Sections studied. Both are designated as members of the Caseyville in Iowa. The Wildcat Den is the lowermost and most widely traceable of the Caseyville coals. It is exposed at Wildcat Den State Park (SW 1/4, section 17 and SE 1/4, section 18, T. 77 N., R. 1 E., Muscatine County), which is designated as the type section. The Wildcat Den Coal is exposed at several other sections in Muscatine County, including the well-known exposure at Wyoming Hill, where it is the basal coal in the section (Fitzgerald, 1977).

Exposures at and near Wyoming Hill include at least three other coal beds, the upper two of which appear to be related and are separated by only a narrow detrital clastic split. This split coal bed is designated the Wyoming Hill Coal Member. Its type section is located in the escarpment along Iowa Highway 22 (NE 1/4, section 34, T. 77 N., R. 1 W., Muscatine County). The Wyoming Hill Coal here is approximately 18 inches (0.46 meters) thick. It lies only a few feet below the "Spoon" Formation sandstones, probably the result of erosional removal of the upper part of the Caseyville and perhaps younger strata prior to "Spoon" deposition. In at least one exposure in the Wyoming Hill area, a thin coal bed occurs between the Wyoming Hill and Wildcat Den Coals, but it does not appear to be persistent, and no name is proposed for it. Mining in the latter part of the 19th and early 20th centuries in Scott and Muscatine counties (Hinds, 1909) may have involved one or both of these coal beds, but this is uncertain. Landis and Van Eck (1965) considered the minable coal in Scott and Muscatine counties to be equivalent to the Rock Island (No. 1) Coal (lower Desmoinesian) of Illinois, but if the mined units correspond to either the Wyoming Hill or Wildcat Den Coals, they are certainly

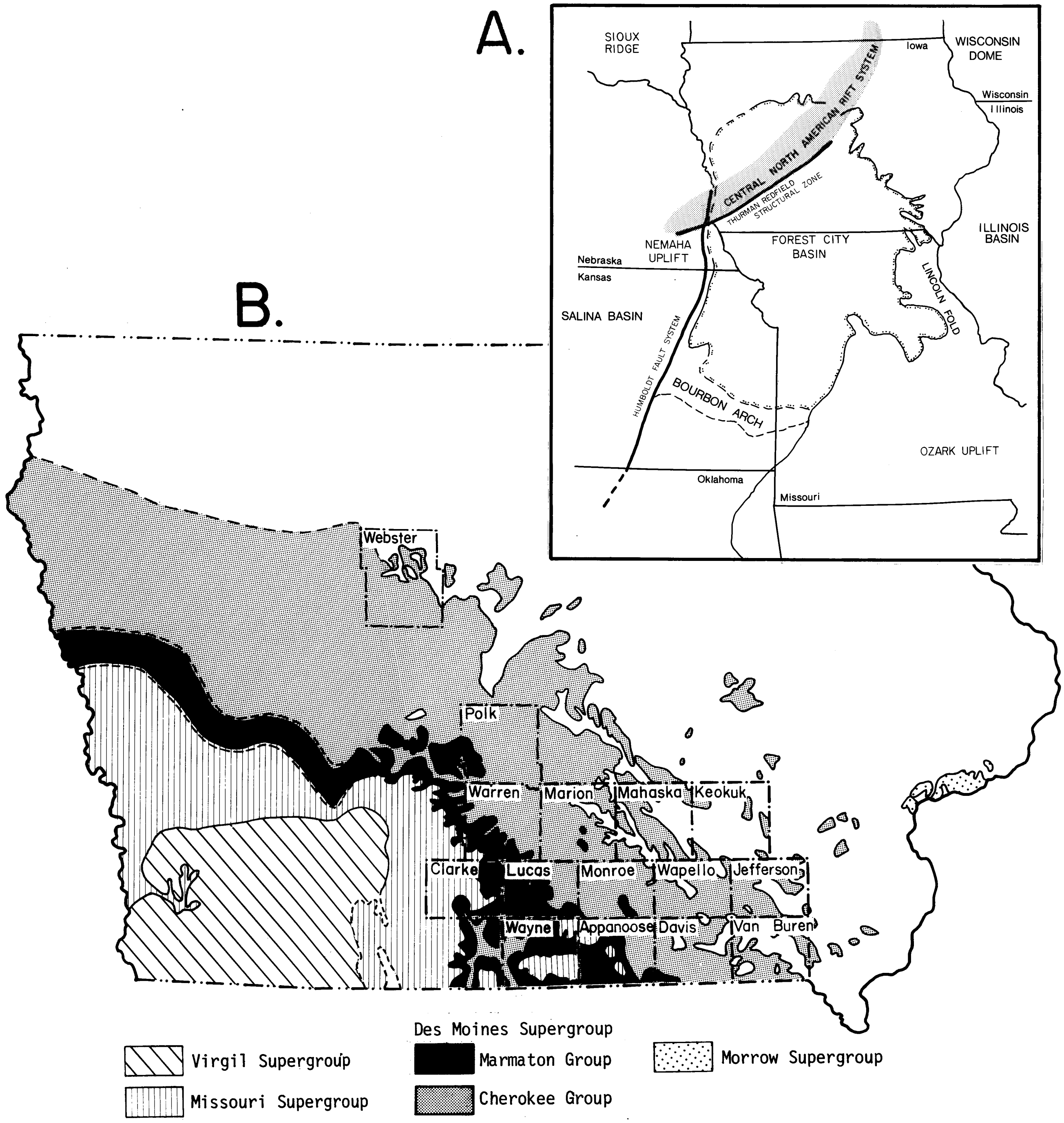


Figure 1. (A) Map of Pennsylvanian structural features of the area, (B) Subcrop map of top of Pennsylvanian in Iowa. Pleistocene deposits overlie most of the area, and Cretaceous strata overlie Pennsylvanian rocks in portions of western Iowa, where group boundaries are dashed.

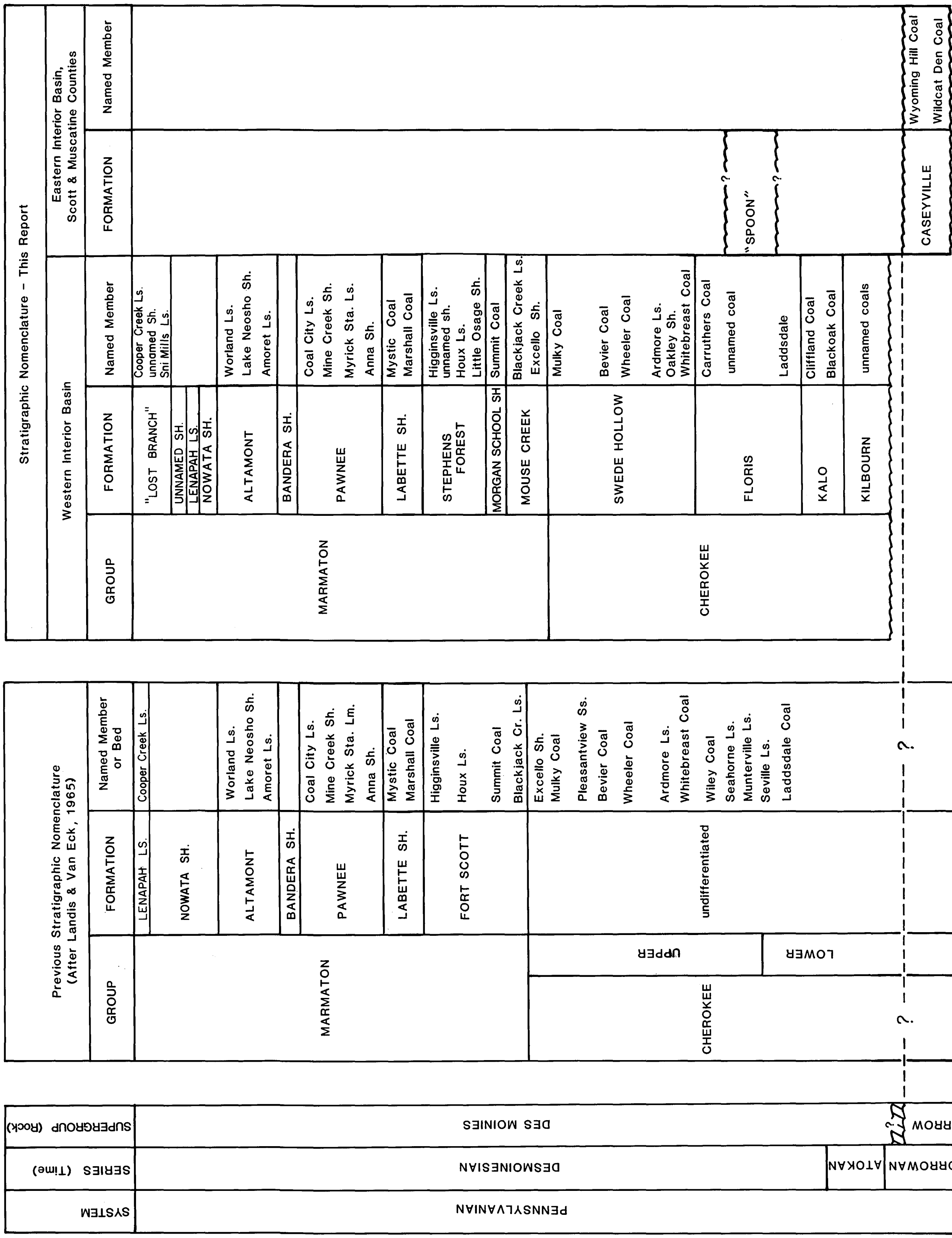


Figure 2. Morrowan and Desmoinesian stratigraphy of Iowa from Landis and Van Eck (1965) and this paper.

not equivalent stratigraphically to the much younger Rock Island (No. 1) Coal (Ravn, in press.)

"SPOON" FORMATION

The sandstone unit unconformably overlying the Caseyville in Scott and Muscatine counties was correlated with the Spoon Formation of Illinois by Fitzgerald (1977) on the basis of lithologic evidence. If this correlation is correct, the "Spoon" in Iowa is a time-stratigraphic equivalent of a portion of the Floris Formation of the Cherokee Group of the Western Interior Basin. It is provisionally considered Desmoinesian in age (Hopkins and Simon, 1975), although, in Iowa, no biostratigraphic evidence yet exists to confirm this interpretation. As a result of this uncertainty, the application of the name "Spoon" Formation for these sandstones, although useful for communication, must be regarded as tentative. No supergroup designation is assigned.

Little study has been devoted to the sediments of the large Pennsylvanian outlier in Scott and Muscatine counties. The possibility exists that strata intermediate in age between the Caseyville and "Spoon" Formations may be present in some localities. Therefore, the lithostratigraphic column for this area may be subject to revision as further study takes place.

DES MOINES SUPERGROUP

CHEROKEE GROUP

The Cherokee Group (Des Moines Supergroup; figure 2) in Iowa is best known for its coals, which constitute the major coal resources of the state (Ravn, 1979). The Group is named for exposures in Cherokee County, Kansas (Haworth and Kirk, 1894). Strata assigned to the Cherokee occur either in outcrop or in subsurface across nearly all of the Western Interior Basin of Iowa, Missouri, Nebraska, Kansas, and Oklahoma. In most of Iowa, sediments of the Cherokee Group represent the basal portion of the Pennsylvanian sequence.

In thickness, Cherokee Group strata make up a third or more of the total Pennsylvanian column in Iowa. The Stratigraphic Column of Iowa published by the Iowa Geological Survey in 1968 lists the average thickness of the Cherokee Group as 755 feet (230 meters), out of a total of approximately 1700 feet (518 meters) of Pennsylvanian section. The systematic coring of the Cherokee carried out by the Coal Division of the Iowa Geological Survey from 1974 to 1979 suggested that this figure is slightly excessive within the Middle Pennsylvanian outcrop belt of Iowa; a more approximate average thickness for the Cherokee Group in southeast and south-central Iowa would be on the order of 500 feet (152 meters), although the unit thickens in the subsurface toward the southwest. Nevertheless, the Cherokee is by far the thickest Pennsylvanian unit of group rank in the state.

Despite its thickness and the potential economic importance of its coals, stratigraphy within the Cherokee Group in Iowa until recently has been approached only in a most tentative, informal manner. In their report on Coal Resources of Iowa, Landis and Van Eck (1965, p. 28, 31, 36) provide a succinct summary of the historical work on Cherokee Group stratigraphy: "For purposes of discussion, the Cherokee Group has been divided informally into the Upper

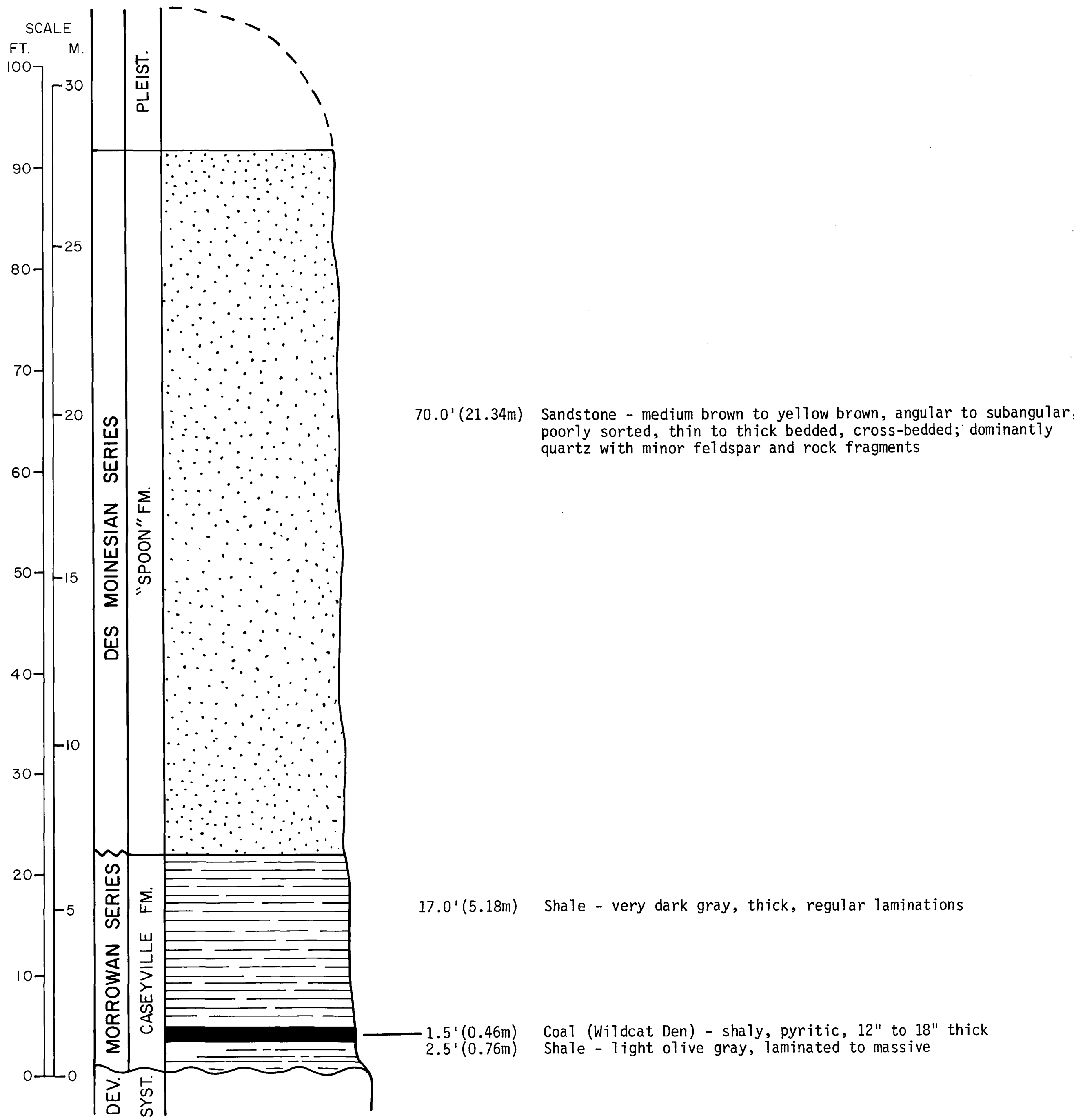
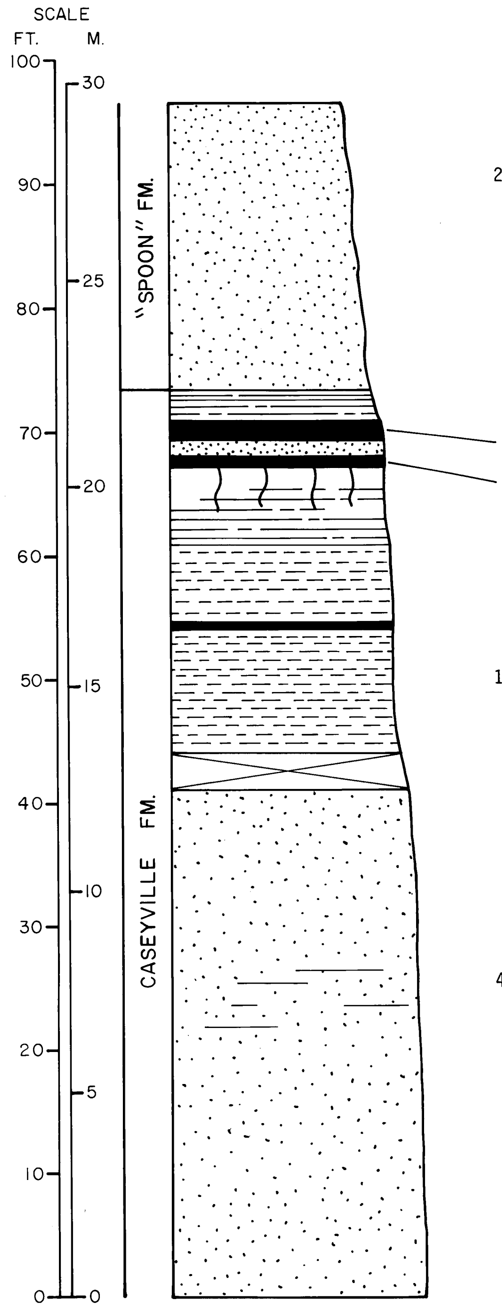


Figure 3. Type exposure of the Wildcat Den Coal Member, Wildcat Den State Park (SW 1/4, section 17 and SE 1/4, section 18, T.77N., R.1E., Muscatine County, Iowa).



23.3'(7.10m)	Sandstone - light brown, fine grained, angular to subangular, moderately to poorly sorted, dominantly quartz with minor feldspar and rock fragments
0.8'(0.24m)	Shale - light olive gray, laminated
1.7'(0.52m)	Shale - dark gray, laminated, ironstone nodules
1.5'(0.46m)	Coal (Wyoming Hill) - shaly, pyritic, moderately weathered.
1.3'(0.40m)	Sandstone - white, very fine grained, rippled bedding
0.8'(0.24m)	Coal (Wyoming Hill) - shaly, moderately weathered
6.5'(1.98m)	Shale - light olive gray, irregularly bedded, grades to mudstone
6.3'(1.92m)	Siltstone - light gray, argillaceous, sandy, laminated, plant
0.5'(0.15m)	Coal (Wildcat Den) disseminated pyrite, moderately weathered
10.0'(3.05m)	Siltstone - medium gray, thinly laminated, pyritic
3.0'(0.91m)	Covered interval
41.0'(12.5m)	Sandstone - white, fine grained, rounded to subrounded, quartzarenite with minor argillaceous zones

Figure 4. Type exposure of the Wyoming Hill Coal Member (along Hwy. 22, NE 1/4, section 34, T.77N., R.1W., Muscatine County, Iowa).

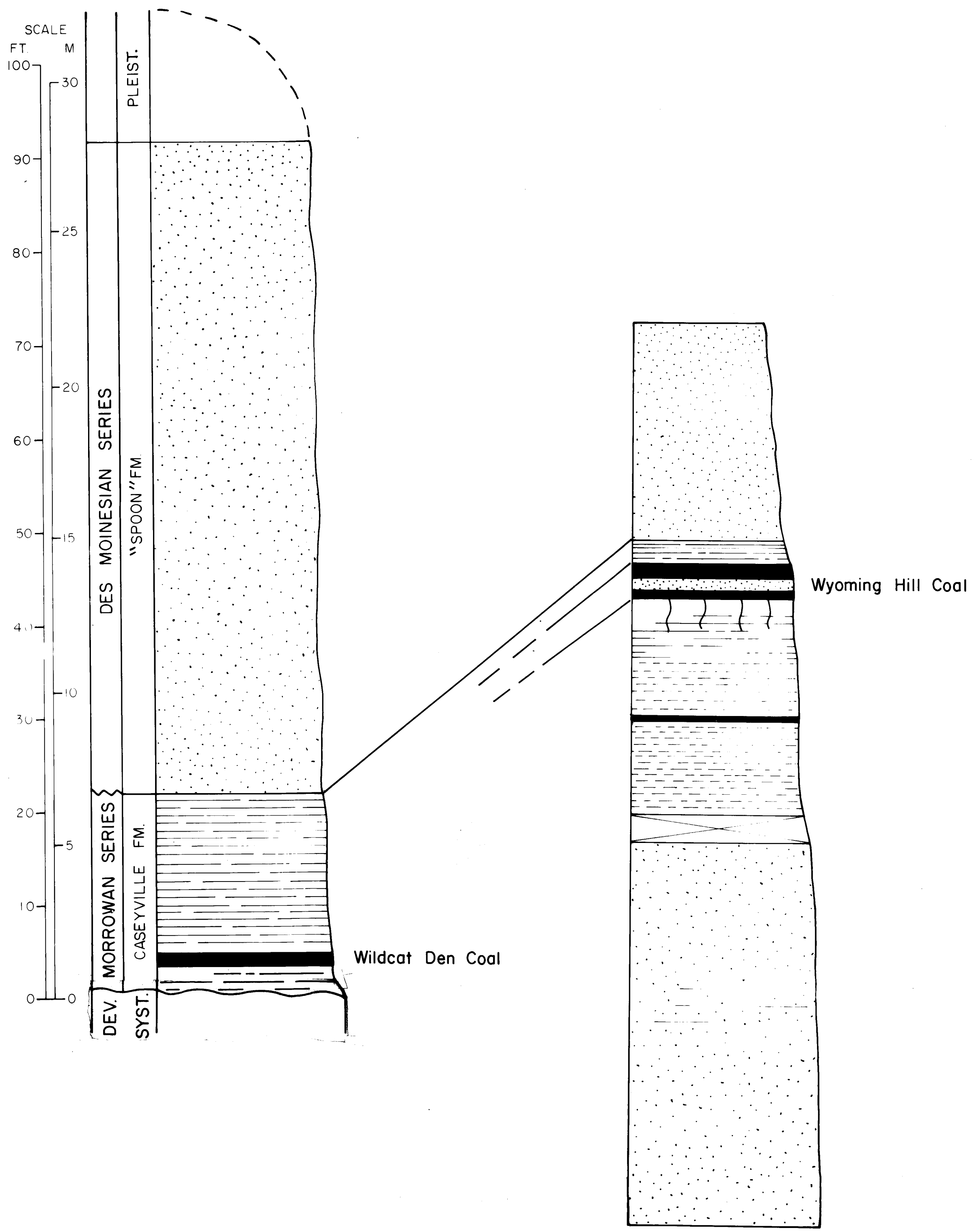


Figure 5. Correlation of the type exposures of the Wildcat Den and Wyoming Hill Coal Members of the Muscatine County outlier (after Fitzgerald, 1977).

Cherokee and the Lower Cherokee. A number of the more persistent rock units, including the coal beds, of the Upper Cherokee have been named . . . In general, the lower part of the Cherokee is distinguished from the higher beds by the relative scarcity of key horizons that are useful in correlation . . . The stratigraphy of the Lower Cherokee in Iowa is virtually unknown, both because stratigraphic relations are very complex and because data are insufficient in several critical areas. No rock units have been continuously traced very far, and few have been given formal names." Various systems of stratigraphic subdivision of the Cherokee are employed in other states, but none has proven to be practical for application to the Iowa section. Even in states where such formal systems are in use (e.g., Kansas; Jewett et al., 1968), difficulties in stratigraphic application and correlation are commonly acknowledged.

The most significant previous attempts to subdivide the Cherokee Group in Iowa into formation units were the unpublished work of L. M. Cline during the 1930s and the unpublished dissertation of Stookey (1935). Stookey proposed a lower Wapello and an upper Lucas Formation, with the contact placed at the widely traceable base of the Whitebreast Coal. Additionally, Stookey described and named eight members of the Wapello and three members of the Lucas. Stookey's revised classification of the Cherokee was never published and has not been followed in the subsequent literature (e.g., Weller et al., 1942; Landis and Van Eck, 1965). Several problems of priority arise regarding certain of his proposed names, and his member subdivisions are not considered acceptable in light of the recent Iowa Geological Survey (IGS) Coal Division's Coal Project. Stookey's work, nevertheless, provided a thorough review of stratigraphic work on the Cherokee and associated strata in the Midcontinent region prior to 1935.

Through the 1940s, Cline and Stookey continued collaboration on stratigraphic interpretation of the Des Moines Supergroup. Their work was concentrated in several central, southern, and southeastern Iowa counties. Primarily through outcrop study, geologic maps and cross sections of the various counties were prepared. They also proposed group, formation, and member names and recognized several fragmentary cyclic depositional sequences. Again, however, the work was never published, and the nomenclature proposed has not been adopted in subsequent work. The extensive coring of the Cherokee Group during the IGS Coal Project has indicated that Cline's and Stookey's work, although still a valuable source of information, did not adequately delineate stratigraphy through the greater part of the Cherokee Group.

Gleim (1955) studied the Cherokee Group in extreme southestern Iowa, employing for stratigraphic subdivision the Krebs and Cabaniss Groups as proposed by Searight and others (1953) in Missouri. The Krebs-Cabaniss Group division was adopted at a conference of state geological surveys (including Iowa, Kansas, Missouri, Nebraska, and Oklahoma), but Searight and co-workers noted that the Iowa Geological Survey did not fully concur with the classification. Despite the 1953 agreement, the Cherokee Group as an appropriate stratigraphic unit appears to have returned to favor, and it continues to be used throughout the Midcontinent. Some of the state surveys have reduced the Krebs and Cabaniss to subgroup or formational status within the Cherokee (e.g., Kansas; Jewett et al., 1968). Gleim (1955) described many Cherokee sections, but was reluctant to correlate them because of their lateral variability and the absence of stratigraphically useful fossils. The Krebs and Cabaniss units, whether as groups, subgroups, or formations, have not been subsequently applied to the Cherokee Group in Iowa.

The IGS Coal Division's Coal Project, mentioned previously and described by Ravn (1979), concluded late in 1979 with the completion of core holes at 85 locations in 14 counties of southeastern and south-central Iowa (figure 6). One of the principal goals of the program was to determine the stratigraphy and the depositional history of the major coal-bearing strata of the Cherokee Group. Application of lithostratigraphic and biostratigraphic analyses to these cores, especially through study of the palynology of the coals, has provided for the first time a practical means of correlating subsurface sections in the Cherokee, and of subsequently correlating coal beds exposed in outcrop and in mines with particular intervals identified within the cores. Ravn (1979) provided an introduction to the technical aspects of the palynostratigraphic study, and Ravn (in press) established a biostratigraphic zonation through which individual Cherokee coals may be correlated. The formal subdivision of the Cherokee Group relies in large part on the correlations determined through application of this biostratigraphic zonation. These zones are related to individually named and unnamed coal beds or equivalent strata in Appendix A of this report. Appendix A relates the IGS Coal Division core holes' lithologic unit numbers (Iowa Geological Survey, 1980), or footage (depth), to coal beds and biostratigraphically-determined coal zones.

The depositional history of the Cherokee in Iowa appears to record four major episodes of sedimentation, each resulting in lithostratigraphic packages displaying certain characteristics peculiar to that depositional regime. Accordingly, four formational units, within the Cherokee Group of Iowa, are designated in ascending order: Kilbourn, Kalo, Floris, and Swede Hollow (figure 2).

These formational units are thicker and contain more complex sequences of strata than do the formations established for strata of the overlying Marmaton Group and the Missouri and Virgil Supergroups. Standard stratigraphic practice across the Western Interior Basin for Pennsylvanian sediments younger than the Cherokee Group has been to designate as separate formations each individual major marine limestone-dominated unit of a cyclic sedimentary phase and each intervening nonmarine, or marginal-marine, clastic-dominated unit. These units, which constitute the cyclothems of Wanless and Weller (1932), occur repetitively throughout much of the Pennsylvanian sequence across the Midcontinent and, despite their relative thinness (tens of feet or less), they are widely traceable in outcrop and in subsurface. The persistent repetition of such units in Iowa is illustrated by the large number of formational names in the Pennsylvanian portion of the Iowa stratigraphic column above the Cherokee (figure 2).

The influence of fluctuating or cyclic depositional environments can be seen in Cherokee Group sediments as well, but it is often masked or subdued by the dominance of less regular, nonmarine deltaic, and fluvial sedimentary regimes. Great uncertainty remains concerning the actual number of major cyclic depositional events in the lower Cherokee. To subdivide the Cherokee into thin, individual cyclic units of formational status parallel to those of the later Pennsylvanian would create an unwarranted proliferation of stratigraphic names, and would lend a false impression of the lateral traceability of horizons within the Group. The present classification, therefore, is designed to provide a system reflecting more accurately the broader depositional setting and history of the Cherokee Group, one that can be applied with at least moderate reliability to as yet unstudied sections.

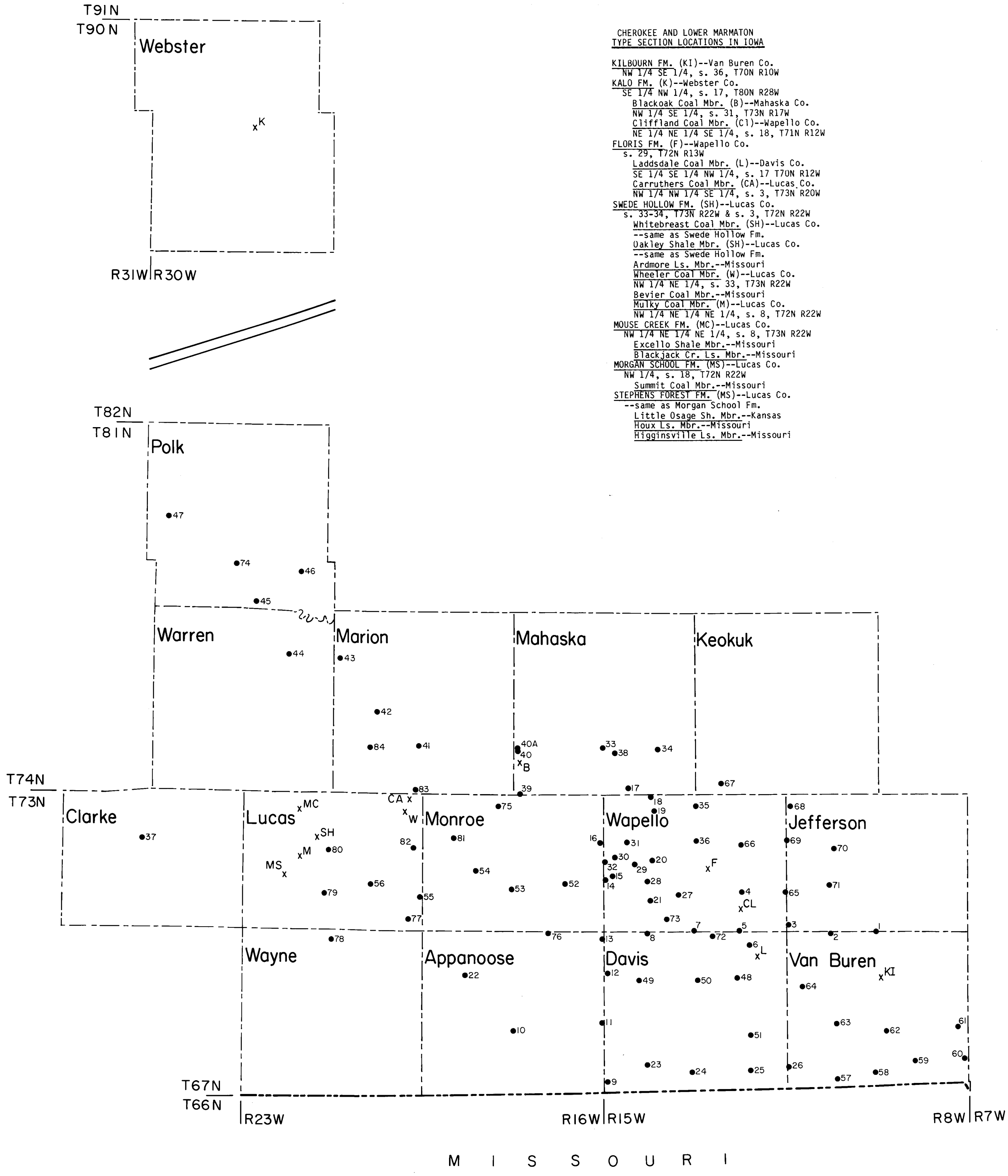


Figure 6. Locations of Cherokee Group and lower Marmaton Group type sections in Iowa (x) and cores obtained by the Iowa Geological Survey Coal Division Coal Project. Numbers identifying core are prefaced with CP (e.g. CP-82) in the text.

KILBOURN FORMATION

The name Kilbourn is assigned to basal Cherokee strata that rest unconformably on Mississippian rocks and range upward to the base of the widespread (newly named) Blackoak Coal Member of the Kalo Formation. The formation name is derived from the community of Kilbourn in north-central Van Buren County, Iowa, and the type locality is an abandoned quarry exposure (figure 7) in NW 1/4, SE 1/4, section 36, T. 70 N., R. 10 W., Van Buren County. Kilbourn strata are characterized by extreme lateral variability, and the unit as a whole is of variable thickness. Sediments of the Kilbourn are dominantly nonmarine sandstones, shales, and siltstones. Thin zones of marine sediments are not uncommon, however, and these locally include some well developed limestones. Relatively thick marginal marine shales, often containing horizons of cone-in-cone limestones, may dominate the section in local areas. Coals of the Kilbourn Formation are thin, discontinuous, and usually of little economic potential. The only areas identified at this time where Kilbourn coals have been mined are south-central Mahaska County (CP33) and the extreme southeastern corner of Van Buren County. Palynological examination reveals most Kilbourn coals to be of similar age to the Tarter and Manley coals of the Illinois Basin, with some possibly as old as the Reynoldsburg Coal of early Atokan age (Hopkins and Simon, 1975). None are named in Iowa.

At its type exposure, the Kilbourn unconformably overlies Mississippian strata; a thin zone of iron-stained pebbles or concretions grading into a greenish clay with total thickness of six to eight inches (15 to 20 centi-

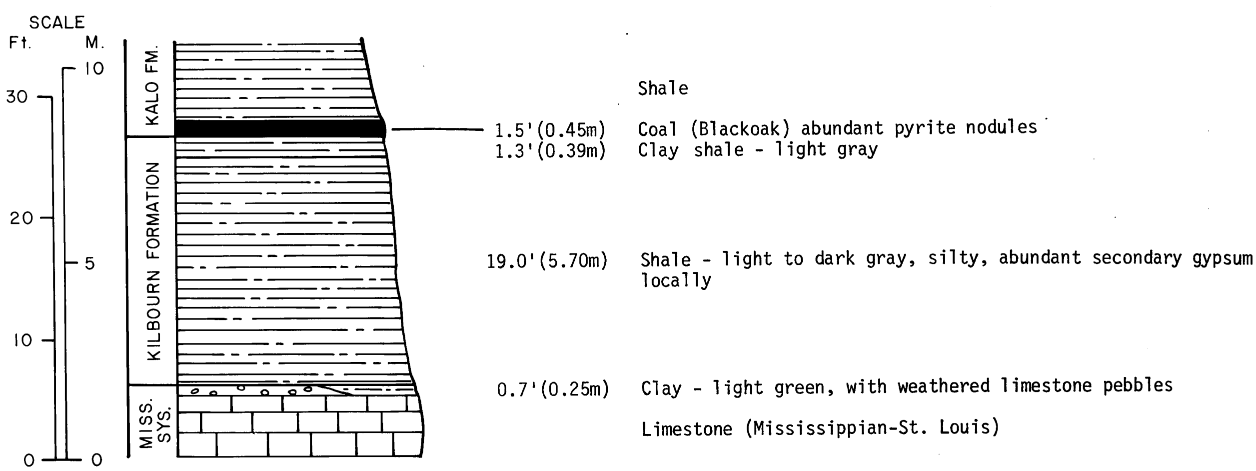


Figure 7. Type exposure of the Kilbourn Formation (NW 1/4, SE 1/4, section 36, T.70N., R10W., Van Buren County, Iowa).

meters) lies atop the Mississippian St. Louis Limestone. This zone probably represents a partially reduced residual soil or weathering surface, and the pebbles may be a lag deposit; the age of this material has not been determined with certainty, but the sedimentary relationships suggest that it is most appropriately included within the Mississippian. The greenish clay has a sharp but interfingered contact with a light gray clay shale of the overlying Kilbourn. Some clasts of the greenish clay were observed within the basal portion of the gray shale.

Above this contact, the Kilbourn at the type locality consists of about 20 feet (6 meters) of interbedded light gray to dark gray shale, finely laminated and silty in some zones, becoming a light gray clay shale in the uppermost 12 to 18 inches (0.3 to 0.5 meters). Gypsum crystals produced by recent weathering are abundant through much of the shale. The clay shale at the top of the Kilbourn is the underclay of a coal, which has been identified as the Blackoak through palynological analysis (see Ravn, in press), and marks the base of the overlying Kalo Formation. At the Kilbourn type section, the Blackoak Coal is 18 inches (0.5 meters) thick and contains abundant large pyrite nodules. An undetermined thickness of Kalo shale overlies the Blackoak at this exposure.

Subsurface study reveals Kilbourn strata elsewhere to be of highly variable thickness and character (see Gregory, 1982, figure 12). Where present, a minimum of one foot was noted in southeastern Davis County (CP25) where only a thin, rooted, conglomeratic sandstone was present between the Blackoak Coal and the Mississippian limestone. A maximum thickness of 218 feet (66 meters) was observed in southeastern Polk County (CP45) in a core in which the Blackoak could be identified only from clasts in a conglomeratic sandstone of the Kalo Formation. Underlying the sandstone are at least four Kilbourn depositional cycles containing complexly interbedded sandstones and siltstones, with one cycle at the top composed of a marine shale overlying a coal smut.

In the southeastern half of the study area (Appanoose, Davis, Van Buren, Monroe, Wapello, Jefferson, and southeastern Mahaska Counties), the Kilbourn Formation generally is thinner and contains fewer depositional cycles than in the northwest. In the southeast, only one core (CP73) encountered more than 65 feet (20 meters) of Kilbourn sediments, whereas to the northwest a minimum of 45 feet (13 meters) was present, and most of the cores contained an excess of 100 feet (30 meters). In the southeast, with the exception of Appanoose and southwestern Davis Counties, the Kilbourn includes sediments of one to three depositional cycles, only one of which generally includes marine strata. In the remainder of the area, from three to seven depositional cycles are observed, and often at least two of these may contain marine beds. In the three westernmost counties of the study area (Polk, Warren, and Clarke), the Kilbourn contains several cycles dominated by channel sandstones, often with intraformational conglomerates and erosional unconformities at the base of each cycle.

The subsurface variability encountered in the Kilbourn and basal Kalo sequence is illustrated in figure 8. All three of these cores penetrated the underlying green mudstone thought to represent a residual "soil" horizon formed on the Mississippian surface. The 35-foot (10.5 meter) section of basal mudstone encountered in CP27 is one of the thickest observed, and clearly shows an upward transition from green to red and back to green, which strongly suggests that a terra rosa was originally present and has since been partially reduced. Distribution of this unit is somewhat sporadic, but appears to be controlled in part by the pre-Cherokee Group exposure of the Mississippian St. Genevieve Limestone. The residual mudstone is most fre-

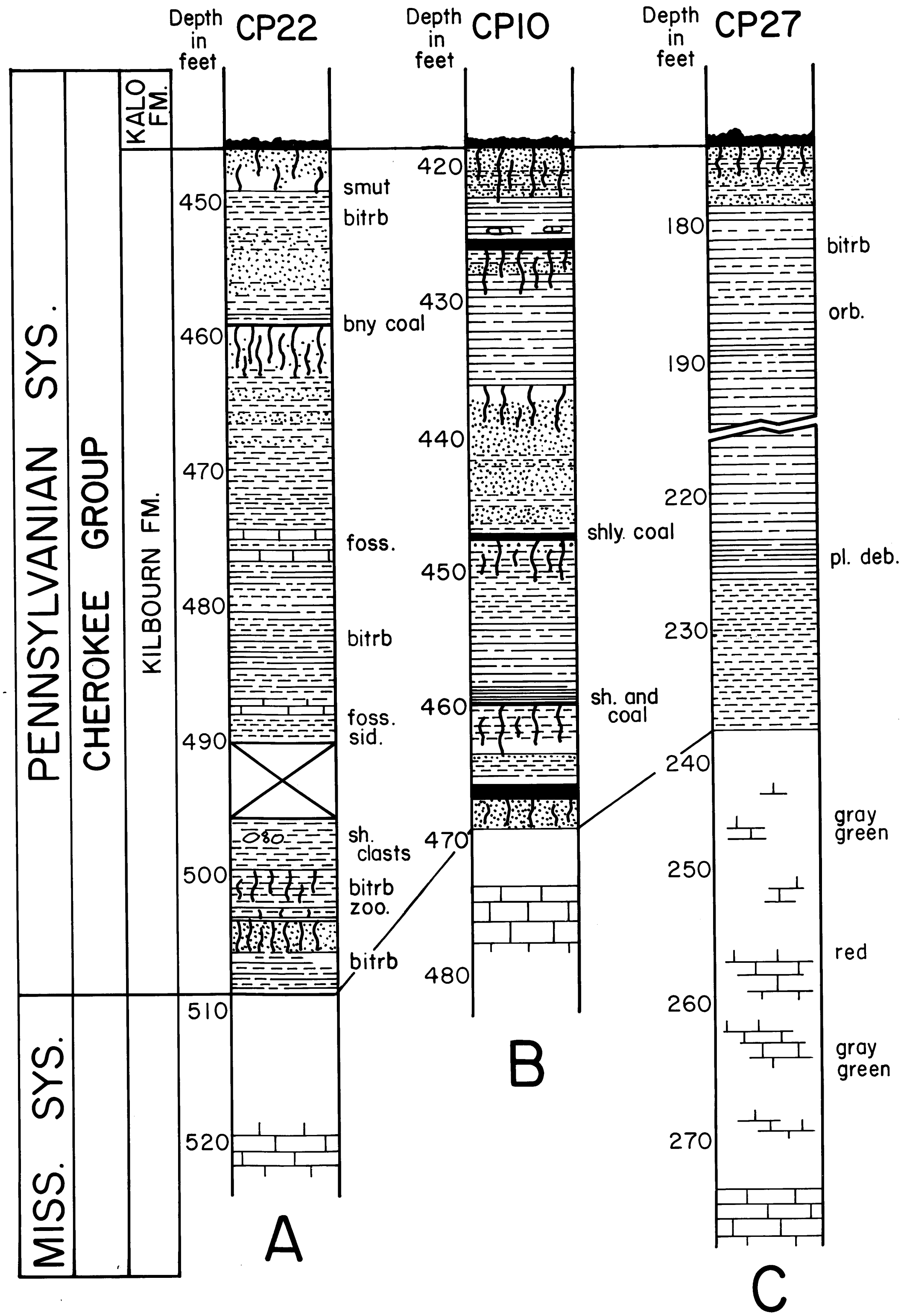


Figure 8. Kilbourn Formation reference cores.
A) CP22 (N.W. Appanoose Co.); 63 foot thick Kilbourn section contains five depositional cycles.
B) CP10 (Cent. Appanoose Co.); 43 foot thick Kilbourn section contains at least six depositional cycles. The four contained coals are the greatest number yet identified in any single Kilbourn section.
C) CP27 (N.C. Wayne Co.); 50 foot thick Kilbourn section contains two depositional cycles.

quently observed in Van Buren, northern Davis, southern Jefferson, Wapello, and southeastern Mahaska Counties.

Although strata assigned to the Kilbourn are widely distributed across the study area, the formation may be absent locally due to subsequent Cherokee erosion. Thick channel sandstones assigned to the Floris Formation unconformably overlie the Mississippian in northwestern Wapello County (CP18) and northeastern Appanoose County (CP76). Other Floris sandstones represent removal of at least the upper portion of the Kilbourn (and the entire Kalo) from central Monroe County (CP53, CP54). In other areas, Kilbourn strata may never have been deposited over highs on the Mississippian surface. In these areas (e.g., CP52, CP55, CP80), the oldest coal present is not the Blackoak, but is either the Cliffland Coal of the Kalo Formation or a Laddsdale Coal of the Floris Formation, underlain by sediments associated with only one or two depositional cycles.

Interpretation of Kilbourn Deposition--Depositionally, the Kilbourn Formation appears to record the major period of infilling of erosional irregularities on the Mississippian surface (figures 9 and 10). That complex surface evidently was dissected by fluvial valleys whose distribution and orientation was controlled by the structural trends and outcrop of the Mississippian strata, as well as by regional gradient and probable local karst development (see Gregory, 1982, figure 11). Weathering of argillaceous carbonates produced local terra rosa; elsewhere mass wasting of material along valley slopes yielded an abundance of unsorted sediments incuding large, angular clasts. Initiation of Pennsylvanian deposition is usually marked by a basal conglomerate composed of these materials, which is often heavily pyritic, suggesting the presence and subsequent alteration of organic material.

Further Kilbourn deposition was probably the result of gradual subsidence of the Forest City Basin in combination with one or more widespread eustatic marine transgressions. The onset of marine transgression was accompanied by a rise of local base levels and the consequent deposition of alluvial and deltaic materials. In areas where local swamps developed, peat accumulated and subsequently formed thin, discontinuous coals. Deposits which are definitely

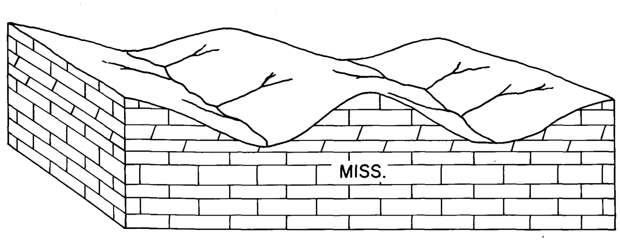


Figure 9. Diagramatic configuration of the pre-Pennsylvanian surface.

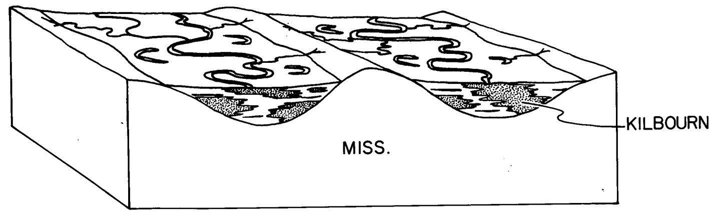


Figure 10. Diagramatic depiction of the depositional setting of the Kilbourn Formation.

marine are found only along the former valley axes, probably deposited during maximum transgression under the influence of estuarine conditions. Thick, marginal marine shale sequences were probably deposited from suspended sediments derived from small deltas and may be considered in part prodeltaic in nature.

During marine inundation, the margins of the river/estuary systems were sites of numerous local environments in which a wide variety of sedimentary lithotypes were deposited. Among the lithotypes that are well represented in cores are bioturbated sandstones and lenticularly interbedded sandstone, siltstone, and shale probably deposited on tidal flats, and cross-bedded sandstones that fine upward as they become increasingly subjected to rooting, indicating the transition to subaerial conditions. Apparently, most of the subaerial regime was well stabilized by vegetation inasmuch as intraformational conglomerates and other evidence of channelization during regression are not common.

KALO FORMATION

The Kalo Formation includes Cherokee Group strata ranging upward from the base of the newly-named Blackoak Coal Member to the base of the newly-defined Laddsdale Coal Member of the Floris Formation. The name is taken from the community of Kalo in southern Webster County, near the location of the type section (SE 1/4, NW 1/4, SW 1/4, section 17, T. 88 N., R. 28 W., figure 11), which consists of exposures in bluffs along the Des Moines River just west of town. The Kalo is distinguished over most of southern and central Iowa, both in outcrop and in subsurface, by the presence of the persistent Blackoak and Cliffland Coals (discussion of these coal members follows discussion of the Kalo Formation). The remainder of the formation is dominated by fluvial and marginal marine deltaic sedimentary sequences. The coals are often overlain by thin, dark, marine shales that grade upward into lighter colored, coarser grained, prodeltaic shales. Marine limestones are uncommon and, where present, are generally lenticular, argillaceous, skeletal calcarenites and calcilutites, which often display cone-in-cone structures.

At the type section, a coal that thins toward the southeast is present near the base of the outcrop and has been identified as Blackoak through palynological analysis. The base of the Kalo is placed at the base of this thin coal. A section of sandstones and siltstones assigned to the Kilbourn Formation is exposed beneath this coal. Overlying the lower coal is about 25 feet (7.5 meters) of interbedded sandstone, siltstone, and shale followed by a second coal, ranging from 3 to 5 feet (1 to 1.5 meters) in thickness, also identified palynologically as Blackoak. This coal grades to a carbonaceous shale to the northwest. Above this second coal are about 12 feet (4 meters) of dark gray to black carbonaceous shale, and 7 feet (2 meters) of siltstone. The top of the Kalo is placed at the contact between the siltstone and an overlying sandstone considered to belong to the Floris Formation, which presumably records erosional removal of upper Kalo and lowermost Floris strata. A more extensive discussion of the type Kalo outcrop is given in Lemish et al. (1981: Kalo Bluffs sections 1, 2, and 3, pps. 70-77).

Elsewhere in the subsurface the Kalo, like the Kilbourn, is of highly variable thickness and character. Where present, a minimum thickness of 17 feet (5.1 meters) is found in core CP40A in western Mahaska County, in which the two coal beds have the appearance of a single split bed; the Blackoak, 10 inches (25 centimeters) thick, is separated from the 17 inch (43 centimeter) thick Cliffland by only 4.5 inches (11.0 centimeters) of black, slickensided mudstone. The remainder of the formation in CP40A consists of a sequence of interlaminated siltstone and sandstone that coarsens upward and becomes rooted near the top, below the 2 foot (0.6 meter) thick mudstone seatrock of the Laddsdale Coal. A maximum thickness of 120 feet (36 meters) of Kalo was observed in south-central Marion County (CP41). In that core, the Kalo includes eight depositional cycles with four marine shales, and both coal members are split by clastic wedges.

Three cored Kalo sequences are illustrated (figure 12) in order to demonstrate the highly variable character of the formation. In CP37 (figure 12A) in Clarke County the thin, split Blackoak Coal is immediately overlain by a thick sandstone that may, in part, represent a channel contemporaneous with the Blackoak coal swamp. The Kalo sequence in CP37 apparently includes portions of at least seven depositional cycles. In CP40 (figure 12B) in Mahaska County, the Kalo sequence appears to be related to a single depositional cycle, although the sequence bears an overall similarity of appearance and lithology to the previously described CP40A. In CP28 (figure 12C) in Wapello County the Kalo includes three depositional cycles. The Blackoak is split into two beds separated by a 5 inch (13 centimeters), black, slickensided mudstone parting, which probably represents an influx of fine, suspended sediment into the coal swamp. The Cliffland Coal here is 6.3 feet (2 meters) thick, the thickest single coal observed in the entire IGS coring project.

In general, thickness trends observed in the Kalo appear to parallel those observed in the Kilbourn and are discussed in detail by Gregory (1982). In the area roughly centered on Wapello County, including portions of Mahaska, Monroe, Appanoose, Davis, Van Buren, and Jefferson Counties, the formation is

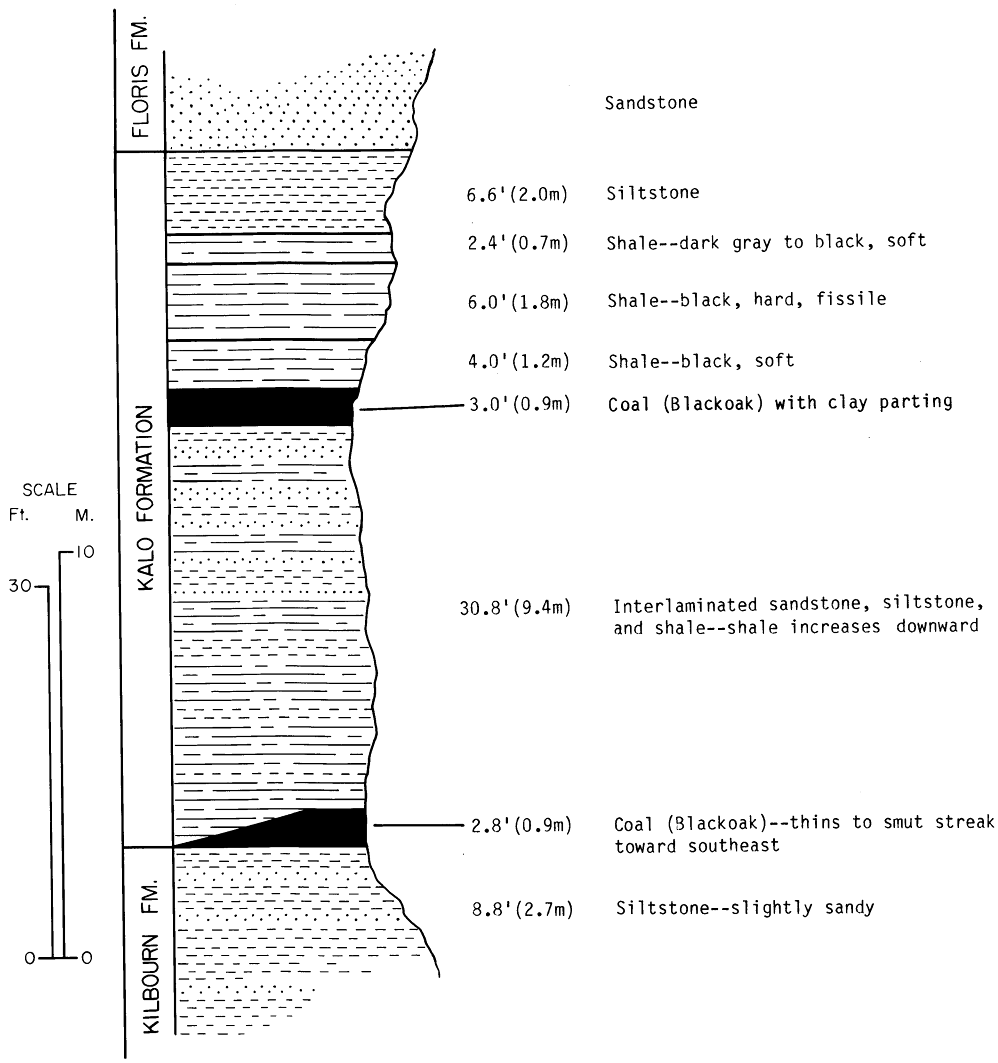


Figure 11. Type exposure of the Kalo Formation (SE 1/4, NW 1/4, SW 1/4, section 17, T.88N., R.28W., Webster County, Iowa).

usually less than 60 feet thick and includes one Blackoak and one Cliffland coal seam. The separation between the coals in this area generally ranges from 2 to 20 feet (0.6 to 6.0 meters) and typically represents strata associated with a single depositional cycle. In the remainder of the study area to the west and northwest (Polk, Marion, Clarke, Lucas, and Wayne Cos.), the thickness of the formation consistently exceeds 60 feet (18.3 meters) although considerable local variation has been noted (Gregory, 1982). The section also becomes increasingly complex. Both coals are frequently split by clastic wedges, and the separation between the Blackoak and Cliffland ranges up to a maximum of 58 feet (17.6 meters) in the westernmost core available, CP37 (figure 12A). As many as six coal beds are present in the Kalo in central Appanoose County (CP10). In that core, the Blackoak Coal is split into four beds that are associated with three depositional cycles over a 22 foot (6.7 meters) stratigraphic interval, and the Cliffland is split into 2 beds separated by 11 feet (3.3 meters).

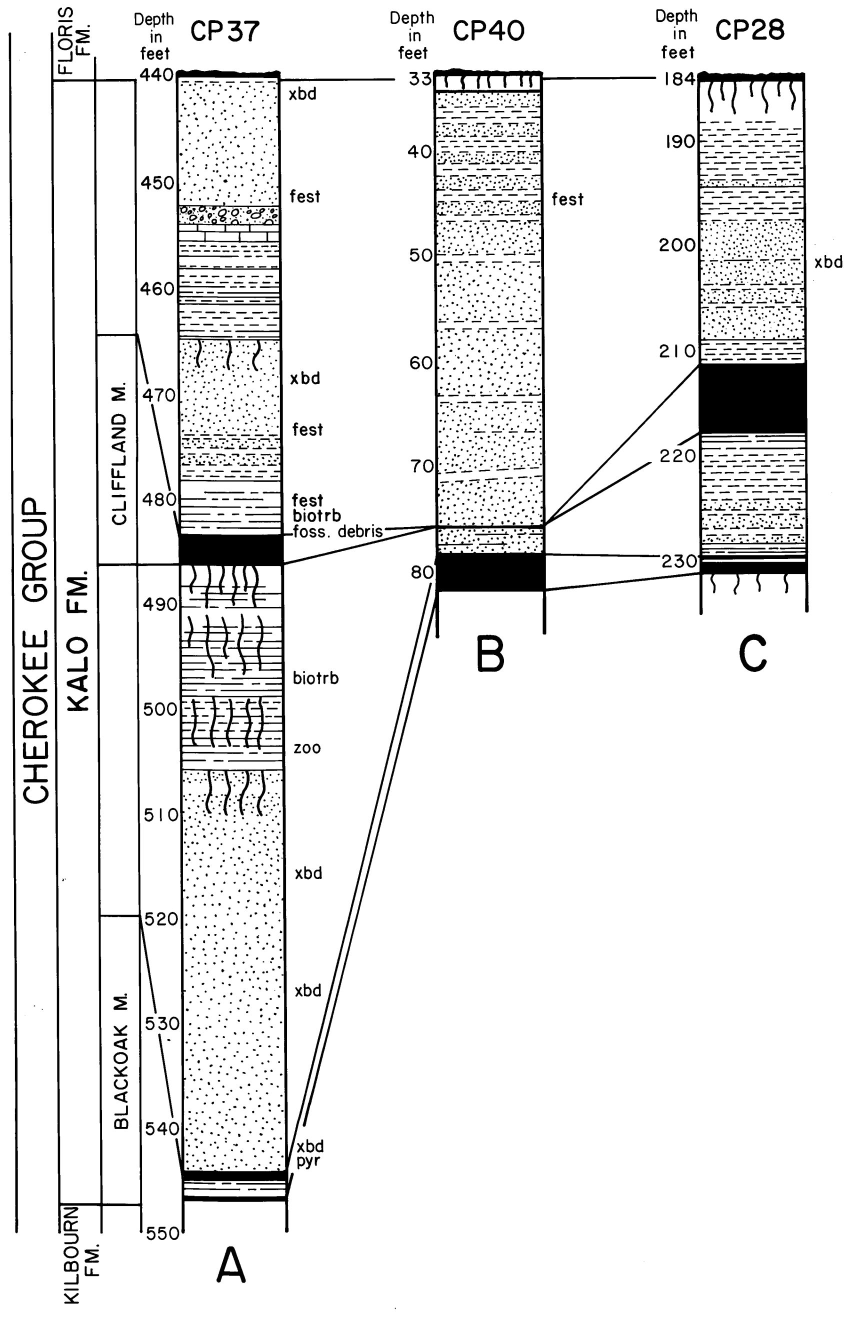


Figure 12. Kalo Formation reference cores.
A) CP37 (Cent. Clarke Co.); 107 foot thick Kalo section contains at least seven depositional cycles.
B) CP40 (S.W. Mahaska Co.); 48 foot thick Kalo section apparently includes only a single depositional cycle.
C) CP28 (Cent. Wapello Co.); 47 foot thick Kalo section includes three depositional cycles.

Strata above the Cliffland Coal are generally more variable laterally than in the lower portion of the formation. Frequently, the Cliffland is separated from the first Laddsdale coal bed by a single, relatively thin depositional sequence dominated by shale and siltstone; but locally, relatively great thicknesses of sandstone dominate the upper part of the Kalo. These sandstones are thought to reflect the onset of depositional conditions that become predominant in the lower portion of the Floris Formation. In a few cores, the interval between the Cliffland and the first Laddsdale bed is occupied by one or more thin mudstone-dominated cycles with several poorly developed smut zones that could not be assigned to either coal. In such areas (e.g., northern Appanoose County, CP22), the placement of the upper formational boundary becomes somewhat problematic. In other areas, the thick sandstone-filled channels originating in the Floris have removed the entire Kalo and portions of the older stratigraphic units (e.g., CP53, CP54, CP75, and CP76; see Gregory, 1982). Local exposures of Mississippian rocks were still in existence during Kalo deposition, as shown by CP13 (N.E. Appanoose Co.), in which the Cliffland is the oldest coal present and is underlain by only 11 feet (3.3 meters) of sediment consisting of one depositional sequence containing probable alluvial materials.

Blackoak Coal Member--The basal coal of the Kalo Formation is the newly named Blackoak Coal Member. The name is derived from Blackoak Township in Mahaska County. The type locality is along an intermittent tributary of Cedar Creek in an abandoned rock quarry in NW 1/4, SE 1/4, section 31, T. 75 N., R. 17 W., Mahaska County (figure 13). The coal is relatively thin at this locality, averaging about 4.5 inches (11.4 centimeters) in thickness, and in the quarry it is observed to pinch out over highs on the irregular Mississippian surface. The coal contains abundant pyrite nodules, a feature common to the Blackoak in many areas, and is overlain by an undetermined thickness of gray-brown shale.

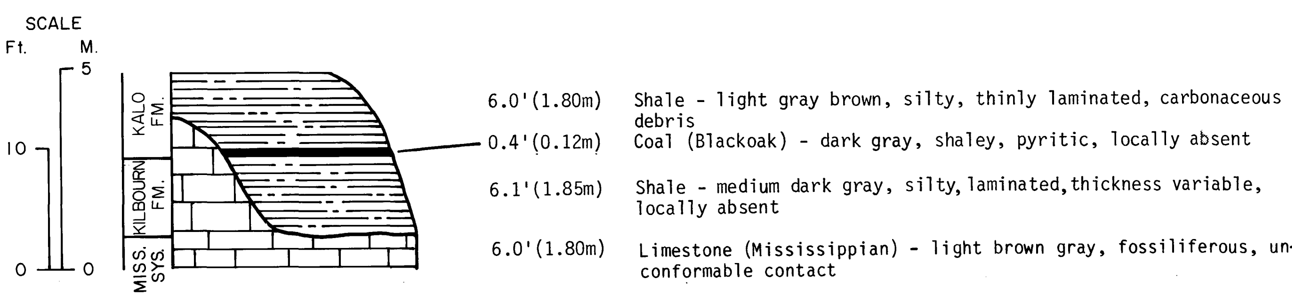


Figure 13. Type exposure of the Blackoak Coal Member (NW 1/4, SE 1/4, section 31, T.75N., R.17W., Mahaska County, Iowa).

The Blackoak is the oldest coal in the Cherokee Group in Iowa that can be considered "persistent" over a sigificant portion of the study area. It is highly variable in thickness, and has been encountered in core in thicknesses of up to 5.7 feet (1.7 meters; see Gregory, 1982, figure 16). The thick coal examined by Ravn (1979) from core CP19 (Wapello Co.) is now assigned to the Blackoak. In general, the greatest thicknesses are noted in western Wapello County, where the coal is consistently in excess of 2 feet (0.6 meters). In a number of cores, particularly those in Marion, Warren, Appanoose, and Van Buren Counties, two or more closely-spaced beds correspond to the Blackoak. This split in the Blackoak Coal appears to thicken and become more complex to the south and west of Wapello County, toward the then-subsiding Forest City Basin. These clastic wedges probably formed when alluvial and deltaic sediments intervened into the coal swamps.

Sediments above and below the Blackoak, as revealed by cores, are highly variable, but frequently a zone of black, non-fissile, carbonaceous shale underlies the unit and may aid in its identification. The pyrite nodules mentioned previously and the frequent occurrence of abundant fusain within the Blackoak reduce its desirability as a minable coal. Nevertheless, the Blackoak has been mined in a number of areas, especially in Wapello and Polk counties.

The names Manbeck and Hastie (Landis and Van Eck, 1965) were applied to coal beds mined in Polk County and may refer at least in part to the Blackoak Coal. However, firm correlation of the named beds in Polk County has not yet been achieved, as they were commonly mined in underground workings which are no longer accessible. As the names Manbeck and Hastie may have been used to refer to more than one coal bed, it is therefore considered advisable to utilize the new designation Blackoak.

The Blackoak is the biostratigraphic equivalent of the Pope Creek Coal Member of the Abbott Formation of Illinois (Hopkins and Simon, 1975). In Illinois time-stratigraphic nomenclature, it would be considered upper Atokan in age.

<u>Cliffland Coal Member</u>--The second major widespread coal of the Kalo Formation is the bed historically known from southeast Iowa as the Cliffland, named for exposures around the town of Cliffland in Wapello County. The type section of the Cliffland is established at an abandoned railroad cut in NE 1/4, NE 1/4, SE 1/4, section 18, T. 71 N., R. 12 W., Wapello County (figure 14). The coal at this locality consists of two beds. The lower bed increases from 1.8 feet (0.5 meters) to 3.4 feet (1.6 meters) thick across the exposure. The upper bed is 1.4 feet (0.4 meters) thick, and separated by a silty shale parting 3.2 feet (1.0 meter) thick. It is underlain by a generally coarsening-upward sequence of thinly interbedded shale, siltstone, and sandstone, and it is overlain by a similar coarsening-upward clastic sequence.

The Cliffland is perhaps even more persistent laterally than the Blackoak. A single bed is present over most of Mahaska, Wapello, and Davis counties, and probably to the east as well, although information from Jefferson and Van Buren counties is sparse due to post-Pennsylvanian erosion. In the remainder of the study area to the west, the Cliffland is usually split into two beds separated by a maximum of 18 feet (5.5 meters; CP44). Where the coal is split, both beds are generally thin, but may range up to 2.3 feet (0.7 meters) and 4.3 feet (1.3 meters) for the upper and lower coals, with a separation of up to 15 feet (4.6 meters) of intervening sediments (e.g., CP44). Where a single bed is present, the lateral variation in thickness is dramatic,

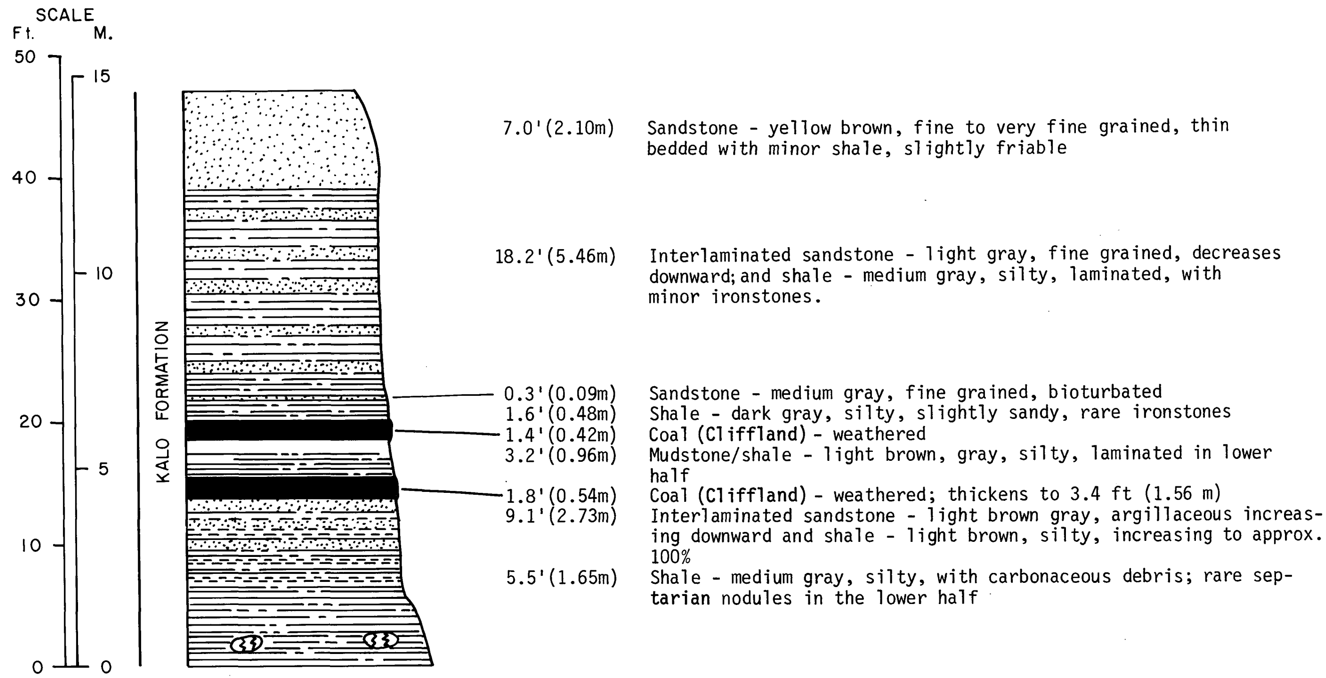


Figure 14. Type exposure of the Cliffland Coal Member (NE 1/4, NE 1/4, SE 1/4, section 18, T.71N., R.12W., Wapello County, Iowa).

ranging from 2 inches (5 cm; CP77) up to a maximum observed thickness of 6.3 feet (1.9 meters; CP 28, figure 12C) in west-central Wapello County.

The Cliffland closely resembles the Blackoak in its variable thickness, its lateral persistence, and its splitting into upper and lower beds. Palynological analysis indicates a similarity of the floral characteristics as well (Ravn, in press), and suggests the likelihood of deposition under similar paleoenvironmental conditions. The overall physical similarity of these coals probably has contributed to historical difficulties in differentiation and correlation, and these problems have been alleviated only through the numerous subsurface sections and detailed biostratigraphic analysis obtained by the IGS Coal Project.

The Cliffland Coal is the possible equivalent of the Hastie Plus Coal of Polk County (Landis and Van Eck, 1965), but again the stratigraphic position of the Polk County coal has not been determined satisfactorily. The Cliffland has evidently been mined in a number of areas, including Polk County, and its general thickness identify this coal as a target of some economic interest.

The Cliffland is the biostratigraphic equivalent of the Rock Island (No. 1) Coal of Illinois. This coal was considered by Hopkins and Simon (1975) to be lower Desmoinesian. This interpretation, placing the Atokan-Desmoinesian boundary in the middle of the Kalo Formation between the Blackoak and Cliffland Coal (figure 2), will be utilized in this report. Peppers (1979) placed the boundary above the Cliffland, but cited no reasons for doing so.

Interpretation of Kalo Deposition--Gregory (1982) made a detailed examination of the stratigraphy and depositional environments of the lower Kalo Formation, between and including the Blackoak and Cliffland coals, and concluded that the Kalo is the product of deltaic progradation across south-central Iowa into the Forest City Basin (figure 15).

Following the infilling of the irregularities of the Mississippian paleotopographic surface by the Kilbourn Formation, the Blackoak Coal was deposited. The widespread nature of the coal suggests that peat deposition most probably resulted from a regional rise in sea level that reduced stream gradients and allowed swamp conditions to develop over a broad, relatively level area. As the sea level continued to rise, it drowned the coal swamps, and marine facies developed primarily in the western portion of the study area (Polk, Warren, Marion, Clarke, Lucas, Wayne, and Appanoose counties), where the Kalo interval is the thickest and most complex. Local development of delta lobes and channel switching, however, prevented widespread continuity of the marine facies. In this western area, the Mississippian surface is lower, and the overlying Kilbourn sediments are thicker than in the eastern counties (Gregory, 1982, figures 11 and 12). The repeated delta shifts and subsequent progradations may be the result of differential compaction of the thicker Kilbourn sediments.

Deltas continued to prograde seaward, probably due to a slight rise in elevation of the source area to the north and northeast (Brown et al., 1977; Lemish et al., 1981). Stream gradients apparently remained relatively low, however, as suggested by less abundant sandstones than in the underlying Kilbourn or overlying Floris Formations, where sandstones make up a larger proportion of the strata.

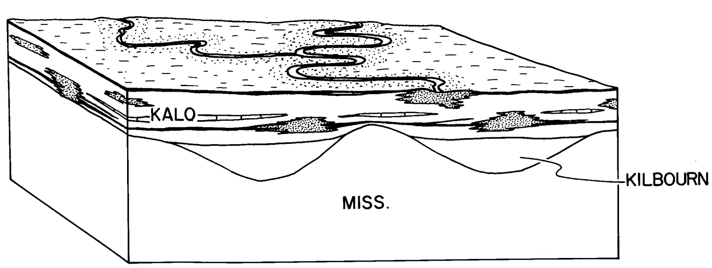


Figure 15. Diagramatic depiction of the depositional setting of the Kalo Formation.

The Kalo represents a complex system of delta lobes, shifting foci of deposition, differential compaction, and possibly minor tectonic movement. The series of delta lobes produced sedimentary sequences that vary in detail laterally, and tend to obscure the overall uniformity expected from region-wide changes in sea level. This has resulted in the historical difficulties in lithostratigraphic correlation in the lower Cherokee Group (Gregory, 1982).

FLORIS FORMATION

The Floris Formation includes Cherokee Group strata ranging from the base of the newly-defined Laddsdale Member to the base of the Whitebreast Coal of the Swede Hollow Formation. The name Floris is derived from a community in northeastern Davis County near the type area. The type area for the Floris consists of a series of cuts (figure 16) along a north-south road on the east edge of section 29, T. 72 N., R. 13 W., east of Ottumwa in Wapello County.

The lower portion of the Floris is characterized by the absence of widely-traceable beds. Lithologies consisting of unfossiliferous shale and sandstone including thick, channel-fill sequences are predominant. Coals in the lower Floris are lenticular and discontinuous, reflecting fluvial-deltaic processes and possible added influence of contemporaneous subsidence. In the middle and upper portions of the Floris, the coals and associated strata are slightly more regular and persistent and are associated with a greater proportion of marine strata that document a shift to more stable and widespread depositional environments.

Coals of the Floris Formation include the newly-defined Laddsdale Member and the Carruthers Coal Member. The Laddsdale Member consists of one or more coals that are characteristically lenticular and which locally reach economic thicknesses; as a group, they are palynologically distinct from other Cherokee coals, but they cannot be differentiated biostratigraphically as individual units (Ravn, in press). The Carruthers Coal is a single, thin, persistent coal in the upper part of the Floris, which is generally recognizable by association with overlying marine strata. It, too, is distinguishable on the basis of palynomorphs. One or more somewhat continuous, palynologically distinct coals occur in the interval between the Laddsdale and Carruthers coals, but the relationships of these coals are poorly understood and no name is proposed at this time.

The Floris type section (figure 16) is approximately 100 feet (30.5 meters) thick and includes seven coals, ranging from 1 inch (2.5 centimeters) to 2.2 feet (0.7 meters) thick. The lower contact of the Floris is placed at the base of the lowermost coal in the outcrop, which is 1.9 feet (0.6 meters) thick. This coal is underlain by 2.7 feet (0.8 meters) of shales and mudstones, which are assigned to the Kalo Formation. Above this lower coal is approximately 63 feet (19 meters) of section (including a 23-foot, 7 meter, covered section) that consists largely of interbedded light to dark gray and brown, fissile shale and mudstones with minor sandstone interlaminations, carbonaceous debris and plant impressions, and 5 coal beds ranging from 1 inch (2.5 centimeters) to 2.2 feet (0.7 meters). All six of the coals in this portion of the Floris are considered palynologically as Laddsdale, and the section encompassing the coals is assigned to the Laddsdale Member. Above the upper Laddsdale coal is approximately 15 feet (4.6 meters) of shale and mudstone, followed by a 1.2 foot (0.4 meter) coal. This coal is palynologically

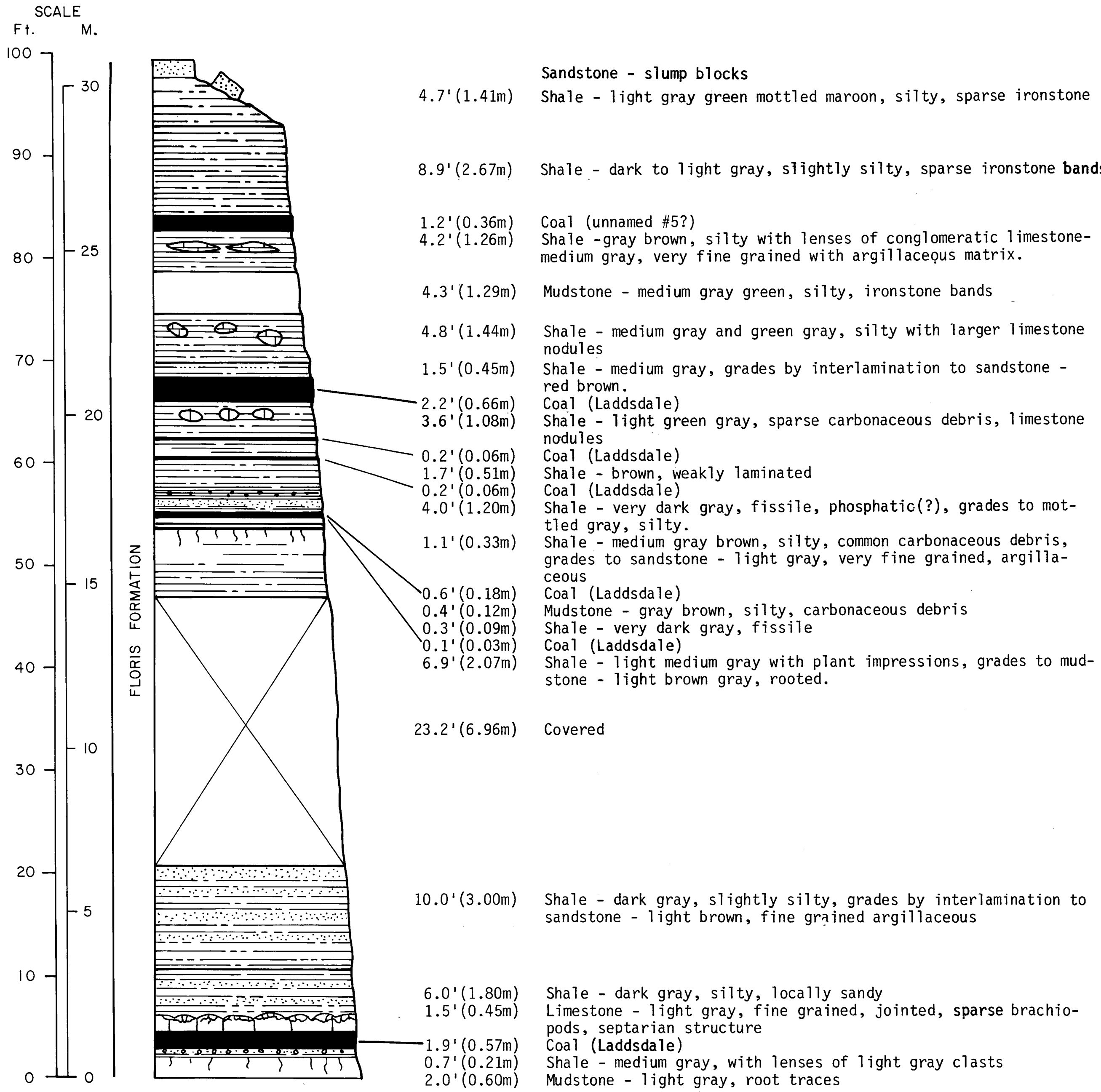


Figure 16. Type exposure of the Floris Formation (along north-south road on the eastern edge of section 29, T.72N., R.13W., in Wapello County, Iowa).

distinct from the underlying Laddsdale coals, but at this time is unnamed. This coal is overlain by 13.6 feet (4.1 meters) of light to dark gray shale, and the section is topped by slump blocks of sandstone. The Carruthers Coal is not present at this section.

The Floris Formation is widely distributed over southeastern and south-central Iowa. The total thickness of the cored Floris ranges from 65 feet (20 meters) to 190 feet (58 meters), with a general trend toward thinning in the southernmost portion of the study area and thickening to the northwest. This corresponds to the general trends found in the Kilbourn and Kalo Formations.

In core CP41 (figure 17A), in Marion County, the Floris includes five coals ranging in thickness from 7 inches (17.8 centimeters) to 1.6 feet (0.5 meters), plus several smut streaks. At least seven depositional cycles are represented. The Floris in CP7 (figure 17B), in Wapello County, is greater than 140 feet (42 meters) thick and includes eight coals, which is the greatest number of coals encountered in this part of the section in any of the IGS cores. These coals range in thickness from 8 inches (20 centimeters) to 5 feet (1.5 meters). The lower six coals are all assigned to the Laddsdale Member. Nearly 200 feet (60 meters) of Floris section are present in CP53, in Monroe County, including 140 feet (42 meters) of sandstone, making this one of the thickest sections found (figure 17C). Only two coals occur, both in the upper portion of the core.

The maximum thicknesses of Floris strata observed in core are the result of thick sequences of channel sandstones, which locally cut downward into the underlying Kalo and Kilbourn strata, and occasionally into the Mississippian (e.g., CP76, CP18, CP53). These thick complexes of channel sandstones were encountered in many of the IGS cores, and occur in various conspicuous exposures in the Cherokee outcrop area (Lemish et al., 1981; Mason, 1980). Keyes (1891) proposed the name Redrock Sandstone for a ferruginous sandstone exposed near the present-day site of Red Rock Lake, Marion County, Iowa. Subsequent literature, however, has not followed the usage, and several other unrelated rock units from other states have been accorded the same name (Elftmann, 1898; Wilson, 1937, Johnston, 1941). The name Cliffland had been used historically for a similar sandstone exposed near the community of Cliffland in Wapello County (Leonard, 1901); this usage has been followed sporadically. As the precise stratigraphic relationships of the sandstones exposed in the Des Moines River Valley and adjacent areas are inadequately known, no formal name for them is proposed here. Their position within the Floris, however, is well established by the study of IGS cores, and evidence suggests that they are stratigraphically related to the unnamed coal beds and the Laddsdale Member. The sands were deposited in fluvial channels, which in a few localities extend downward into the Mississippian (CP18) as indicated by the presence of coarse sandstones and conglomerates containing chert and carbonate clasts at the base of the Pennsylvanian sequence in cores CP75, CP76, CP54, CP39.

Laddsdale Member--The interval encompassing all coals considered palynologically as Laddsdale (Ravn, in press) constitutes the newly-defined Laddsdale Member, and is located at the base of the Floris Formation, immediately above the Kalo Formation. The type section is located at a stream cut on Soap Creek in SE 1/4, SE 1/4, NW 1/4, section 17, T. 70 N., R. 12 W., northeastern Davis County. The name Laddsdale is derived from the abandoned mining community of Laddsdale, in Davis County. At its type section (figure 18) the Laddsdale Member consists of four coals totalling 8.6 feet (2.6 meters) in thickness distributed through approximately 30 feet (9.1 meters) of strata. Historically, the name Laddsdale was informally applied to a coal or coals mined in the area. It is reasonably certain that the coals designated here as

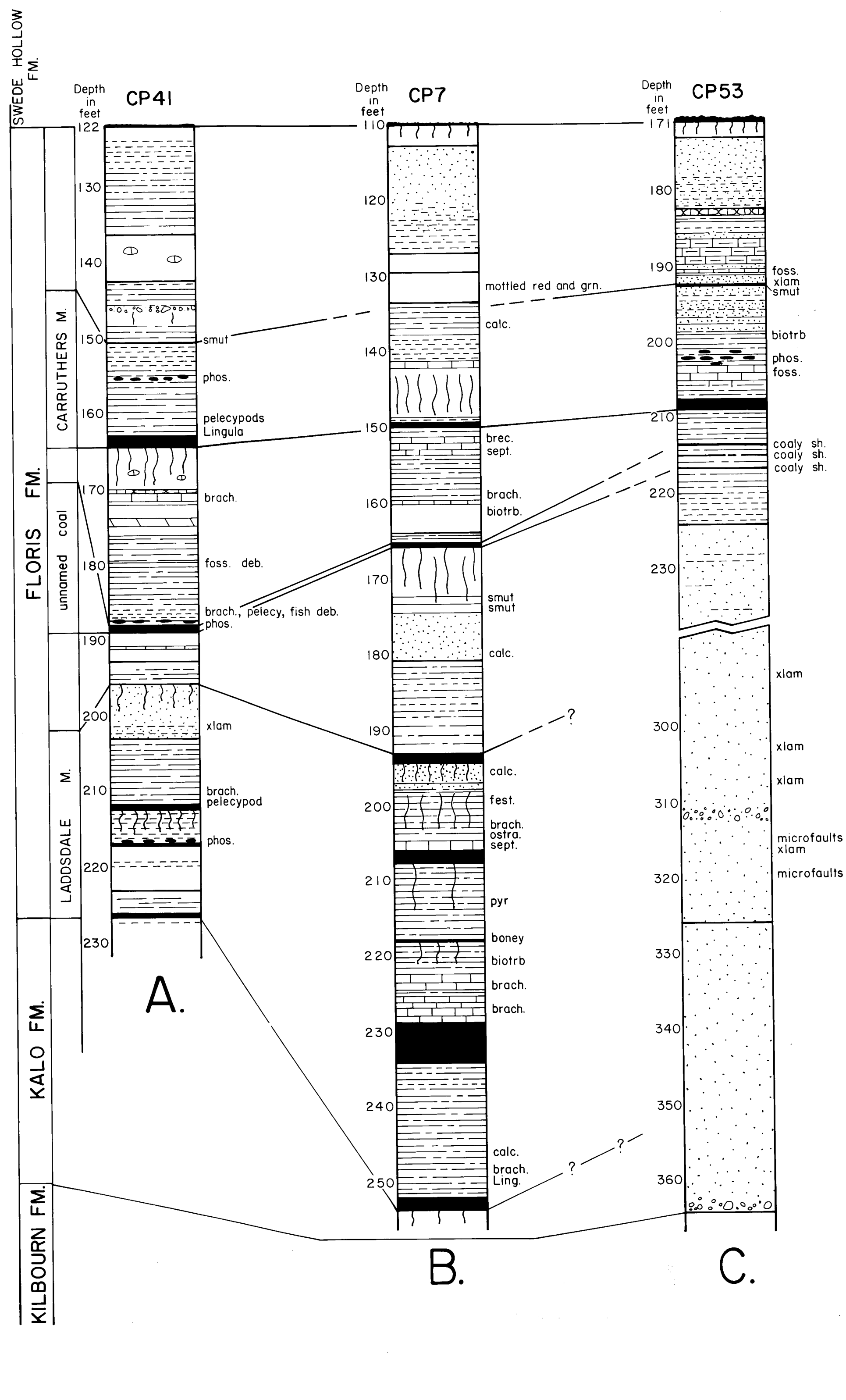


Figure 17. Floris Formation reference cores.
A) CP41 (Cent. Monroe Co.); 105 foot thick Floris section.
B) CP7 (S.C. Wapello Co.); 140 foot thick Floris section.
C) CP53 (Cent. Monroe Co.); 196 foot thick Floris section.

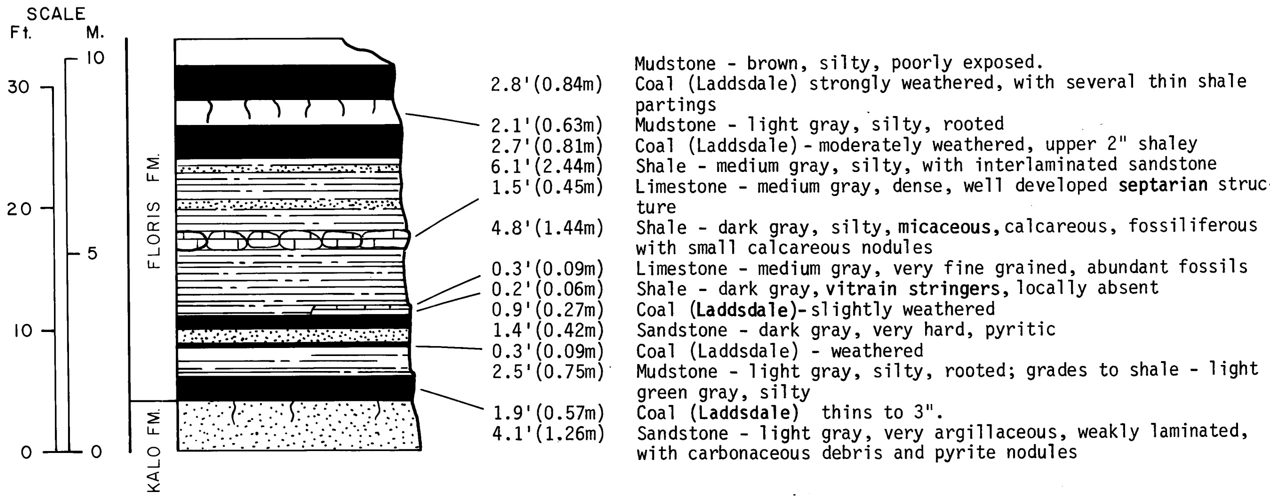


Figure 18. Type exposure of the Laddsdale Member, (stream cut on Soap Creek, SE 1/4, SE 1/4, NW 1/4, section 17, T.70N., R.12W., Davis County, Iowa).

the Laddsdale include these same mined coals. The strata associated with the coals are predominantly nonmarine shales and siltstones except for those above the second coal from the base, which comprise a thin marine shale with abundant, diverse fossils, and a fossiliferous limestone with septarian structures at the upper contact. Both of these marine beds are lenticular.

In cores, the Laddsdale contains from one to as many as six coal beds. Smut streaks represent one or more of the coal horizons in many of the cores. The associated strata are predominantly nonmarine clastics, although a few thin marine shales or limestones are present immediately above some of the coals. These generally grade upward into coarsening-upward sequences of shale to sandstone and may represent from one to six depositional cycles. The Laddsdale Member varies from 13 feet (4 meters) in CP9 (Davis Co.) to 91 feet (28 meters) in CP47 (Polk Co.). The unit shows a general tendency to thin toward the south and west and thicken to the northwest.

The maximum number of coals of the Laddsdale Member encountered in the subsurface are present in CP7 (Wapello Co.), which penetrated five coals ranging in thickness from a smut streak to 5.1 feet (1.6 meters) distributed through a total thickness of 61 feet (18 meters). Six depositional cycles are present in this core, which is illustrated and discussed as a reference section for the Floris Formation (figure 17B). Marine sediments occur in three of the six cycles. Several cores penetrated channel sandstones and other probable fluvial deposits in this interval, as discussed previously. These all consist of moderately- to well-sorted sandstones with minor shaley or conglomeratic zones.

The Laddsdale coals, although lenticular in nature, locally reach mineable thicknesses and constitute a major coal resource in Iowa. As noted, many of the currently and recently operated mines produced from the Laddsdale coals.

"Seville" Limestone--In the area of its type section, the Laddsdale Member is frequently overlain by a lenticular, impure, fossiliferous limestone. This limestone has been correlated by previous workers (e.g., Landis and Van Eck, 1965) with the Seville Limestone of Illinois, which has been correlated across Missouri into Kansas (Searight et al., 1953, Howe, 1956) and is now regarded as a member of the Spoon Formation in Illinois (Kosanke et al., 1961; Hopkins and Simon, 1975). In Iowa, this limestone has also been historically referred to as the "Laddsdale" Limestone, an informal designation employed by the coal miners who worked the coals near Laddsdale. On the basis of its lenticular nature in Iowa and the uncertain biostratigraphic correlation between Illinois and Iowa coals associated with it, the historical correlation the "Seville" Limestone in Iowa and the Seville Limestone in Illinois is considered questionable, and therefore the use of that name for the Iowa limestone is discouraged. Furthermore, the lenticular nature of this limestone and lack of distinctive fauna makes it difficult to characterize, so no formal name is suggested at this time.

Carruthers Coal Member --The uppermost coal of the Floris Formation is the newly named Carruthers Coal Member. The name is derived from Carruthers Creek in northeastern Lucas County. The type section is in a road cut in the NW 1/4, NW 1/4, SE 1/4, section 3, T. 73 N., R. 20 W., Lucas County. At the type section (figure 19) the Carruthers is 1.4 feet (0.4 meters) thick, and is overlain by a dark gray clay shale with lingulid brachiopods and pelecypods. This is overlain by 6 feet (1.8 meters) of shale followed by a thin zone of abundant phosphate nodules. A 10.8 foot (3.2 meter) siltstone above this is overlain by a persistent smut.

In contrast to the Laddsdale coals, the Carruthers Coal is relatively persistent and ranges in thickness from a smut, as in CP37 (Clarke Co.) and CP44 (Warren Co.), to a maximum of 2.8 feet (0.8 meters) in CP24 (Davis Co.). In general, the coal thickens to the south and north, but is thin in the central and western parts of the study area.

Historically, the Carruthers Coal has been correlated with the Wiley Coal of Illinois and referred to by this latter name. The name Wiley was extended into Iowa by Weller and others (1942) on the basis of a proposed correlation with the Wiley Coal of Illinois. Biostratigraphic analysis (Ravn, in press) has revealed, however, that an unnamed coal below the Carruthers is the probable equivalent of the Wiley. The Carruthers instead may be correlated with the Greenbush-Dekovan Coals of Illinois (Hopkins and Simon, 1975). A persistent smut that lies ten to fourteen feet above the Carruthers is thought to correlate with the Abingdon Coal of Illinois. For these reasons, the use of the name Wiley for this coal is discouraged.

Although generally too thin to be considered mineable, reserves have been estimated (under the name Wiley) in Warren, Marion, Lucas, and Guthrie counties (Landis and Van Eck, 1965).

Interpretation of Floris Deposition--The Floris represents a transition from sedimentation largely dominated by nonmarine fluvial and deltaic processes of the Kalo to sedimentation influenced more by lagoonal and marine processes (figure 20). The closely related coals of the Laddsdale Member

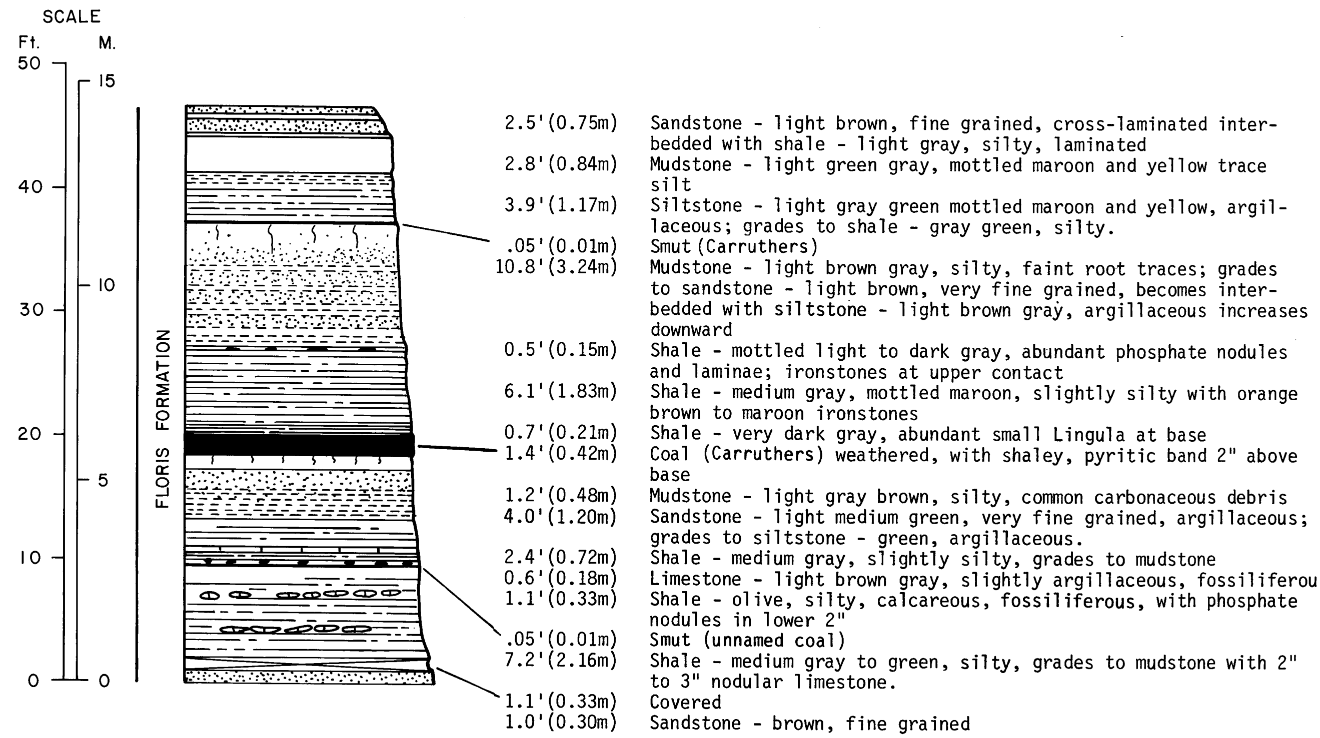


Figure 19. Type exposure of the Carruthers Coal Member (NW 1/4, NW 1/4, SE 1/4, section 3, T.73N., R.20., Lucas County, Iowa).

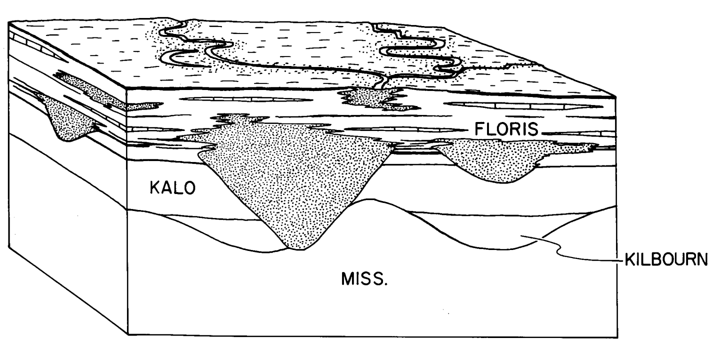


Figure 20. Diagramatic depiction of the depositional setting of the Floris Formation.

appear to represent a single major coal-forming event split by wedges of dominantly clastic sediment that periodically inundated the swamps in various areas. Localized marine deposition, perhaps occurring in interdistributary bays, is indicated by the impure, lenticular, fossiliferous limestones which are common in southeastern Wapello and northern Davis counties. Minor tectonic movements may also have contributed to the lateral irregularity of sedimentation. The coals in the upper portion of the Floris show a greater persistence than the Laddsdale coals. This increasing regularity of widespread coal beds, coupled with a greater proportion of associated marine sediments, appears to reflect the increasing marine influence upon sedimentation in the uppermost Cherokee Group. Major channelization, now represented by thick sandstones, probably occurred before the onset of deposition of the Carruthers Coal and associated strata.

SWEDE HOLLOW FORMATION

The Swede Hollow Formation includes strata from the base of the Whitebreast Coal to the base of the Excello Shale, which is redesignated as the boundary between the Cherokee and Marmaton Groups; reasons for this redesignation are discussed in the following section on the Marmaton Group. The name Swede Hollow is derived from the type locality, a series of exposures along a tributary to Whitebreast Creek in Swede Hollow, sections 33 and 34, T. 73 N. R. 22 W., and section 3, T. 72 N., R. 22 W., Lucas County, Iowa (figure 21). Although the uppermost beds assignable to the formation are not exposed in the immediate vicinity of the type section, the top of the Swede Hollow is exposed at the type locality of the newly defined Mouse Creek Formation (see discussion of the Marmaton Group) approximately two miles to the northwest. Named members of the Swede Hollow include the Oakley Shale (newly named), the Ardmore Limestone, and the Whitebreast, Wheeler, Bevier, and Mulky Coals.

Overall, the Swede Hollow records a period of increasing marine influence on sedimentation in southern Iowa. Fully marine limestones and shales were deposited periodically across virtually all of the Western Interior Basin area in Iowa during regional transgressions of the Midcontinent Pennsylvanian sea; these are interbedded with nonmarine sediments deposited during regional regressions of the sea. During Swede Hollow deposition, this "cyclicity" is not entirely uniform, but it is much more so than in the older portions of the Cherokee Group, and it initiates the strongly-alternating marine-nonmarine cyclothemic sedimentation that dominated the depositional history of Iowa throughout the rest of the Pennsylvanian.

As a result of this increase in marine influence, the sediments of the Swede Hollow are characterized by the lateral persistence of thin, but easily traceable beds, and by an overall relatively uniform thickness; the formation averages approximately 100 feet (30 meters) in thickness over a large area of southeastern and south-central Iowa. Certain units, such as the Whitebreast Coal and Ardmore Limestone, are extremely persistent and uniform, and can be correlated to equivalent units (bearing other names) in states from Illinois to Oklahoma. The term Ardmore cyclothem was proposed by Van Dorpe (1980) for the sequence that contains the Whitebreast Coal, the Ardmore Limestone, and associated strata, equivalent to the Liverpool cyclothem of western Illinois.

The Whitebreast Coal together with the overlying Oakley Shale and Ardmore Limestone form the most easily recognizable lithologic interval in the entire Cherokee of Iowa, and permit relatively easy recognition of the base of the

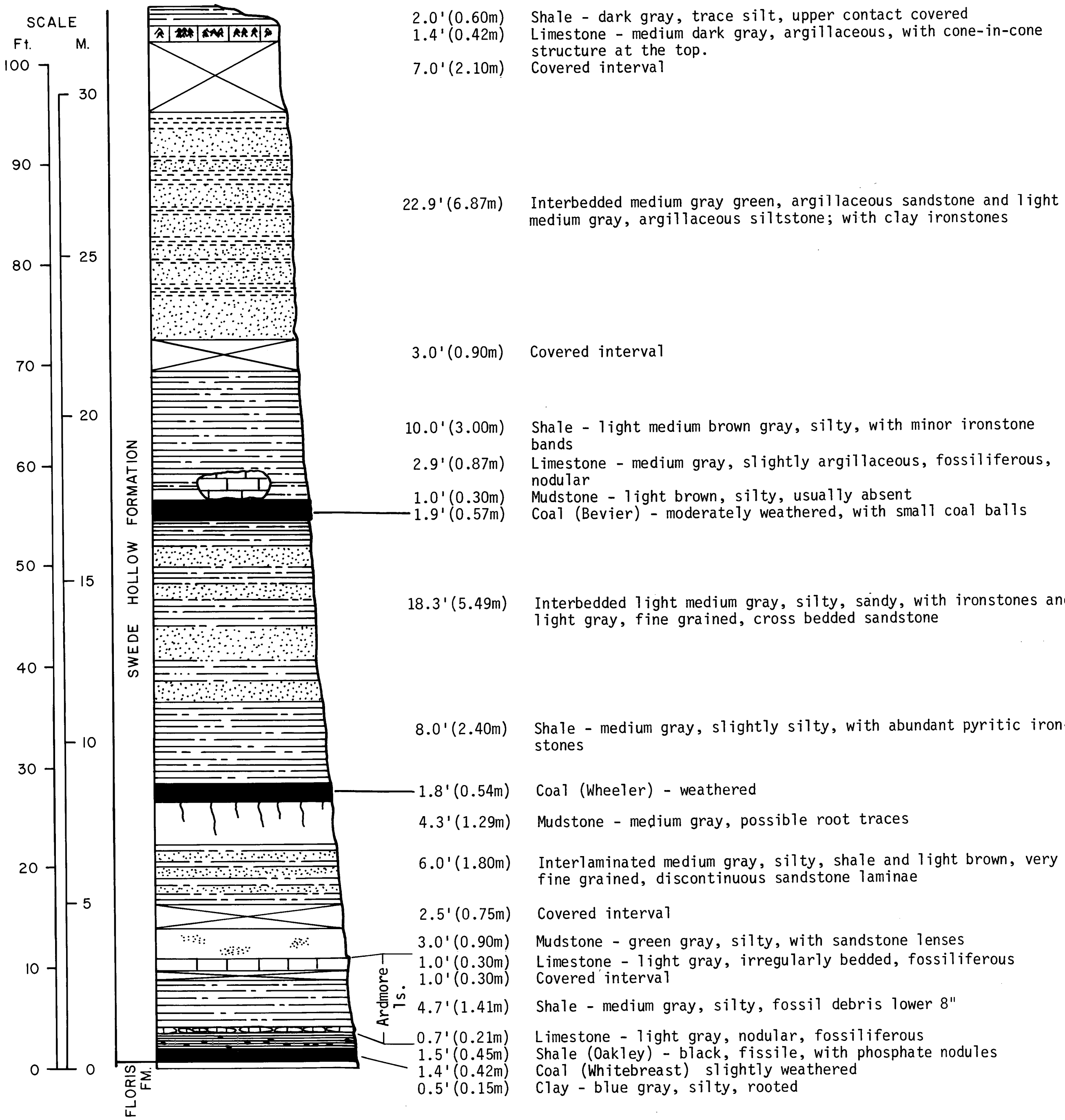


Figure 21. Type exposure of the Swede Hollow Formation (exposures along Whitebreast Creek, sections 33 and 34, T.73N., R.22W. and section 3, T.72N., R.22W., Lucas County, Iowa).

Swede Hollow Formation. Thus identified, the base of the Swede Hollow is equivalent to the base of Stookey's (1935) Lucas Formation. The name Lucas, however, cannot be retained, as it was employed at least twice for other rock units prior to Stookey's dissertation (Lucas Formation, Middle Devonian Detroit River Group, Ohio, Michigan, and Ontario: Prosser, 1903; Lucas Formation, Middle Devonian, eastern Iowa, from a locality in Johnson County: Keyes, 1912). Without proposing a formational name, Lugn (1927) described the basic stratigraphy of the beds in the vicinity of Swede Hollow as a sequence similar to the type section described in this report.

Representative Swede Hollow sequences (figure 22) demonstrate the relative uniformity of Swede Hollow sediments in Iowa. The upper portions of all three cores show approximately 60 feet (18 meters) of sandstones, siltstones, and shales. The Mulky Coal is virtually absent, represented only by a smut in CP37. The Bevier Coal exceeds one foot (30 centimeters) in thickness in all three cores, but its stratigraphic relationship with the underlying Wheeler Coal is variable. In CP37 and in CP78 approximately 25 feet (7.5 meters) of shales and sandstones intervene between the two coal beds, but in CP76 only a few inches of shale are present. The Wheeler Coal lies very near the Ardmore Limestone Member in both CP37 and CP78, but in CP76 nearly 30 feet (9 meters) of shale and siltstone separate the two units.

The lower part of the Swede Hollow, from the Whitebreast Coal upward through the Ardmore Limestone, is very similar in CP37 and CP76, but is unusually expanded in CP78. There, it consists of 48 feet (14.4 meters) of strata that are dominantly shale. Neither the limestone nor the fissile black shale facies of the Oakley Member are as strongly developed in CP78 as in other cores, and a 15 foot (4.5 meter) section of silty shale, rooted at the top, occurs between the Whitebreast Coal and the first fissile black shale within the Oakley. A zone of phosphate nodules, usually found within the fissile black shale facies, occurs approximately eight feet (2.4 meters) above the black shale in CP78. Nevertheless, in comparison to underlying strata of the Cherokee Group, the Swede Hollow sediments in these three cores demonstrate considerably greater lateral lithologic continuity.

<u>Whitebreast Coal Member</u>--The Whitebreast Coal Member is named from Whitebreast Creek near the Swede Hollow type section. Its type section is at the Swede Hollow type section in sections 33 and 34, T.73N., R.22W., and section 3, T.72N., R.22W. in Lucas County, Iowa (figure 21). Lugn (1927) also described and illustrated good exposures of the Whitebreast Coal.

The Whitebreast Coal is remarkable in its lateral persistence and uniformity of thickness, as it is present over most of the entire 14 county area with a thickness consistently of about 1 foot (0.3 meters) thickening to about 1.5 feet (0.5 m) in southern Monroe County. The Whitebreast is regionally persistent as well, as it is equivalent to the Colchester (No. 2) Coal in Illinois (Hopkins and Simon, 1975) and the Croweburg Coal in Kansas and Missouri (Howe, 1956). It also has been tentatively correlated with the Lower Kittanning Coal of the Appalachian Field (Hopkins and Simon, 1975). The Whitebreast has been mined in Monroe County and other areas, but under present economic and technical conditions, it is of minimal economic importance.

<u>Oakley Shale Member</u>--The name Oakley Shale is proposed for the dominantly marine shale interval above the Whitebreast Coal and below the Ardmore Limestone. The type section is designated within the Swede Hollow type section (figure 21), and the name is derived from the community of Oakley in northern Lucas County.

In southern Iowa, the Oakley is mainly a fissile, black, phosphatic shale. In the eastern half of the 14 county area the black facies generally

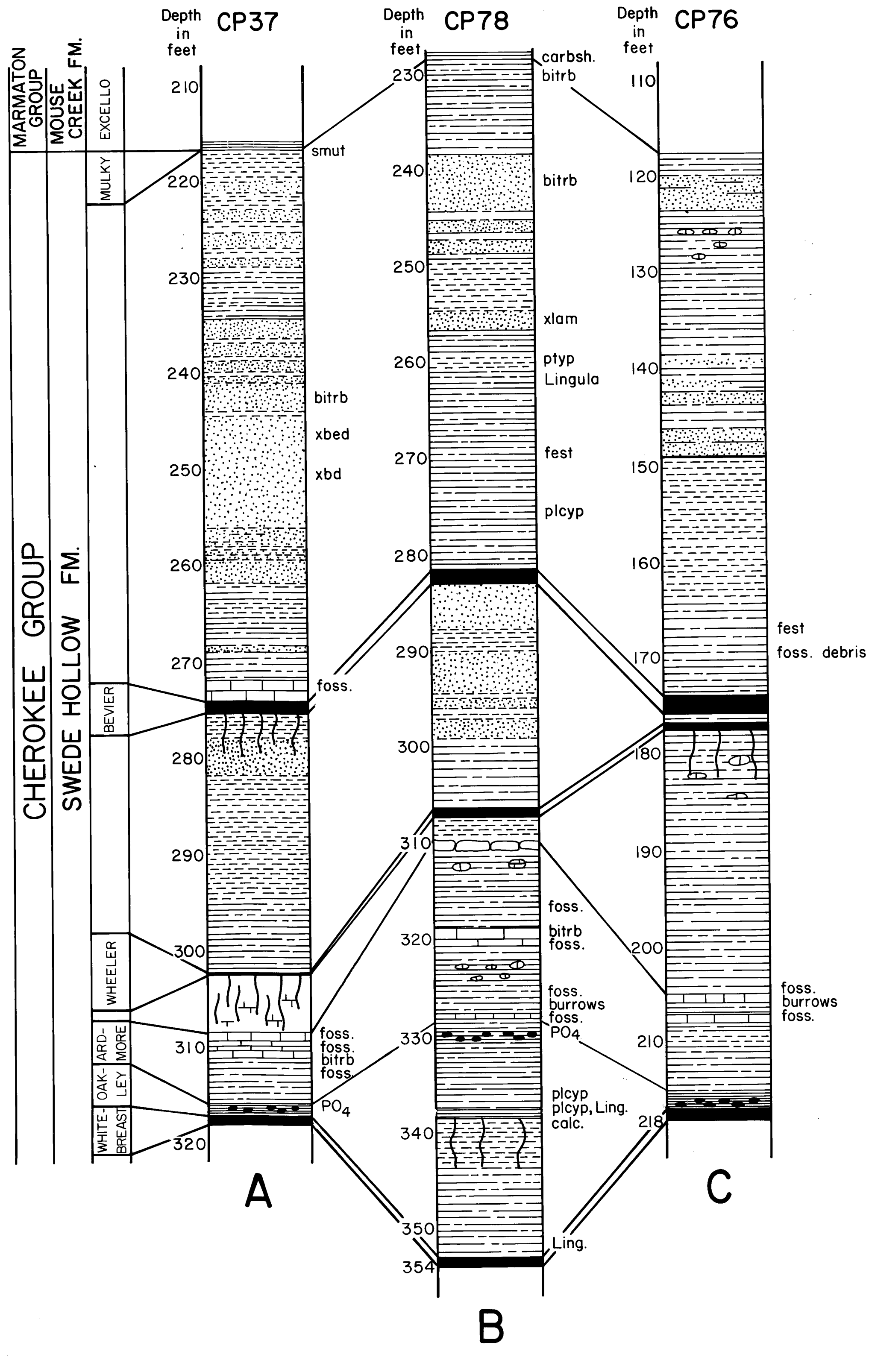


Figure 22. Swede Hollow Formation reference cores.
A) CP37 (Cent. Clarke Co.); 100 foot thick Swede Hollow section.
B) CP78 (N.C. Wayne Co.); 109 foot thick Swede Hollow section.
C) CP76 (N.E. Appanoose Co.); 88 foot thick Swede Hollow section.

directly overlies the Whitebreast Coal with a sharp, irregular contact and is consistently one foot thick, with local concentrations of non-skeletal phosphate at its base. In this area, the black facies is usually overlain by about 0.5 feet (15 centimeters) of bioturbated gray shale below the first of the overlying limestone beds. In the western half of the study area, the black fissile facies is thicker, generally 1.8 to 3 feet (0.5 to 0.9 meters), and is separated from the Whitebreast by plant fossil-bearing gray shales and siltstones that range up to 22 feet (6.7 meters) thick. Where these clastics are thick, the Whitebreast may be represented by only a smut zone (e.g., CP79, Lucas Co.). This is followed by a thin gray shale with marine fossils. This sequence may represent deposition within the valley axis of a contemporaneous river flowing through the coal swamp. Throughout this area, the lowermost bed of the overlying limestone rests directly on the black, fissile facies, generally with chondrites-type burrows penetrating the upper portion of the shale.

Although recognized as a widespread marker horizon over much of Iowa, Kansas, and Missouri, no formal name had previously been proposed for the black shale bed of the Oakley. This black, phosphatic shale bed is probably equivalent to the shale bed identified as the Mecca Quarry Shale in northeastern Illinois by Hopkins and Simon (1975). Nevertheless, because the interbasinal extension of member names is considered undesirable, no name is proposed for the Western Interior Basin.

Ardmore Limestone Member--The Ardmore Limestone is the most persistent limestone in the entire Cherokee Group. Named from Macon County, Missouri (Gordon, 1893, p. 20), it is traceable in the subsurface and along outcrop from Iowa southward into Oklahoma, where it is correlated with the Verdigris Limestone (Jewett, 1945). It is also equivalent to the Oak Grove Limestone of northwestern Illinois (Hopkins and Simon, 1975), and possibly to the Velpen Limestone of western Indiana. In each of these areas, the limestone is present as two or more beds separated by shale. In Iowa, this led to the informal miner's name, "Two-Layer Limestone" for this interval.

In the study area, the lower limestone is generally a single massive bed averaging about 0.5 feet (15 centimeters) thick. Locally, however, it may be separated into two thin beds by shale, or the interval may be represented by only a thin zone of calcareous fossil debris above a zone of chondrites-like burrows. The middle shale of the Ardmore is present over the entire study area, and ranges from 4.5 to 8 feet (1.3 to 2.5 meters) thick. It is generally dark gray, slightly silty and micaceous, but where thin, is often mottled green in anastomosing zones along lamination surfaces and fractures. The upper limestone is generally about two feet thick, with two beds separated by a thin shale, although locally the number of beds and thickness of the interval increases. In southern Davis, Marion, Lucas, and Wayne counties the upper limestone interval is as much as 15 feet (4.5 meters) thick (e.g., CP78, figure 22B). In these areas, three or four limestone beds are present, and the uppermost bed is generally sandy and locally shows signs of subaerial weathering.

Wheeler and Bevier Coal Members--The Wheeler Coal Member is the lower, and the Bevier Coal Member the upper, of two closely related coal beds, which have been considered synonymous by some workers. The Wheeler is named for Wheeler Bridge, which formerly stood in the NW 1/4, NE 1/4, section 33, T. 73 N., R. 22 W., Lucas County, spanning the Swede Hollow tributary to Whitebreast Creek. Although the bridge is no longer standing, the outcrop still exists and is still considered the type section. It is, however, poorly exposed, and the exposure of the Wheeler Coal in the nearby Swede Hollow Formation type section is much better.

Bevier is a name carried into Iowa from Missouri, and considerable confusion has existed in the past over the stratigraphic relationships of the Bevier and Wheeler coals. Weller and others (1942) regarded these names as synonymous and recognized the name Bedford for the upper of the two coals. Present nomenclature in Missouri, however, recognizes the name Wheeler for the lower coal and Bevier for the upper coal (Robertson, 1971). This is in accord with the nomenclature employed by Landis and Van Eck (1965) in Iowa. For purposes of consistency with the more recent literature, the names Wheeler and Bevier are retained here. It must be noted, however, that the name Bedford was used in much of the early literature (e.g., Hinds and Greene, 1915), and the reasons for the change in the nomenclature of these two coals in Missouri is obscure.

Study of IGS cores indicates that the interval between the Wheeler and Bevier coals is generally less than 20 feet (6 meters), and they appear to coalesce in some areas. A general trend, with local exceptions, is for the Wheeler-Bevier interval to thicken toward the southwest. In some cores (e.g., CP77, S.E. Lucas Co.), three coals are encountered in the Wheeler-Bevier interval, in which case it is not practical to distinguish them by separate names.

Both the Wheeler and Bevier coals are more variable in thickness than is the Whitebreast. The Bevier in particular is important economically in Missouri (Robertson, 1971). In Iowa, the two beds seldom exceed two feet (0.6 meters) in thickness individually, but in areas where they are close, potential may exist for mining both beds. Landis and Van Eck (1965) estimated reserves for the Wheeler and Bevier coals collectively in several southern Iowa counties. Together they may be considered as the biostratigraphic equivalent of the Lowell Coal of Illinois (Hopkins and Simon, 1975).

Although the entire upper portion of the Swede Hollow Formation was recovered in only eight IGS cores, they clearly demonstrate that the strata overlying the Bevier Coal are much more complex than previously thought. Landis and Van Eck (1965) reported approximately 30 feet (9 meters) of shale above the Bevier Coal, overlain (often with an erosional contact) by a supposedly widespread sandstone that they considered to be the basal sandstone of the depositional cycle that contains the Mulky Coal. Based on their correlation of the Mulky with the Summum (No. 4) Coal in Illinois, they applied the Illinois name Pleasantview (see Hopkins and Simon, 1975, p. 188) for the sandstone (although the misnomer, Pleasantville, is present in Landis and Van Eck, 1965, figure 4). Study of the IGS cores reveals that the number of depositional cycles present above the Bevier varies from one cycle with no sandstone (CP41, in Marion Co.) to as many as four cycles, each containing a sandstone (CP37, in Clarke Co., figure 22A). In light of the degree of uncertainty involved in correlating laterally discontinuous sandstone bodies, further use of the name "Pleasantview" for any of the Iowa sandstones is discouraged.

Mulky Coal Member--The Mulky Coal is the uppermost member of the Swede Hollow Formation (and of the Cherokee Group). The name is extended into Iowa from Missouri. The Mulky is a thin unit of sporadic occurrence in Iowa, although the coal horizon is readily recognized by the presence of the persistent, distinctive, overlying Excello shale. In IGS cores, the Mulky is usually only represented by a smut, but in one core (CP41, in Marion Co.), 5 inches (13 centimeters) of coal are present. It is also known in outcrop in a section along Whitebreast Creek (NW 1/4, NE 1/4, NE 1/4, section 8, T. 72 N., R. 22 W., Lucas County), not far from the Swede Hollow type section. Landis and Van Eck (1965) estimated small reserves for the Mulky Coal in Lucas County. The Mulky is equivalent to the Summum (No. 4) coal of Illinois.

Interpretation of Swede Hollow Deposition--The Swede Hollow Formation contains sediments related to two different depositional regimes. The Whitebreast Coal, Oakley Shale, and Ardmore Limestone were deposited as a result of a major episode of eustatic marine transgression and regression. The remainder of the formation consists of depositional cycles, probably related to deltaic progradation and abandonment (figure 23).

The thin lower portion of the Swede Hollow is in many ways comparable to the marine limestone-dominated portions of younger Marmaton Group and Missouri Supergroup depositional cycles. Heckel (1977, 1980) has developed a regional model for deposition of those younger Pennsylvanian cycles, which can be applied to the Swede Hollow Formation. The Whitebreast Coal was evidently deposited on a widespread surface of low relief that resulted from infilling of irregular early Floris topography by the upper portion of the Floris Formation. The initiation of eustatic marine transgression resulted in elevated local base levels and the widespread accumulation of peat. Clastic sediments in transport toward the basin center became stranded and were deposited in or adjacent to the channels of rivers flowing through the coal swamp. Although these deposits are time-transgressive, the degree of diachroneity may be slight. Peat probably accumulated in the eastern portion of the study area at the same time that the western portion of the area experienced oxygenated, shallow marine conditions and deposition of the thin gray, fossiliferous shale that underlies the black shale facies of the Oakley.

The black, fissile, phosphatic, clay-shale facies of the Oakley is in all respects identical to those younger Pennsylvanian black shales discussed by Heckel (1977), and may be interpreted to have originated from the same processes. Water depths in the epeiric sea during the maximum phase of eustatic transgression became sufficiently great to permit formation of a thermocline. This restriction of vertical circulation resulted in the eventual depletion of oxygen in the near-bottom waters and in the creation of reducing conditions at or above the sediment-water interface. The relative abundance of phosphate and other heavy elements in these black shales can be explained by the upwelling of cool, low-oxygen, nutrient-rich water from intermediate depths of the open ocean which, in conjunction with the thermocline, formed a circulatory trap for these materials. The great lateral extent of the Oakley Shale and its midcontinent correlatives suggest that this marine inundation may have been one of the most widespread of the Pennsylvanian transgressions.

The Ardmore Limestone Member represents the equivalent of the regressive (or upper) limestone discussed by Heckel (1977, 1980). The lower limestone bed evidently records the breakup of the thermocline and renewed vertical circulation during the initial stages of eustatic regression. The middle shale bed, with sparse fossils of low diversity, was evidently deposited rapidly, perhaps as distal prodeltaic influx was becoming widespread in water of intermediate depths (for an epeiric sea). The dark color of the shale may have resulted from the extremely high organic content (Hatch, personal communication) of the outflow of coal swamps to the north and east, rather than reestablishment of a thermocline. There is no suggestion of subaerial weathering at the top of the shale, and the green mottling noted earlier is most common where sediments between the Ardmore and the Wheeler Coal are thin, suggesting partial oxidation by meteoric waters during later stages of soil formation preceding deposition of the coal. Either the shifting of deltaic influx elsewhere or a minor transgression resulted in deposition of the upper Ardmore Limestone, which is commonly split by later prodeltaic pulses as re-

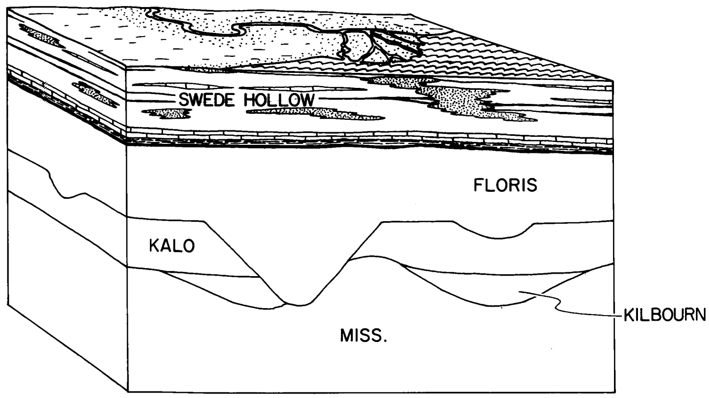


Figure 23. Diagramatic depiction of the depositional setting of the Swede Hollow Formation.

gression continued or resumed. The great lateral persistence of the Wheeler Coal argues strongly for subaerial exposure of the entire study area during final regression of the Oakley-Ardmore eustatic cycle.

MARMATON GROUP

Strata of the Marmaton Group reflect the increasing trend toward cyclicity characteristic of Late Pennsylvanian sedimentation in the Midcontinent. In the Marmaton Group and younger Pennsylvanian units of the Western Interior Basin, standard practice for definition of formation units has been to recognize in nomenclature this widespread depositional cyclicity. Each sedimentary cycle (cyclothem) is divided into two formations, a marine formation normally consisting of a limestone to marine shale to limestone succession recording deposition during marine inundation, and a nonmarine or marginally marine clastic formation that records deposition during the retreat of marine waters. These formations are carried across the Western Interior Basin from Oklahoma to Iowa, and are so consistent in their repetition and so widespread that they are believed to be the result of eustatic fluctations in sea level that affected virtually the entire basin. Heckel (1977, 1980) described in detail the depositional setting for these cyclic sediments.

Revision of the Cherokee-Marmaton Boundary and the "Fort Scott" Formation

Evaluation of the IGS Coal Project cores through the lower portion of the Marmaton Group reveals that the "Fort Scott" Formation, as historically recognized in Iowa, is not delineated in a fashion consistent with that of overlying formations, as outlined above. The "Fort Scott" contains marine portions of two different cyclothems, a fact noted in Iowa by O'Brien (1977) and Swade (1977), although the need for revision of the "Fort Scott" has been recognized for many years (Searight et al., 1953). As the strata constituting the "Fort Scott" are readily recognized and are easily traceable in Iowa, revision of uppermost Cherokee and lower Marmaton stratigraphic nomenclature to bring the "Fort Scott" into conformity with the system employed for overlying units is considered desirable.

Prior to this report, the Cherokee-Marmaton boundary historically has been placed at the top of a widely-recognized marine shale known elsewhere in the Midcontinent as the Excello, a name derived from a locality in Macon County, Missouri (Searight, 1955). Athough widely used in other areas in the Western Interior Basin and in Illinois, the name Excello has been applied previously in Iowa only in unpublished theses (e.g., O'Brien, 1977). Two complete marine-nonmarine depositional cycles are recorded in the interval from the base of the Excello Shale through the "Fort Scott" Formation to the top of the overlying Labette Shale (figure 24). The lower of these two cycles (designated as the lower Fort Scott cyclothem by O'Brien, 1977) begins immediately above the Mulky Coal Member of the Swede Hollow Formation. In Iowa, the Mulky is not everywhere present, but the base of the marine Excello is easily recognized as it commonly overlies a nonmarine seatrock-like mudstone. As with other thin marine shales having dominant fissile, phosphatic black facies, such as the Oakley Shale Member of the Swede Hollow and many younger Upper Pennsylvanian shales, the Excello is very persistent laterally and is a useful lithostratigraphic marker throughout the Midcontinent.

Regional study of the Excello by James (1970) has demonstrated that a three-part subdivision is present throughout the unit. The lower, transgressive "limestone" interval is poorly developed, and is usually absent in Iowa, as is also the case with the analogous Oakley Shale Member of the Swede Hollow Formation. In southeastern Iowa, the middle black phosphatic shale facies of the Excello is separated from the Mulky Coal horizon by only 2 or 3 inches (5 to 8 centimeters) of soft, dark gray shale. The upper portion of the phosphatic facies frequently becomes mottled green-gray and usually grades into the upper, bioturbated gray shale facies, which ranges from 6 to 10 inches (15 to 25 centimeters) in thickness.

Depositionally the Excello represents the lower two-thirds of a marine cyclothem that includes as its upper member the Blackjack Creek Limestone, which historically has been regarded as the basal member of the "Fort Scott" Formation. The bases of the marine cyclothemic formations overlying the "Fort Scott" are consistently placed at the base of the lowest recognized marine bed. In keeping with this usage, we herein redefine formational boundaries through the interval from the base of the Excello to the top of the Labette

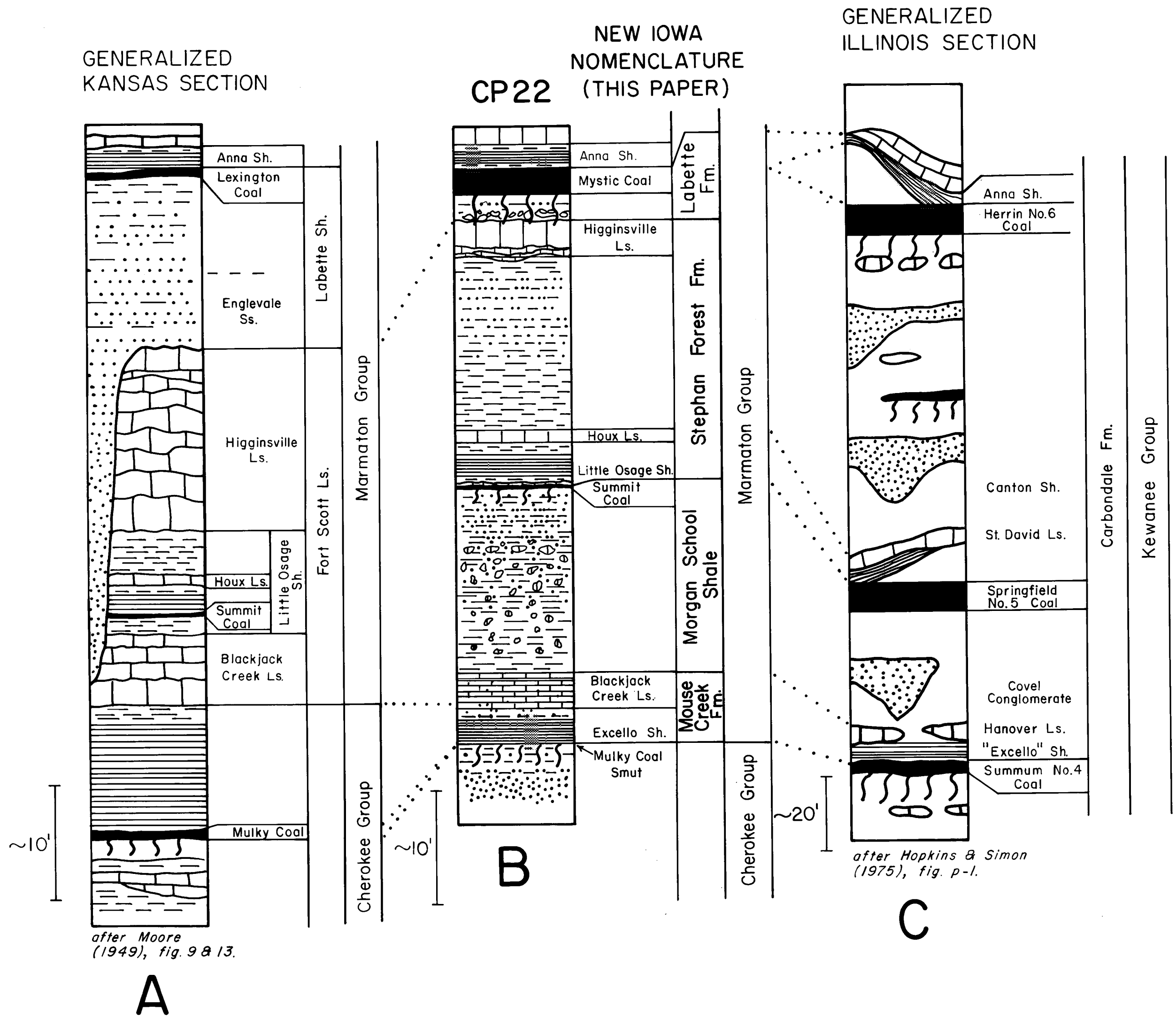


Figure 24. Correlation of the Mouse Creek, Morgan School, and Stephens Forest Formations of Iowa with generalized sections in Illinois and Kansas. Dotted lines show correlations.
A) Generalized Kansas section, revised from Moore (1949), figures 9 and 13.
B) CP22, Appanoose County, Iowa showing newly proposed nomenclature.
C) Generalized Illinois section, revised from Hopkins and Simon (1975), figure P-2, p. 166.

Shale, and place the boundary between the Cherokee and Marmaton Groups at the base of the Excello rather than at its top. The boundary would then be placed below the first demonstrably marine unit overlying the Mulky Coal horizon.

With this recognition of two complete cyclothemic intervals from the Excello to the Labette, the "Fort Scott" is no longer considered acceptable as a formation name in Iowa, and three new formational subdivisions are named. They are, in ascending order: Mouse Creek Formation, Morgan School Shale, and Stephens Forest Formation (figures 2 and 24). The Mouse Creek and Morgan School encompass the lower of the two depositional cycles, and the Stephens Forest and overlying Labette Shale constitute the upper. Regional relationships of this stratigraphic interval are shown on figure 24.

MOUSE CREEK FORMATION

The lowermost Marmaton Group Formation, the Mouse Creek, consists of the strata from the top of the Swede Hollow Formation to the base of the Morgan School Shale. In Iowa, this interval essentially consists of the Excello Shale Member and the overlying Blackjack Creek Limestone Member. The type exposure of the formation (figure 25) is located in NW 1/4, NE 1/4, NE 1/4, section 8, T. 73 N., R. 22 W., Lucas County, Iowa in a gully along Whitebreast Creek. Owing to a scarcity of formal geographic names in the immediate vicinity of the type locality, the formation name is selected from Mouse Creek, situated approximately five miles to the west-northwest. At its type section, the Mouse Creek Formation rests on 14.3 feet (4.3 meters) of Swede Hollow Formation Shales. Both the Excello Shale and Blackjack Creek Limestone Members are present, but the upper contact of the formation is not exposed.

A more complete section of rocks equivalent to the Mouse Creek Formation was identified in Kansas by Knight (in preparation). He named the unit "Dry Branch Creek Formation" and described a type section in the NW 1/4, NE 1/4, section 25, T.28S., R24E., near the town of Englevale in Crawford County, Kansas. At this location the unit includes the Excello Member, 2.8 feet (0.8 meters) of nodular black shale overlain by the Blackjack Creek Limestone Member, about 8.2 feet (2.5 meters) of gray calcilutite with thin claystone lenses present near its base.

Excello Shale Member--The Excello Shale Member (Searight, 1955), as it is exposed at the type section of the Mouse Creek Formation, consists of two feet (0.6 meters) of dark gray shale with abundant light brown phosphate nodules. It grades upward into 2.9 feet (0.9 meters) of greenish-brown, sparsely fossiliferous mudstone.

Blackjack Creek Limestone Member--The Blackjack Creek Limestone Member, named from Johnson County, Missouri (Cline, 1941) has been widely traced across the Midcontinent. In southeastern Iowa it usually consists of a single massive bed of argillaceous, skeletal calcilutite, two to four feet thick. At the type section of the Mouse Creek Formation the Blackjack Creek is poorly exposed, consisting only of fossiliferous limestone blocks. It has also been correlated with the Hanover Limestone of Illinois (Hopkins and Simon, 1975).

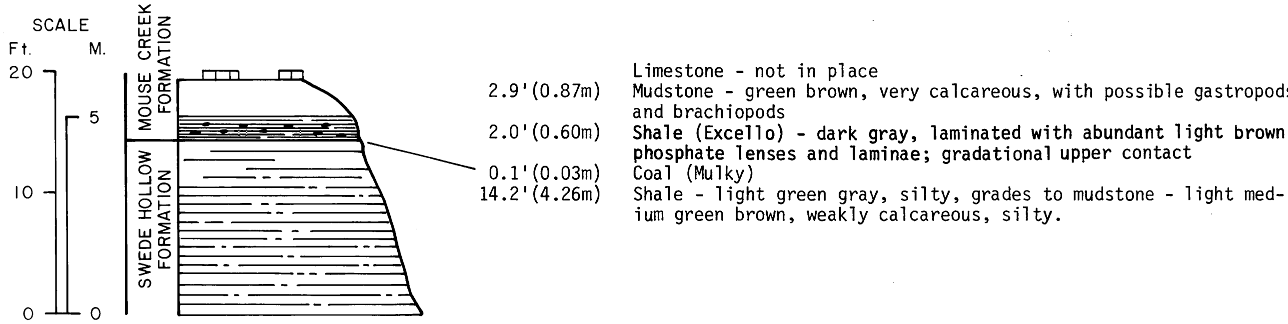


Figure 25. Type exposure of the Mouse Creek Formation (NW 1/4, NE 1/4, NE 1/4, section 8, T.73N., R.22W, Lucas County, Iowa).

MORGAN SCHOOL SHALE

The name Morgan School Shale is applied to for the nonmarine to marginal marine clastic unit overlying the Blackjack Creek Limestone, and underlies the first recognizable marine unit that marks the base of the Stephens Forest Formation. The type section of the Morgan School (figure 26) is located at the center of the east line, NW 1/4, section 18, T. 72 N., R. 22 W., Lucas County, and the name is derived from the former site of Morgan School approximately one mile to the southeast. The Summit Coal is the only named member and occurs at the top of the formation in Iowa. At its type section the Morgan School Shale consists of 5.6 feet (1.7 meters) of olive to brownish-green, variably calcareous shale. The base is not exposed. A weathered carbonaceous streak marks the position of the Summit Coal Member at the upper contact of the formation. Overlying the Morgan School Shale Formation at its type section is 16.5 feet (5.0 meters) of the Stevens Forest Formation.

The Morgan School Shale ranges from a maximum observed thickness of about 19 feet (6 m) in Wayne County (CP79) to less than one foot (0.3 m) in Clarke County (CP37). It usually consists of a single clastic sequence that coarsens upward from shale to siltstone and contains carbonate nodules in the upper portion. In CP37, however, the unit is reduced to a few inches of mudstone with a thin conglomerate composed of dark limestone and pyrite nodules at the base. In Illinois, the Covel Conglomerate is lithologically similar and is located in a similar stratigraphic position (Hopkins and Simon, 1975). Owing to the lateral discontinuity of that unit in Illinois, however, the use of the name in Iowa is discouraged, although correlation has been made by Wanless (1975).

Summit Coal Member--The Summit Coal Member, named from Missouri by McGee (1885), is poorly developed in Iowa and is usually represented by only a smut zone (Landis and Van Eck, 1965). In CP37, however, 8 inches (20 centimeters) of black, carbonaceous shale with alternating bands of vitrain and calcareous fossil debris occurs at the coal horizon. The Summit Coal has been correlated with the Springfield (No. 5) Coal of northwestern Illinois (Hopkins and Simon, 1975; Ravn, in press).

STEPHENS FOREST FORMATION

The Stephens Forest Formation consists of the strata from the top of the Morgan School Shale to the base of the Labette Shale and encompasses the marine portion of the upper depositional cycle represented in the "Fort Scott" interval. The type locality is the same exposure as that of the Morgan School (figure 26), and the formational name is derived from Stephens State Forest, tracts of which are found south of the town of Lucas, approximately 1.5 miles (2.4 kilometers) to the southwest. The Stephens Forest normally consists of, in ascending order, the redefined Little Osage Shale, the Houx Limestone, an unnamed shale, and the Higginsville Limestone, all of which are designated

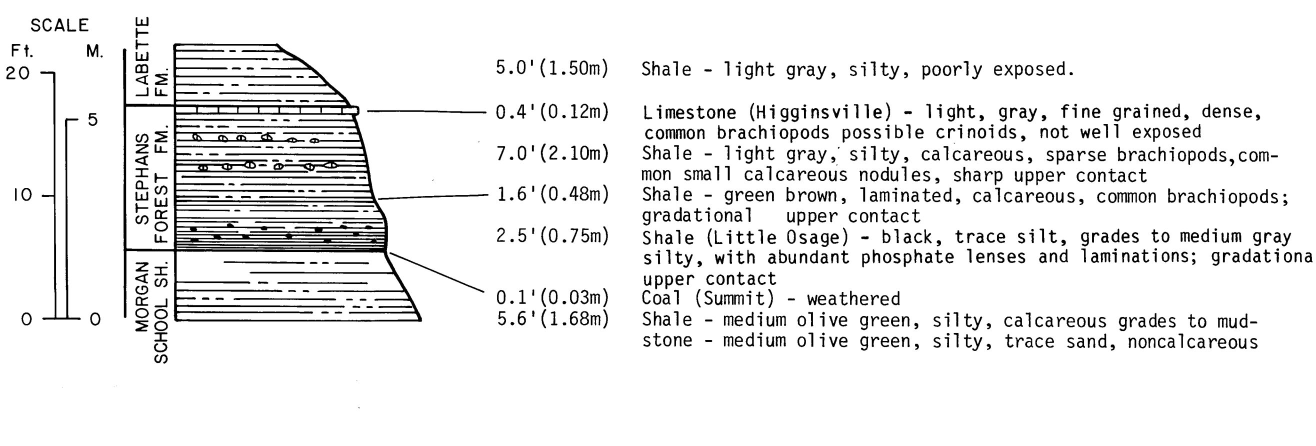


Figure 26. Type exposure of the Morgan School Shale and Stephens Forest Formation (center of east line, NW 1/4, section 18, T.72N., R.22W., Lucas County).

here as members.

At the type section of the Stephens Forest Formation, the basal Little Osage Shale Member consists of 2.5 feet (0.8 meters) of fissile, black, phosphatic shale, overlain by 8.8 feet (2.5 meters) of calcareous, fossiliferous shale with scattered limestone nodules. The Houx Limestone Member is not exposed at the type section of the Stephens Forest Formation. The unnamed shale member above the Little Osage shale is a light gray, silty shale whose upper contact is not exposed at this location. The Higginsville Limestone Member lies above the unnamed shale member and includes 0.4 feet (0.1 meters) of fossiliferous limestone.

A more complete section of rocks equivalent to the Stephens Forest Formation has been described in Kansas by Knight (in preparation). This section is exposed at the Fort Scott Quarry in the W 1/2, NE 1/4, section 19, T.25S., R.25E. in Bourbon County, Kansas. The unit, named the Wolverine Creek Formation by Knight (ibid.), includes the Little Osage Member, 1.7 feet (0.5) meters) of dark gray to black shale with irregular lenses of calcilutite, unconformably overlain by the Higginsville Limestone Member, about 12 feet (3.6 meters) of light gray calcilutite.

Little Osage Shale Member--The Little Osage Shale Member was named by Jewett (1941) from exposures in Bourbon County, Kansas, to encompass the strata between the Blackjack Creek and Higginsville Limestones. In the northern Kansas and eastern Missouri outcrop areas, Jewett (1945) noted that five distinct units were present in the Little Osage: 1) a lowermost gray shale; 2) the Summit Coal bed; 3) a black, fissile shale; 4) the Houx Limestone bed; and 5) an uppermost gray calcareous shale. He also noted that southward along the outcrop belt in southeastern Kansas and northeastern Oklahoma, the Little Osage is dominantly black, fissile shale with phosphatic nodules. Recent stratigraphic practice in Iowa, however, has not employed the name Little Osage, but has recognized the Summit and Houx as individual members of the former "Fort Scott" Formation (Landis and Van Eck, 1965). Although it is well known that the interval between these members is dominantly black phosphatic shale, only O'Brien (1977) and Swade (1982) have used the name Little Osage in Iowa in their unpublished theses.

In recognition of the increased understanding of the depositional environment represented by the black, phosphatic shale facies summarized by Heckel (1977, 1980), and the implications of its central position with respect to the marine portions of major Midcontinent Pennsylvanian depositional cycles (cyclothems), we propose that the name Little Osage Shale be restricted to the strata overlying the Summit Coal and underlying the Houx Limestone. Strata formerly included in the Little Osage below the first marine beds now constitute the Morgan School Shale. In Iowa, a thin calcareous shale with interbedded lenticular limestones and marine fossils is usually present between the Summit Coal and the black shale; in Clarke County (CP37), this interval thickens to about three feet. Ordinarily, a separate name might be accorded this "limestone" interval, but none is proposed here pending further, more detailed study. For the present, this interval is included in the Little Osage Shale Member.

Houx Limestone Member--The Houx Limestone Member, named from Johnson County, Missouri (Cline, 1941), is perhaps the thinnest regressive limestone in the Marmaton Group, but is persistent over all of south-central Iowa. Although generally only about 0.3 feet thick, it does increase to almost one foot thick in Appanoose County. The Houx has been correlated with the St. David Limestone in Illinois (Hopkins and Simon, 1975).

Unnamed Shale Member--The unnamed shale member overlying the Houx Limestone and underlying the Higginsville Limestone are included in the Stephens Forest Formation because preliminary study of the vertical stratigraphic sequence, areal relationships, and faunal content indicate that the Higginsville is a good example of what Moore (1936) termed a "super" limestone, in many ways comparable to the Coal City Member of the Pawnee. The unnamed shale member is somewhat remarkable for its uniformity of thickness in southeastern Iowa, ranging from 14 to a little over 16 feet in cores. It consists of a single, coarsening-upward clastic sequence of thinly interbedded shale, siltstone, and minor sandstone, which is equivalent to the Flint Hill Sandstone (Unklesbay, 1952) of central Missouri. Along the outcrop belt, a thin mudstone with a coal smut has been reported at the top (Landis and Van Eck, 1965), but this was not observed in the subsurface.

Higginsville Limestone Member--The Higginsville Limestone Member, named from Lafayette County, Missouri (Cline, 1941), is of quite variable character in Iowa. In Appanoose County, it generally ranges from two to four feet thick, but westward into the subsurface it thickens to about ten feet and is dominated by calcareous mudstone with several interbedded limestones in the lower portion. The upper portion of the Higginsville generally shows signs of subaerial weathering and/or root penetration, especially in Appanoose County (CP22) where the Labette Shale below the Mystic coal consists of only one foot of rooted, green mudstone.

MIDDLE MARMATON FORMATIONS

The middle Marmaton formations of Iowa include the Labette Shale, Pawnee Formation, Bandera Shale, and the Altamont Formation. The stratigraphic nomenclature as published by Landis and Van Eck (1965) are not modified at this time (figure 2).

UPPER MARMATON FORMATIONS

Recent work has led to a redefiniton of the Nowata Shale and Lenapah Limestone in Iowa, and to the recognition of two new and presently unnamed formations above the Lenapah and below the Pleasanton Formation, the lowermost Missourian unit.

NOWATA SHALE

The Nowata Shale was originally named from Nowata County, Oklahoma, by Ohern (1910). It was later defined by Jewett (1941) and Hershey and others (1960) as a sequence of shales and sandstones above the Worland Limestone Member of the Altamont Formation and below the Lenapah Formation, which at that time was correlated with the Cooper Creek Limestone Member in Iowa. Hershey and others (1960, p.30) described three outcrops of Nowata Shale in Madison County, Iowa, where they observed about 50 feet (15 meters) of grayish-brown sandstones, and red and green silty shales. They suggested, however, that this interval "may include part of the overlying Lenapah Formation .... as recognized in Missouri" (ibid.).

Swade (1982, p.70-71) characterized the "Nowata Shale" as "a terrestrial or marginally marine clastic sequence that records the regressive episode that followed deposition of the Altamont Formation." He divided an 18 foot (5.4 meter) section of "Nowata Shale" encountered in CP37 in Clarke County, Iowa, into two distinct units. The lower unit is a barren mudstone 4 feet (1.2 meters) thick. It grades upward from green to brick red and then to gray with maroon mottling. Irregular carbonate nodules are most abundant toward the base of this unit, which Swade (1982) interpreted as possibly part of a thin soil profile. In this report we recognize only this lower terrestrial unit as Nowata Shale and place Swade's upper "Nowata" unit in the Lenapah and unnamed overlying formations.

LENAPAH FORMATION

Above the lower terrestrial "Nowata" unit in CP37, Swade (1982, p.71) described approximately 4 feet (1.2 meters) of gray, silty, marine shale which becomes less calcareous, fossiliferous, and laminated upward. The basal 0.2 foot (6 centimeters) interval of this unit is an unnamed skeletal calcilutite with calcareous brachiopods, molluscs, and echinoderm debris. This unit had been included in the "Nowata" by previous workers (e.g. Hershey et al., 1960, Landis and Van Eck, 1965) as well as by Swade (1982), although Swade (ibid., p.71) stated that it represented a "minor marine incursion...at approximately the same horizon as the Lenapah Formation in northern Oklahoma." This marine unit is now considered a probable northern equivalent of the Lenapah Limestone, which in southern Kansas consists of three members representing two minor marine transgressions (Parkinson, 1982). The basal Norfleet Limestone Member (and equivalent Eleventh Street Limestone of Oklahoma) is the transgressive limestone of the lower cyclothem, and may be the equivalent of the unnamed limestone of CP37 in Iowa (P. H. Heckel, personal communication). Overlying the Norfleet Limestone, the Perry Farm Shale Member reflects a regressive basin infilling during a marine stillstand (Parkinson, 1982). The Idenbro Limestone Member of Kansas, which was deposited by the second Lenapah transgression, is not known in Iowa. The correlation of this limestone unit with the Lenapah Limestone necessitates a modification of the interpretations of Landis and Van Eck (1965) who correlated the Cooper Creek Limestone with the Lenapah (figure 2). This reinterpretation is discussed in more detail in the section on the Cooper Creek Limestone (p. 49).

UNNAMED SHALE FORMATION

Above the probable Lenapah-equivalent limestone and marine shales in CP37, Swade (1982) described about 10 feet (3 meters) of barren, red silty mudstone, with common irregular carbonate nodules near its base. He referred to this interval as upper "Nowata Shale." If the underlying unit is lower Lenapah, then this mudstone probably was deposited contemporaneously with the upper Perry Farm and Idenbro Members of the Lenapah and the overlying Dawson coal and its associated strata of Oklahoma and Kansas (Heckel, 1984). A probable northern equivalent of the Dawson Coal is the Laredo coal of Missouri (ibid.). The name "Mound Valley Formation" has been proposed for this unit by Heckel (in review).

"LOST BRANCH" FORMATION

The uppermost formation in the Marmaton Group in Iowa is a unit consisting in general of a basal limestone (the Sni Mills Limestone), an overlying marine shale (unnamed), and an upper limestone (the Cooper Creek Limestone). Heckel (1984) provisionally introduced the name "Lost Branch" Formation for an extremely widespread marine horizon, which, at its proposed type section near Mound Valley, Kansas (Heckel, in review), includes all of the marine rocks above the Dawson coal and below the Missourian Pleasanton Group. This formation is characterized by a distinctive Desmoinesian conodont fauna described by Swade (1982) from samples of the Cooper Creek Limestone and underlying beds in CP37 in Clarke County, Iowa.

Sni Mills Limestone Member--The basal member of the "Lost Branch" Formation in north-central and western Missouri is the transgressive Sni Mills Limestone, named from Missouri by F. C. Green (in Moore, 1936b) and correlated into Iowa by Heckel (1984). An offshore black to gray, phosphatic shale lies above the Sni Mills and becomes the basal member where the Sni Mills is absent, as is the case where black shale rests on the Laredo coal of northern Missouri and on the Dawson coal of southern Kansas and Oklahoma. Southward this shale is the Nuyaka Creek shale bed at the top of the Holdenville Formation of Oklahoma (ibid.). In northern Missouri much of this unit has been called Holdenville.

In Iowa, Swade (1982) described a previously unnamed 0.1 foot (3 cm) thick skeletal calcilutite lying above the "upper Nowata" red shale in CP37 (Clarke Co.), as a transgressive limestone. Stratigraphic relationships and overall compositional similarity indicate correlation of this limestone with the Sni Mills Member of the "Lost Branch" Formation of Heckel (1984).

Unnamed Shale Member--Lying above the Sni Mills in CP37 with an abrupt contact is a thin, green, calcareous, phosphatic, and fossiliferous shale, 0.1 foot (3 cm) thick (Swade, 1982). This is shown in figure 2 as "unnamed shale" member. An abundant conodont fauna was described from this shale by Swade (1982), who suggested that the unit represents the core shale of a cyclothem. This member is equivalent both to the phosphatic black shale that is found above the Sni Mills in Missouri and to the Nuyaka Creek Shale bed of the Holdenville Formation in Oklahoma, and its equivalents in Kansas and western Missouri (Heckel, 1984).

Cooper Creek Limestone Member--The uppermost member of the "Lost Branch" Formation in Iowa is the Cooper Creek Limestone Member, named from Appanoose County, Iowa, by Cline (1941). The Cooper Creek attains a maximum thickness in outcrop of about 7 feet (2.1 meters) in its type area, but is 8.5 feet (2.3 meters) thick in CP37. In that core the Cooper Creek is a mottled, bioturbated, skeletal calcilutite with common phylloid algal blades. Howe (1953) had equated the Cooper Creek to the Sni Mills Limestone, which previously had been correlated with the Idenbro Limestone of the Lenapah Formation by Cline and Greene (1950). Consequently the Cooper Creek had been considered to be a member of the Lenapah Formation in Iowa (figure 2). Howe and Koenig (1961) noted that the Sni Mills lies stratigraphically below the phosphatic, black shale facies of the "Holdenville Shale", which is now recognized as the core shale of the major depositional cycle that includes the Cooper Creek (Heckel, 1984). But, since the Cooper Creek lies above the equivalent phosphatic, unnamed shale member in Iowa, the Sni Mills is probably equivalent to the unnamed underlying basal limestone member, not the Cooper Creek. Furthermore, the entire "Lost Branch" lies stratigraphically above, and should not be correlated with, the Lenapah Formation as recently described in its type area by Parkinson (1982).

MISSOURI SUPERGROUP

Revision of Missouri Supergroup Stratigraphic Nomenclature

Prior to its elevation to Group rank under the name Pleasanton in Kansas in 1948, the old Bourbon Formation was included in the Bronson Group. The Bronson Group also included the Hertha, Ladore, Swope, Galesburg, and Dennis Formations (Moore, 1936). With the formal recognition of the Pleasanton Group at the state survey meeting in 1948, the remaining five formations of the Bronson Group were placed in an expanded Kansas City Group, and the Bronson was downgraded to the lowermost subgroup of the Kansas City Group (figure 27).

Removal of the Pleasanton from Group rank, and its return to Formation rank in Iowa, as is recommended in the next section, leaves only two recognized group designations within the Missouri Supergroup: Kansas City and Lansing. Inclusion of the Pleasanton Formation within the Kansas City Group is not desirable for two reasons. First, it would aggravate an already considerable imbalance in the relative amounts of stratigraphic section included in the Kansas City and Lansing Groups. As defined in Kansas by Jewett, O'Connor, and Zeller (1968), the Kansas City Group already contains twelve formational units, whereas the Lansing Group contains only three. More significantly however, Ravn (1981) has suggested that the group designations be redefined to recognize major depositional similarities among formations; this can be accomplished most readily by returning to the group designations of Moore (1936a). Therefore the following changes are made in stratigraphic nomenclature in Iowa:

1. Resurrection of the Bronson Group as the lowermost subdivision of the Missouri Supergroup. As defined here, the Bronson Group includes, in ascending order, the Pleasanton, Hertha, Ladore, Swope, Galesburg, and Dennis Formations. The Bronson encompasses three complete major cyclothems in Iowa, and groups together three marine units (Hertha, Swope, Dennis) that display considerable depositional similarity throughout much of their midcontinent outcrop.

SYSTEM	SERIES (Time)	SUPERGROUP (Rock)	Previous Stratigraphic Nomenclature (After Landis & Van Eck, 1965): GROUP		FORMATION	Named Member or (Bed)	Stratigraphic Nomenclature – This Report: GROUP		FORMATION	Named Member
PENNSYLVANIAN	MISSOURIAN	MISSOURI	LANSING		STANTON	South Bend Ls. Rock Lake Sh. Stoner Ls. Eudora Sh. Captain Creek Ls.	LANSING		STANTON	South Bend Ls. Rock Lake Sh. Stoner Ls. Eudora Sh. Captain Creek Ls.
					VILAS SH.				VILAS SH.	
					PLATTSBURG	Spring Hill Ls. Hickory Creek Sh. Merriam Ls.			PLATTSBURG	Spring Hill Ls. Hickory Creek Sh. Merriam Ls.
			KANSAS CITY	ZARAH SUBGROUP[1]	BONNER SPGS. SH.		KANSAS CITY		BONNER SPGS. SH.	
					WYANDOTTE	Farley Ls. Island Creek Sh. Argentine Ls. Quindaro Sh. Frisbie Ls.		ZARAH SUBGROUP	WYANDOTTE	Farley Ls. Island Creek Sh. Argentine Ls. Quindaro Sh. Frisbie Sh.
					LANE SH.				LANE SH.	
				LINN SUBGROUP[1]	IOLA	Raytown Ls. Muncie Creek Sh. Paola Ls.		LINN SUBGROUP	IOLA	Raytown Ls. Muncie Creek Sh. Paola Ls.
					CHANUTE SH.				CHANUTE SH.	
					DRUM	Corbin City Ls. Cement City Ls.			DRUM	Corbin City Ls. Cement City Ls.
					QUIVIRA SH.				CHERRYVALE	Quivira Sh. Westerville Ls. Wea Sh. Block Ls. Fontana Sh.
					WESTERVILLE LS.					
					CHERRYVALE	Wea Sh. Block Ls. Fontana Sh.				
				BRONSON SUBGROUP[1]	DENNIS	Winterset Ls. Stark Sh. Canville Ls.	BRONSON		DENNIS	Winterset Ls. Stark Sh. Canville Ls.
					GALESBURG SH.				GALESBURG SH.	
					SWOPE	Bethany Falls Ls. Hushpuckney Sh. Middle Creek Ls.			SWOPE	Bethany Falls Ls. Hushpuckney Sh. Middle Creek Ls.
					LADORE SH.				LADORE SH.	
					HERTHA	undifferentiated			HERTHA	Sniabar Ls. Mound City Sh.
			PLEASANTON		undifferentiated	Exline Ls. Ovid Coal Chariton Congl.			PLEASANTON	unnamed Sh. Exline Ls. unnamed Sh.

[1]Kansas stratigraphic subdivision not used previously in Iowa.

Figure 27. Missourian stratigraphy of Iowa from Landis and Van Eck (1965) and this paper.

2. Reduction of the Kansas City Group to the original definition used by Moore (1936a), to include the Cherryvale, Drum, Chanute, Iola, Lane, Wyandotte, and Bonner Springs Formations. These also represent a fairly natural grouping of depositionally related units centered around the widely persistent Iola cyclothem (see Mitchell, 1981). The Linn and Zarah Subgroups of the Kansas City Group (Moore, 1949; Jewett et al., 1968) are no longer recognized in Iowa.

3. The Lansing Group is unchanged from previous usage.

BRONSON GROUP

PLEASANTON FORMATION

On the basis of recent study and proposed stratigraphic revision in the State of Kansas (Ravn, 1981), we have reduced the Pleasanton Group in Iowa to the status of a formation. This change also necessitates revision of the overall Group nomenclature applied to the Missouri Supergroup in Iowa, as previously discussed.

The type area of the Pleasanton Group is located near the town of Pleasanton in Linn County, Kansas, where it is a relatively uniform detrital sequence consisting of shales and sandstones. Except for its somewhat lesser thickness, the Pleasanton in Iowa displays a generally similar lithologic character. The correlation with the type Pleasanton of Kansas is firmly established by its position below the widespread Hertha Limestone.

Group status was adopted for this unit at a meeting of state geological survey stratigraphers in 1948. Their purpose was to achieve uniformity of stratigraphic nomenclature for the Pennsylvanian column in the Western Interior Basin (Moore, 1949). Through a compromise, the Pleasanton Group was formally recognized by the various state surveys, although the Iowa Geological Survey accepted the compromise with some reservations because of the relative thinness and lithologic homogeneity of the unit in Iowa. Similarly, the Kansas Geological Survey appears to have been less than entirely pleased with this agreement (Moore, 1949). Prior to the meeting, the unit in Kansas had been designated as the Bourbon Formation, based on a type area in Bourbon County, Kansas, south of Pleasanton. Despite these reservations, the Pleasanton Group was formally accepted as the lowermost Group of the Missouri "Series" across the Midcontinent.

In Iowa, the Pleasanton is a thin unit, about 25 feet (7.5 meters) thick, dominated by nearshore to non-marine clastics. It is, therefore, similar in origin and thickness to other detrital formations of the Missouri Supergroup, such as the Ladore and Galesburg Shales. We believe therefore, that in Iowa no justification exists for continuing to regard the Pleasanton as a unit of Group rank, and it shall be considered the basal formation of the Bronson Group.

In the past, little study has been devoted to the Pleasanton in Iowa, and its stratigraphy is poorly understood. Work presently in progress by M. A. Nielsen and P. H. Heckel at the University of Iowa should help to clarify the stratigraphic relationships of this unit. Three units previously had been recognized within the Pleasanton, although a poor understanding of the Pleasanton had precluded differentiation of formations (Landis and Van Eck, 1965). The units were, in ascending order: "Chariton Conglomerate," "Ovid Coal," and Exline Limestone. These units as well as two additional unnamed shale units are discussed in this report. The stratigraphic relationships differ somewhat from earlier interpretations (figure 27), as the ascending sequence presently recognized is: unnamed basal shale member, Exline Limestone Member, and unnamed upper shale member.

Unnamed Basal Shale Member--The unnamed basal shale member of the Pleasanton Formation in Iowa ranges from 0 to a few feet (1 meter) in thickness, and rests on the Cooper Creek Limestone Member of the uppermost formation ("Lost Branch") of the Desmoinesian Marmaton Group. The shale is of terrestrial to shallow marine origin and commonly includes evidence of soil formation (P. H. Heckel, personal communication). In CP37 (Clarke Co.) this member is represented by a 6 inch (15 centimeter) mudstone (Swade, 1982, figure 14, bed 9F) lying disconformably on the Cooper Creek Limestone. In Harrison County in west-central Iowa, an Iowa Geological Survey core at Logan, WC22, includes 12 feet (3.6 meters) of gray, green, and red mottled shales and sandstones at the base of the Pleasanton. To the south, at Offutt Air Force Base south of Omaha, Nebraska, a core shows a basal Pleasanton shale similar in appearance to the section at Logan, but reduced to about 6 feet (1.8 meters) in thickness, and containing scattered plant remains near the top. A coal sometimes found in this unit has mistakenly been correlated with the "Ovid Coal" in some locations (for example, see Hershey and others, 1960, figure 18). This coal is probably equivalent to the recently named Grain Valley Coal of west-central Missouri (Howe, 1982), which underlies the Exline Limestone there.

Exline Limestone Member--The Exline Limestone is here afforded Member status in Iowa. The Exline Limestone was first named and described by Cline (1941) from exposures near the town of Exline in Appanoose County, Iowa (SE 1/4, sec. 6, T.67N., R.17W.). In CP37 (Clarke Co.) the unit is represented by a 2.5 foot (0.8 meter) thick, irregularly bedded, skeletal calcilutite with gray argillaceous partings increasingly abundant towards the top (Swade, 1982). In WC22 (Harrison Co.) the Exline is represented by about 5 feet (1.3 meters) of weathered skeletal calcilutite to calcarenite (Heckel, personal communication). In the Offutt Air Force Base core, the unit displays 6 feet (1.8 meters) of skeletal algal calcarenite to calcilutites with the upper half badly weathered (ibid.).

The Exline extends southward into Missouri where, in Sullivan and Adair Counties, it lies beneath a sandstone with what was interpreted by Cline (1941) as an unconformable contact, which he defined as the top of the Des Moines "Series." This sandstone has subsequently been identified as part of a prograding delta complex (Howe, 1982), and no pronounced unconformity has been identified above the Exline in Iowa (Swade, 1982). The upper Des Moines "Series" (now Supergroup) boundary remains where it has historically been placed, at the top of the Cooper Creek Limestone but below the Exline Limestone in Iowa.

Unnamed Upper Shale Member(s)--Above the Exline, a clastic-dominated sequence, about 17 feet (5.1) thick, was described from core CP37 by O'Brien (1977) who identified 3 clastic units. The lowermost of these, Unit 1, is a 10 foot (3 meter) thick green-gray laminated, silty mudstone, which coarsens upward to a green-gray crossbedded sandstone with limestone nodules. Unit 2 is a 4 foot (1.2 meter) thick sequence of carbonaceous mudstone with a 3 inch coal bed. The uppermost unit, Unit 3, is a 3 foot (0.9 meter) thick sequence of thinly interbedded dark gray, noncalcareous shale and light colored, very fine-grained sandstones with carbonaceous fragments and sparse invertebrate fossils.

The three units described by O'Brien (1977) are probably related to the deltaic sequence of detrital rocks described by Howe (1982) above the Exline Limestone in Missouri. O'Brien (1977) identified the coal in Unit 2 as "Ovid," but its stratigraphic position suggests that the coal may be, instead, the Locust Creek Coal of Howe, (1982), and the carbonaceous fragments that he identified in the upper unit may represent the "Ovid" Coal. In WC22 (Harrison Co.) the upper Pleasanton is represented by 5 feet (1.5 meters) of gray shale and mudstone, while in the Offutt Air Force Base core (Sarpy Co., Nebraska) it includes only 2 feet (0.6 meters) of gray mudstone. Additional study will be required before these upper Pleasanton units can be further delineated.

"Ovid" Coal--The name "Ovid" has been applied to a thin, but apparently persistent coal bed in the upper portion of the Pleasanton throughout southwestern Iowa. Considered by some to be a useful stratigraphic marker, it has been correlated northward from Missouri, where it was named and has been locally mined. Because of its apparently limited areal distribution in Iowa and the need for more work on its correlation and stratigraphic position, the "Ovid" Coal will not be considered a formal member of the Pleasanton Formation at this time.

"Chariton" Conglomerate--The "Chariton" conglomerate of Bain (1896) is known only from isolated exposures, and its exact stratigraphic relationships remain virtually unknown. Cline (1941) stated that it is definitely younger than the Coal City Limestone Member of the Pawnee Limestone, but its precise stratigraphic position is otherwise indeterminable. Despite this uncertainty, he supported the correlation of the "Chariton" with lower Pleasanton sandstones in Missouri, which were considered to mark the unconformity between the Des Moines and Missouri Supergroups. This correlation was extended by Weller, Wanless, Cline, and Stookey (1942) to include eastern Kansas as well, a practice reiterated by Jewett (1945). Howe (1982) included the "Chariton" with clastics of the Warrensburg and Moberly channel-fill sequence of Missouri, which lie above the Exline Limestone and below the Locust Creek coal (Howe, 1982).

The stratigraphic position of the "Chariton" conglomerate in Iowa is still not yet established. It may well record more than one period of channel development in Iowa. Correlation of the "Red Rock" sandstone with the Warrensburg and Moberly deposits and hence the "Chariton" conglomerate by Howe (1982) is not accepted because the "Red Rock" sandstone in Iowa is unquestionably associated with the Floris Formation of the Cherokee Group. Because the exact stratigraphic position of the "Chariton" conglomerate in Iowa is not known at this time, it is not here considered a formal member.

HERTHA LIMESTONE

Two members of the Hertha Limestone (Adams, 1903) are here formally recognized in Iowa, the Mound City Shale and the Sniabar Limestone (figure 27), which were recognized in several places by Ravn (1981).

Mound City Shale Member--The Mound City Shale Member, named from Linn County, Kansas by Jewett (1932), ranges in thickness in Iowa from 0 to about 5 feet (1.5 meters). The unit is dominated by gray shale, but also includes a thin black shale with phosphatic laminae near its base (Ravn, 1981). A thin limestone at the base correlated by Ravn (1981) with the Critzer Limestone Member of the Hertha is here included in the Mound City because of uncertainty of the northward extension of the type Critzer as reported by Heckel (1984).

Sniabar Limestone Member--The Sniabar Limestone Member, named from west-central Missouri by Jewett (1932), varies in thickness from 0 to 9 feet (2.7 meters) as described by Hershey and others (1960). It ranges in composition from a skeletal-algal calcilutite to a phylloid-algal calcilutite (Ravn, 1981) and frequently includes conspicuous shale partings.

No reference sections for the Mound City Shale or Sniabar Limestone in Iowa are designated in this report. However, Ravn (1981) described four representative sections including three cores and an outcrop.

MIDDLE AND UPPER BRONSON GROUP FORMATIONS

Bronson Group Formations overlying the Hertha Limestone are, in ascending order, the Ladore Shale, Swope Limestone, Galesburg Shale, and the Dennis Limestone. The stratigraphic nomenclature as detailed in Landis and Van Eck (1965) is retained at this time, with the exception of their removal from the Kansas City Group and inclusion in the resurrected Bronson Group.

KANSAS CITY GROUP

CHERRYVALE FORMATION

The Westerville Limestone and the Quivira Shale, previously recognized as formations, are here included as members within the Cherryvale Formation. This primarily semantic change is made in order to bring the Iowa nomenclature into conformity with that of Kansas (Jewett et al., 1968). The precise identification and stratigraphic relationships of the Westerville Limestone in its type area near the town of Westerville, Union County, Iowa continue to be uncertain. Studies in progress by P. H. Heckel and others at the University of Iowa will probably lead to further revision of this interval.

MIDDLE AND UPPER KANSAS CITY GROUP FORMATIONS

The stratigraphic nomenclature of the middle and upper Kansas City Group, including the Drum Formation, Chanute Shale, Iola Formation, Lane Shale, Wyandotte Formation, and Bonner Springs Shale (figure 27), is not changed from that described by Landis and Van Eck (1965).

LANSING GROUP

The stratigraphic nomenclature used by Landis and Van Eck (1965) to divide the Lansing Group (figure 27) is not revised at this time.

VIRGIL SUPERGROUP

The Virgil Supergroup includes the Douglas, Shawnee, and Wabaunsee Groups (figure 28). The nomenclature used by Landis and Van Eck (1965) has not been modified.

Stratigraphic Nomenclature
(After Landis & Van Eck, 1965)

SYSTEM	SERIES (Time)	SUPERGROUP (Rock)	GROUP		FORMATION	Named Member or Bed
PENNSYLVANIAN	VIRGILIAN	VIRGIL	WABAUNSEE	UPPER	undifferentiated	French Creek Sh. Jim Creek Ls. Friedrich Sh. Grandhaven Ls. Dry Sh. Dover Ls. Langdon Sh. (Nyman Coal) Maple Hill Ls. Wamego Sh.
				MIDDLE		Tarkio Ls. Willard Sh. Elmont Ls. Harveyville Sh. Reading Ls. Auburn Sh. Wakarusa Ls. Soldier Creek Sh. Burlingame Ls.
				LOWER		Silver Lake Sh. Rulo Ls. Cedar Vale Sh. (Elmo Coal) Happy Hollow Ls. White Cloud Sh. Howard Ls. Severy Sh. (Nodaway Coal)
			SHAWNEE		TOPEKA	Coal Creek Ls. Holt Sh. DuBois Ls. Turner Creek Sh. Sheldon Ls. Jones Point Sh. Curzon Ls. Iowa Point Sh. Hartford Ls.
					CALHOUN	undifferentiated
					DEER CREEK	Ervine Creek Ls. Burroak Sh. Haynies Ls. Larsh Sh. Rock Bluff Ls. Oskaloosa Sh. Ozawkie Ls.
					TECUMSEH	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.
					KANWAKA	Stull Sh. Clay Creek Ls. Jackson Park Sh.
					OREAD	Kereford Ls. Heumader Sh. Plattsmouth Ls. Heebner Sh. Leavenworth Ls. Snyderville Sh. Toronto Ls.
			DOUGLAS		LAWRENCE	
					STRANGER	unnamed coal

Figure 28. Virgilian stratigraphy of Iowa, from Landis and Van Eck, 1965.

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APPENDIX A

Correlation chart: Iowa Geological Survey Coal Division core holes' unit numbers (or footage) to named and unnamed coals and biostratigraphic coal zones.

Formation	Member	Biostratigraphic coal zone	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8
			Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic	"Upper"								
Morgan School	Summit	"Upper"								
Swede Hollow	Mulky	#10								
Swede Hollow	Bevier	#9								
Swede Hollow	Wheeler	#8								
Swede Hollow	Whitebreast	#7							5	
Floris	Carruthers	#6							15	
Floris	unnamed	#5							22	
Floris	Laddsdale	#4			9			8 13 16 18	26 30 32 35 37	
Kalo	Cliffland	#3	8		18	10			43	
Kalo	Blackoak	#2	9(92') 9(99')		21	13	?4(142')		46	12
Kilbourn	unnamed	#1	?9(101')	10(127')					50	

			Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
Formation	Member	Biostratigraphic coal zone	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic									
Morgan School	Summit			18						
Swede Hollow	Mulky	#10								
	Bevier	#9	4	26						
	Wheeler	#8	6	28						
	Whitebreast	#7	12	31						
Floris	Carruthers	#6	16	34						
	unnamed	#5	19 21							
	Laddsdale	#4	23 25 ?28(405')	40 ?43(376')				?2(40')		
Kalo	Cliffland	#3	32 34	46	4	2(289')	5	5		
	Blackoak	#2	36	49 50 55 58	7	5		8	7	7
Kilbourn	unnamed	#1	41	61 64 67						11(smuts)

Formation	Member	Biostratigraphic coal zone	Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
			CP17	CP18	CP19	CP20	CP21	CP22	CP23	CP24
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic							7		
Morgan School	Summit							11(166')		
Swede Hollow	Mulky	#10								
	Bevier	#9						17		3
	Wheeler	#8					2	19	2	5
	Whitebreast	#7					8	23	4	9
Floris	Carruthers	#6					14	30	8	17
	unnamed	#5					18 20 22	33	9(263')	?19(249')
	Laddsdale	#4				4(62')	26 29 31	38(361') 41(384')	10(266') 14	?21(255') ?22(256') 26(276')
Kalo	Cliffland	#3				11	34	44	18	30
	Blackoak	#2	9		4	13	36	48 51	19(327') 21	?32(313') ?36(339')
Kilbourn	unnamed	#1	13				40	60(503')	27	

Formation	Member	Biostratigraphic coal zone	CP25	CP26	CP27	CP28	CP29	CP30	CP31	CP32
			Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic	"Upper"								
Morgan School	Summit	"Upper"								
Swede Hollow	Mulky	#10								
Swede Hollow	Bevier	#9								
Swede Hollow	Wheeler	#8				4				
Swede Hollow	Whitebreast	#7				11				2
Floris	Carruthers	#6				15 18(118')				6
Floris	unnamed	#5								8(65') ?13(82')
Floris	Laddsdale	#4	2 ?5(225')		7 ?8(141')	20(132') 21(138') 24 27 31	?6(80')	7 9		15(93') 17 20
Kalo	Cliffland	#3	8		12	35		13(99') 14(104') 14(107') 15(109') 17	2	22
Kalo	Blackoak	#2	13		15	38	15	20		28
Kilbourn	unnamed	#1							7(111')	27(177') 31

Formation	Member	Biostratigraphic coal zone	Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
			CP33	CP34	CP35	CP36	CP37	CP38	CP39	CP40
Pleasanton	"Ovid"	"Upper"					7(58')			
Labette	Mystic	"Upper"					20			
Morgan School	Summit	"Upper"					25(209')			
Swede Hollow	Mulky	#10					27(217')			
Swede Hollow	Bevier	#9					31			
Swede Hollow	Wheeler	#8					32(302')			
Swede Hollow	Whitebreast	#7					35			
Floris	Carruthers	#6					39(343') 40			
Floris	unnamed	#5					41(358')			
Floris	Laddsdale	#4				?6(88')	46 52(407') 57	2	6 8 13 16	5
Kalo	Cliffland	#3					61(460') 62(461') 66			7(76')
Kalo	Blackoak	#2	5	2		10(146')	71 73	5(101')		8
Kilbourn	unnamed	#1	11	5				7		11

			Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
Formation	Member	Biostratigraphic coal zone	CP40A	CP41	CP42	CP43	CP44	CP45	CP46	CP47
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic									
Morgan School	Summit									
Swede Hollow	Mulky	#10		2						
	Bevier	#9		5						
	Wheeler	#8		8			3			
	Whitebreast	#7		18			7			5
Floris	Carruthers	#6		24 27(172')	2		14			?9
	unnamed	#5		32	10		17(153') 20			15
	Laddsdale	#4	2 5 7	38 41 44	15(77') 16(86') 19	6 8	27			21(168') 24
Kalo	Cliffland	#3	11(upper)	48 51	21(125') 23	13 16 18	30 33	2 4	4(138')	32 35
	Blackoak	#2	11(lower)	58 60	26 32	25 28	37 38(288') 40	6(104')	7	38 39 ?41(304')
Kilbourn	unnamed	#1	14	67	36	33	44		13	

			Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
Formation	Member	Biostratigraphic coal zone	CP48	CP49	CP50	CP51	CP52	CP53	CP54	CP55
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic									
Morgan School	Summit									
Swede Hollow	Mulky	#10						4(63')		
	Bevier	#9								
	Wheeler	#8						8		
	Whitebreast	#7						13		
Floris	Carruthers	#6						22		
	unnamed	#5					?3			
	Laddsdale	#4							?9 ?11	1(210') 6
Kalo	Cliffland	#3		7		?2(307')				
	Blackoak	#2		9			?11			
Kilbourn	unnamed	#1		10(368')					?25	

			Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
Formation	Member	Biostratigraphic coal zone	CP56	CP57	CP58	CP59	CP60	CP61	CP62	CP63
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic									
Morgan School	Summit									
Swede Hollow	Mulky	#10								
	Bevier	#9								
	Wheeler	#8								
	Whitebreast	#7	2							
Floris	Carruthers	#6	6							
	unnamed	#5	8(167') 10(178')							
	Laddsdale	#4	14 16							
Kalo	Cliffland	#3			8					1
	Blackoak	#2			11 13 15					4
Kilbourn	unnamed	#1			18					?5(162')

Formation	Member	Biostratigraphic coal zone	Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
			CP64	CP65	CP66	CP67	CP68	CP69	CP70	CP71
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic	"Upper"								
Morgan School	Summit	"Upper"								
Swede Hollow	Mulky	#10								
Swede Hollow	Bevier	#9								
Swede Hollow	Wheeler	#8								
Swede Hollow	Whitebreast	#7								
Floris	Carruthers	#6								
Floris	unnamed	#5		3	1(131')					
Floris	Laddsdale	#4		8 11 14	5 9					
Kalo	Cliffland	#3		18	12 13(228')			7		5
Kalo	Blackoak	#2		20	16			10		?7 11
Kilbourn	unnamed	#1			?19(265')					

Formation	Member	Biostratigraphic coal zone	Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth							
			CP72	CP73	CP74	CP75	CP76	CP77	CP78	CP79
Pleasanton	"Ovid"	"Upper"								
Labette	Mystic	"Upper"							5	
Morgan School	Summit	"Upper"								
Swede Hollow	Mulky	#10						3(66')	13(228')	
Swede Hollow	Bevier	#9		2			10		19	
Swede Hollow	Wheeler	#8		4			12	14	21	6
Swede Hollow	Whitebreast	#7		10 13(154')		4	16	18	31	8
Floris	Carruthers	#6		17			22	21	34	18
Floris	unnamed	#5		?23		8		25(218')	38	21
Floris	Laddsdale	#4		26 28 31 33		12		30	43 46	?26 27(298') 29 31 33 35
Kalo	Cliffland	#3	4	36 39				35	51 53	40
Kalo	Blackoak	#2	8	41				38	57 59	44
Kilbourn	unnamed	#1							65	

			Iowa Geological Survey Coal Division core holes' lithologic unit number and/or depth				
Formation	Member	Biostratigraphic coal zone	CP80	CP81	CP82	CP83	CP84
Pleasanton	"Ovid"	"Upper"					
Labette	Mystic						
Morgan School	Summit						
Swede Hollow	Mulky	#10					
	Bevier	#9					
	Wheeler	#8	3				
	Whitebreast	#7	11(167')				3
Floris	Carruthers	#6	15				10 17 18(141')
	unnamed	#5	?20	5			?27(166')
	Laddsdale	#4	25(251') 26(257')	8(162') 11		?3(113')	31 ?36
Kalo	Cliffland	#3				7	
	Blackoak	#2	?28			11	
Kilbourn	unnamed	#1	35 38 40(412')			17	