# DEPOSITIONAL ENVIRONMENTS OF THE WOOD SIDING FORMATION AND THE ONAGA SHALE (PENNSYLVANIAN-PERMIAN) IN NORTHEAST KANSAS

by

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B.S., Kansas State University, 1982

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1986

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# INTRODUCTION

## Purpose and Scope of Investigation

Repetition of rock units is characteristic of the Permian and Pennsylvanian Systems in Kansas. The cyclic repetition of limestones and shales associated with the arbitrarily placed Pennsylvanian-Permian boundary typifies the stratigraphy of the Mid-continent (Mudge and Yochelson, 1962). While previous investigations (Mudge and Yochelson, 1962) have considered the general environment of deposition of these rocks, a detailed environmental study of the formations above and below the systemic boundary had not been undertaken.

This study was undertaken to determine depositional environments of the Wood Siding Formation and the Onaga Shale and to identify recognizable cyclic events within the two formations. Recognition and correlation of small-scale cyclic events was then used to reconstruct paleogeographic conditions along the outcrop belt. This interval was also appropriate for study because while "there is no apparent faunal evidence for placing the systemic boundary at the top of the Brownville Limestone Member of the Wood Siding Formation" (Mudge and Yochelson, 1962, p. 127), there had been no attempts to reconstruct the sequence of depositional events across this boundary which might have revealed subtle physical evidence of a hiatus.

# PREVIOUS INVESTIGATIONS

## Early Field Investigations

The Wood Siding Formation was first described by Condra and Reed (1943) and was named after exposures at Wood Siding Station, Nemaha County, Nebraska; it included the strata below the Brownville Limestone and above the French Creek Shale Members. Moore and Mudge (1956) later included the Brownville limestone as a member of the formation. The Wood Siding Formation, as now defined, contains the following members in ascending order; Nebraska City Limestone, Plumb Shale, Grayhorse Limestone, Pony Creek Shale, and Brownville Limestone (Mudge and Burton, 1959).

The Onaga Shale was named after exposures near the town of Onaga in northern Pottawatomie County, Kansas, by Moore and Mudge (1956), and included the strata between the Falls City Limestone and the Wood Siding Formation. As presently defined, the formation contains the following members in ascending order; Towle Shale, Aspinwall Limestone, and Hawxby Shale (Mudge and Burton, 1959). Figure 1 shows the stratigraphic position of the Onaga Shale and the Wood Siding Formation.

## Classification of Sedimentary Cycles

Several workers have attempted to classify sedimentary cycles in the rock record. A summary of classification schemes is shown Table 1.

Moore (1931) was the first investigator to describe the cyclicity of sedimentary rocks in Kansas. He later (1935) differentiated 10 characteristic members (facies) within cyclothems of the Wabaunsee

Group. Jewett (1933) identified ten repetitions of lithologies (cyclothems) in the Wolfcampian Series (now Gearyan Stage, Lower Permian Series) of Kansas. Elias (1937) defined Permian cyclothems on the basis of lithologies and fossil assemblages and included a depth zonation chart as part of his interpretation. Mudge and Yochelson (1962) differentiated the cyclothems of the Wabaunsee, Admire, and Council Grove Groups and recognized three cyclothems within the Wood Siding Formation.

Heckel and Baesemann (1975) and Heckel (1977), in studying Upper Pennsylvanian (Missourian) rocks, identified four facies within a cyclothem sequence; 1) outside (nearshore) shale consisting mostly of nonmarine shale deposits; marine shales, where present, contain sparse fossil assemblages of low diversity; 2) middle (transgressive) limestone composed of thin, dense, dark skeletal calcilutites with relatively abundant and diverse marine fauna; 3) core shale of thin, nearly nonsandy, dark marine shales that are sparsely to abundantly and diversely fossiliferous; and 4) upper (regressive) limestone of thick wavy-bedded, skeletal calcilutite with an abundant and diverse marine biota. According to Heckel (1977), variable climatic conditions and changes in water depth and circulation contributed to lithologic differences in Middle and Late Pennsylvanian deposits.

Recent workers, in studying sedimentary sequences, have attempted to construct a hierarchy of transgressive-regressive (T-R) units (Busch and Rollins, 1984). Vail, et al., (1977), identified three major orders of cycles of sea level changes on a global scale. "Cycles of first, second, and third-order have durations of 200 to 300 million, 10 to

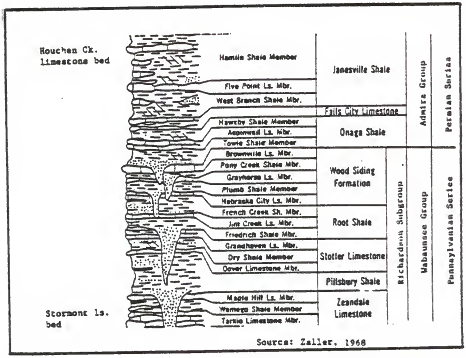



Figure 1. Stratigraphic position of the Onaga Shale and Wood Siding Formation

| MAGNITUDE OF TRANSGRESSIVE-REGRESSIVE UNIT | Names of Carboniferous Transgressive-Regressive Units | | | | | |
|---|---|---|---|---|---|---|
| | Vail et al.,1977 | Chang,1975 and Ramsbottom, 1979 | Moore,1936 | Anderson and Goodwin, 1980 and 1982 (as applied here) | Heckel 1977 and Heckel et al. (1979) | Wanless and Weller,1932 |
| 1st Order: 225 to 300 million years | 1st Order Depositional Sequences | | | | | |
| 2nd Order: 65 million years | Penn.-Permian 2nd Order Depositional Sequence | Penn.-Permian Synthem | | | | |
| 3rd Order: 8 to 10 million years | 3rd Order Depositional Sequence | | | | | |
| 4th Order: 0.8 to 1.5 million years | | Mesothems | | | | |
| 5th Order: 400 to 500 thousand years | | Cyclothems | Megacyclothems | Cyclothemic PAC Sequences | Cyclothems | Cyclothems |
| 6th Order: 100 to 225 thousand years | | | Cyclothems (ls.-shale couplets) | Punctuated Aggradational Cycles (PACs) | Minor T-R Sequences | |

(Modified after Busch and Rollins, 1984)

Table 1. Hierarchal classifications of Carboniferous transgressive-regressive units. (Source: Busch and Brezinski, 1984)

80 million, and 1 to 10 million years respectively" (Vail, et al., 1977, p. 83). Within the Phanerozoic, Vail, et al.,(1977), identified two first-order cycles, at least 14 second-order cycles, and 80 third-order cycles. All Mississippian strata comprise one second-order T-R unit while all Pennsylvanian and Lower Permian strata comprise part of another second-order T-R unit (Busch and Rollins, (1984).
Busch and Rollins (1984) noted that the largest T-R units which can be recognized within Mississippian or Pennsylvanian to Lower Permian strata are third-order T-R units. In the northern Appalachian Basin these third order T-R units have periodicities of 8 to 10 million years (Busch and Rollins, 1984).

In addition to Vail's three major scales of T-R units, Busch and Rollins (1984) have identified three scales of minor T-R units. Fourth-order transgressive-regressive units such as those in the Late Pennsylvanian of the northern Appalachian Basin have periodicities of 0.8 to 1.5 million years (Busch and Rollins, 1984). Ramsbottom's (1979) mesothems of the Carboniferous of Europe are also fourth-order T-R units (Busch and Rollins, 1984). Fifth-order T-R units of 400,000 to 500,000 years duration are the same order of magnitude as Moore's (1936) megacyclothems and Heckel's (1977) Kansas cyclothems (Busch and Rollins, 1984). Sixth-order T-R units of 80,000 to 225,000 years duration have been identified by Goodwin and Anderson (1985) in the Helderberg Group of New York and have been referred to as punctuated aggradational cycles (PAC's).

The PAC hypothesis of Goodwin and Anderson (1985) interprets the stratigraphic record as a shallowing-upward sequence of cycles separated by surfaces marked by abrupt changes to deeper water facies. In the Mid-Continent the boundaries between these smaller sixth-order cycles are marked by transgressive surfaces such as thin, laterally persistent fossiliferous beds or by climate change surfaces such as coal beds or paleosols. Identification of these smaller sixth-order T-R units is extremely useful in making palaeogeographic reconstructions on a basin-wide scale as has been demonstrated by Busch (1984).

## AREA AND METHODS OF INVESTIGATION

### Field Procedures

Reconnaissance.--Rocks encompassing the PennsylvanianPermian contact crop out in an approximately northeast (Brown County) - southwest (Cowley/Chautauqua Counties) belt across Kansas. Detailed field studies were limited to exposures in the northeastern part of this belt (figures 2-3).

Preliminary work for this investigation began in the summer of 1983. Using topographic and geologic maps from the United States and Kansas Geological Surveys possible outcrops of the Wood Siding Formation and Onaga Shale outcrops were identified. Four criteria governed selection of an outcrop for description and interpretation. These were: 1) completeness of the formation 2) geographic spacing 3) accessibility and 4) lateral extent of each exposure. The localities were then checked and the stratigraphic position of each outcrop verified using the sequence of observed lithologies.

Eight sections were identified by reconnaissance work and carefully measured and described in detail. In addition, Section 4 near Flush, Kansas, an outcrop previously described by Mudge and Yochelson (1962), was remeasured in detail with appropriate additions and revisions. Information from the nine measured sections was supplemented by seventeen measured sections from Mudge and Yochelson's (1962) Kansas investigations (Sections 25, 28, 33, 34, 52, 60, 65, 71, 104, 113, 114, 187, 213, 323, 328, 338, Mudge and Yochelson, 1962) and by a section (Stop 18) in Richardson County, Nebraska, from the Ninth International Congress of Carboniferous Stratigraphy and Geology, Field Trip No. 10 Guidebook (Heckel, et al., 1979; Section A, figure 2). Previous investigations were used to characterize members of the two formations which were absent at the localities studied (e.g. the Nebraska City Limestone Member), and to obtain average thicknesses of units across the entire outcrop belt.

Stratigraphic Description.--Each section at the nine localities was carefully measured and described using the United States Geological Survey checklist for field description (Appendix II). Thicknesses were measured to the nearest centimeter and later converted to English units. Color of both fresh and weathered samples (according to Kinney, 1980), bedding, contacts, fossils, and sedimentary structures were recorded. Palaeontologic information was recorded using Ager's (1963) checklist as a guide. On the basis of lithologic and palaeontologic descriptions each unit's relative stratigraphic position was determined.

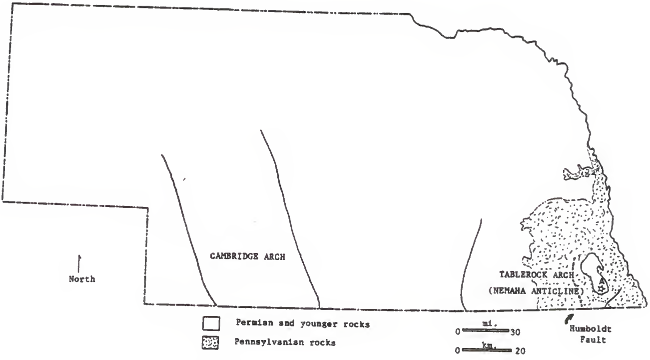



Figure 2. Major structural features of southern Nebraska, Permian-Pennsylvanian outcrop belt, and location of Section A

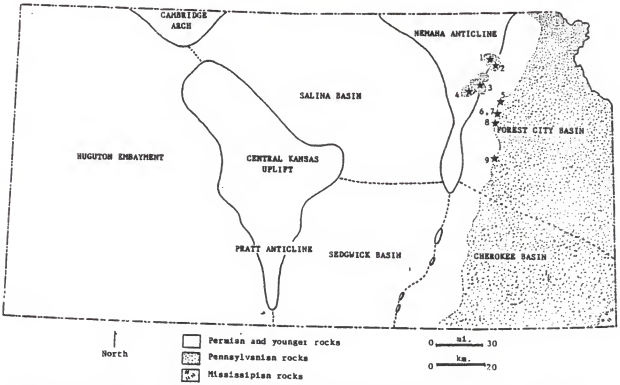



Figure 3. Major structural features of Kansas, Permian-Pennsylvanian outcrop belt, and location of measured sections.

Sampling.--Fresh (unweathered) channel samples of shale and sandstone (200 to 500 gms. each) were collected at each lithology change within each measured section. Weathered portions of limestone outcrops were removed and fresh, oriented samples collected.

## Laboratory Procedures

Laboratory examination and description (using a dissecting microscope) were used to augment field descriptions.

Washed residues of shale and sandstone samples were prepared using a dispersing agent (Quaternary 0) and the residues examined microscopically. Most samples (200-500 gms each) became completely disaggregated after boiling for several (1-5) hours in the dispersing agent. (More calcareous samples did not completely disaggregate.) To facilitate microscopic examination the disaggregated residues were sieved through a U.S. standard 230 mesh (4.0 phi) sieve.

This procedure was useful in identifying microfossils and fossil debris not easily recognized in the field. Fossils recognized in each washed residue are listed in Appendix V.

Five thin sections (perpendicular to bedding) of the Brownville Limestone Member were prepared and studied petrographically for their fossil and mineral content. Slides were made from exposures of the Brownville at Sections 1, 3, 6, and 9. The thin section from locality A was prepared from a sample taken from an outcrop (previously measured by Heckel, et al.,1979) in southern Richardson County, Nebraska (Locality A, figure 3) . All five thin sections were point counted using Chaye's (1949) method. Five hundred points were counted in an area 2.5 cm. by 2.0 cm. (.98" x .79") on each slide (Appendix III).

To provide continuity in observing textural relationships, the remaining exposures of the Brownville Limestone Member which were not studied using thin sections (Sections 2,4,7, and 8) were examined using acetate peels. Samples of limestone were slabbed and the cut surface polished. After etching with .01 N hydrochloric acid, acetone and an acetate film were applied to the polished surface. After drying, a small portion of the peel (2.5 cm. x 2.0 cm.) was then mounted on a microscope slide and examined petrographically in the same manner as the thin sections. The data are summarized in Appendix IV.

## STRUCTURAL SETTING

In northeastern Kansas the Nemaha Anticline trends approximately northeast-southwest. The Wood Siding Formation-Onaga Shale outcrop belt trends nearly parallel to this feature (figure 3). Sections 1,2, and 3 are on the eastern flank of the Nemaha while section 4 is near the axis of the Nemaha. Sections 5,6,7,8, and 9 are in the Forest City Basin. Steeples noted that seismic evidence suggests that "either uplift along the Nemaha Anticline occurred contemporaneously with Pennsylvanian deposition or uplift and peneplanation occurred during a period of exposure between the deposition of Mississippian sediments and Pennsylvanian sediments" (Steeples, 1982, p. 55). In either case, sedimentation contemporaneous with the tectonically active Nemaha probably would have caused the deposition of more terrestrial sediments in the northern part of this area. To the south and east, thicker, more marine deposits would have developed in the Forest City and Cherokee Basins.

Figure 4 is a north-south stratigraphic cross-section of the study area illustrating the presence of coal (Section 1) and channel facies (Section 5) in the northern part of the state. Figure 5 is a longer north-south stratigraphic cross-section from Section 4 in Pottawatomie County to Section 324 (described by Mudge and Yochelson, 1962) in Cowley County. This cross-section clearly depicts the dramatic increase in thickness of the Wood Siding Formation and the Onaga Shale from north to south along the outcrop belt. Note that the Pony Creek and Towle shales at Section 324 in Cowley County are nearly twice as thick as exposures at Section 4 in Pottawatomie County.

## STRATIGRAPHY

### General

Results of the field work are summarized in the measured sections found in Appendix I.

Washed residues were obtained from all nine outcrops and their contents examined and described. Although no quantitative data were obtained, fossil identifications were used and are tabulated in Appendix V.

### Description of Stratigraphic Units

Nebraska City Limestone Member.--The Nebraska City Limestone Member was first named by Condra (1927, p. 116) for exposures in a clay pit southeast of Nebraska City, Nebraska. Although the unit

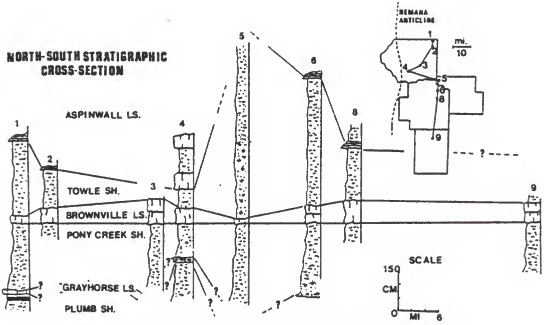



Figure 4. North-south stratigraphic cross-section from northern Pottawatomie County to north-central Lyon County.

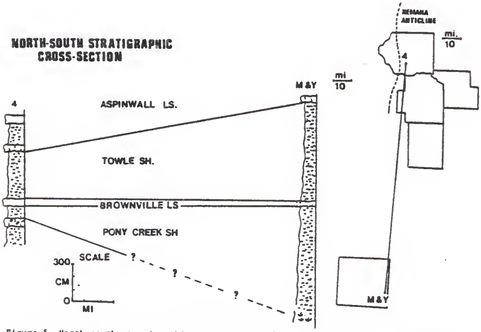



Figure 5. North-south stratigraphic cross-section from central Pottawatomie County to eastern Cowley County.

was not observed in outcrops chosen for this investigation, sections (28, 33, 65, 71, 104, 113, 114, 323, 324, and 328) previously described by Mudge and Yochelson (1962) were used to characterize the Nebraska City. Generally, the Nebraska City limestone may be described as a massive, hard, micritic limestone, with an abundant and relatively diverse brachiopod assemblage. Derbyia, Neochonetes, and Neospirifer are the common genera associated with this unit. Bryozoans and crinoids are also common (Mudge and Yochelson, 1962).

Thickness of the Nebraska City limestone is significantly different at several exposures. The unit averages 1 foot (30.5 cm) in thickness but may reach a maximum thickness of 4.4 feet (134.1 cm) (Mudge and Yochelson, 1962).

Plumb Shale Member.--The Plumb Shale Member was named by Mudge and Burton (1959, p 34-35) for exposures in a roadcut in Plumb Township, Wabaunsee County, Kansas.

During this investigation the Plumb shale was observed at two outcrops. In the extreme northern portion of the study area, at Section 1 near Havensville, Kansas, the Plumb shale is a medium gray, micaceous (muscovite) mudstone containing a thin, finely laminated coal seam (see Section 1, Appendix I). Southward, at an exposure near Flush, Kansas, the unit is a medium, dark gray mudstone with abundant coalified and pyritized plant fossils (see Section 4, Appendix I). It is finely laminated and contains pyrite and marcasite nodules as well as large limestone and sandstone clasts. Marine fossils were not observed at either locality. In contrast, undifferentiated intervals of the Plumb and Pony Creek shales in the eastern and southern parts of the state contain fossiliferous limestone beds (Sections 71 and 323, Mudge and Yochelson, 1962).

Mudge and Yochelson (1962) noted that the average thickness of the Plumb shale is about 10 feet (304.8 cm) At Section 1, near Havensville, Kansas, the exposed thickness of the Plumb is 53.0 cm (1.74 ft) whereas near Flush, Kansas, the unit has an exposed thickness of 238 cm. (7.7 ft). Extremely thick exposures of the Plumb Shale Member in southern Kansas (Sections 65 and 71, Mudge and Yochelson, 1962) account for the difference between my thickness data and the average thickness reported by Mudge and Yochelson (1962).

Grayhorse Limestone Member.--Bowen (1918) named the Grayhorse limestone for outcrops on the crest of the Little Grayhorse Anticline in Osage County, Oklahoma. Three exposures of Grayhorse limestone were identified, measured, and described for this report. These were at Section 1, north of Havensville, Kansas, Section 4 near Flush, Kansas, and Section 6, south of Maple Hill, Kansas.

North of Havensville, Kansas, the Grayhorse is a brownish- gray conglomerate with platy "clay ball" inclusions up to 5 mm in diameter. It has an abundant brachiopod assemblage including Derbyia, Meekella, and chonetids. Bivalve steinkerns are also preserved. Thickness of the unit at this locality is 30 cm (1.8 ft) (see Section 1, Appendix I).

The most complete exposure of Grayhorse limestone in the study area is near Flush, Kansas (see Section 4, Appendix I). At this locality the Grayhorse forms a persistent blocky ledge. Its lithology is a medium dark gray calcirudite with abundant pyrite inclusions on the upper bedding surface. The upper 25 cm is conspicuously conglomeritic with subangular limestone and "clay ball" clasts up to 6 cm in diameter. Myalinid bivalves are the most common fossils, but chonetid brachiopods, bryozoans, and crinoid columnals are also present. Thickness of the bed is 60 cm (1.97 ft). South of Maple Hill, Kansas, the Grayhorse Limestone Member is a hard grayish-brown conglomeritic limestone containing chonetid brachiopods, bivalve fragments, and crinoid colulmnals. Clasts (mostly subangular) in the unit measure up to 20 mm in diameter. The base of the Grayhorse Limestone Member is not exposed at this locality (see Section 6, Appendix I).

Pony Creek Shale Member.--The Pony Creek shale, named by Condra (1927), is present at all nine sections measured and described in this investigation. In general, the Pony Creek consists of a lower reddish-brown mudstone which grades vertically into an olive-green, sparsely fossiliferous mudstone. At five localities thin limestone and sandstone beds (1-5 cm) are present within this predominantly mudstone sequence (see Sections 1, 3, 5, 6, 7, Appendix I). Many of these thin, laterally persistent units are fossiliferous and, at certain intervals, mark the boundaries between sixth-order cyclic events. At Sections 6 and 7, West and Palmer (1983) documented one of these limestone beds as a subaerially formed "hardground" which probably formed in a marginal marine environment. The Pony Creek Shale Member usually does not show bedding or other sedimentary structures.

A channel sand, containing glauconite, muscovite, coalified plants, as well as sparse marine fossils, is developed within the Pony Creek near Flush, Kansas (see Section 4, Appendix 1). This cut-and-fill channel, which probably formed in a marginal marine environment, contains well sorted, subangular to subround quartz grains. Parts of the channel exhibit laminar cross-bedding. Field relationships suggest that more than one cut-and-fill event may be represented by this sandstone. Parts of the sandstone contain well-cemented ($CaCO3$) intervals.

At Section 9, near Admire Junction, Kansas, the Pony Creek Shale Member is obviously a marine deposit as evidenced by Orbiculoidea, pectenacean bivalves, ostracodes, conodonts, and fish scales.

Thickness of the Pony Creek in the study area ranges from 125 cm (4.14 ft) at Flush (Section 4) to 270 cm (8.9 ft) at Maple Hill (Section 6,7). The average thickness of the Pony Creek in Kansas is 268 cm (8.8 ft) (Mudge and Yochelson, 1962).

Brownville Limestone Member.--The Brownville limestone was first named by Condra and Bengston (1915, p. 17) from exposures in Nemaha County, Nebraska. The unit is relatively consistent in thickness and lithology. In the field the Brownville limestone is easily recognized as a blocky to massive, gray, micritic limestone. It usually contains limonite inclusions and weathers reddish-brown. Marginiferid brachiopods are the most common and easily recognized fossils within the unit but crinoids, bryozoans, echinoderms, and horn corals are also common.

Across the study area, the Brownville Limestone Member ranges in thickness from 24 cm (9.4 in) at an exposure east of St. Marys, Kansas, (see Section 5, Appendix I) to 94 cm (3.1 ft) thick at an exposure south of Westmoreland, Kansa, (see Section 3, Appendix I). The average thickness of the Brownville limestone is 2.2 ft (67 cm) (Mudge and Yochelson, 1962).

Using Folk's (1962) carbonate classification, a rock name was assigned to each of five thin sections and five acetate peels of the Brownville limestone. Percentages of orthochemical, allochemical, and terrigenous constituents were determined and are summarized in Table 2. Orthochemical constituents are divided into micrite (1-4 microns), microspar, (4-10 microns), and spar (greater than 10 microns) (Folk, 1962).

Using Folk's (1962) method, all samples of the Brownville Limestone Member, except sample S1-4 from Flush, Kansas, are described as recrystallized fossiliferous biomicrites and are classified as type II limestones. Sample S1-4, because it contains less than ten percent allochems, is a type III limestone, fossiliferous micrite. Although all of the thin sections show some evidence of the oxidation of iron minerals within the rock, distinct differences exist.
Especially evident is the paucity of fossils and abundance of terrigenous sediments in the northern part of the study area.

At locality A in southern Nebraska, the Brownville Limestone Member is a fine calcarenite: immature, silty, partly recrystallized, brachiopod, echinoderm, bivalve biomicrite. Silt size quartz and plagioclase grains comprise 25.8 percent and traces of the rock, respectively. Fossil abundance (11.4 percent of the rock) and diversity are relatively low (S1-A, Appendix IV). Plate 1 (figure 1) is a photomicrograph of the Brownville from locality A illustrating the low diversity of taxa and abundance of terrigenous sediments.

Southward, at Section 1 north of Havensville, Kansas, the Brownville limestone is a coarse calcarenite: immature, slightly silty,

TABLE 2

Percentages of Orthochemical, Allochemical, and Terrigenous Constituents in the Brownville Limestone Member*

| Sample | Orthochemical Constituents | | | Allochemical Constituents | Terrigenous Constituents |
|---|---|---|---|---|---|
| | Micrite | Microspar | Spar | | |
| S1-A | 48.8 | 6.6 | 1.6 | 11.4 | 29.0 |
| S1-1 | 44.0 | 28.6 | 2.4 | 20.4 | 1.4 |
| S1-2 | 69.8 | 4.0 | --- | 24.6 | .8 |
| S1-3 | 47.2 | 30.0 | 1.4 | 18.4 | 2.0 |
| S1-4 | 86.4 | --- | --- | 4.6 | 9.0 |
| S1-5 | 61.6 | 8.0 | 3.6 | 24.8 | 2.0 |
| S1-6 | 67.6 | 7.6 | 1.0 | 20.0 | 2.2 |
| S1-7 | 67.2 | --- | --- | 32.4 | .4 |
| S1-8 | 82.8 | .8 | 1.6 | 13.8 | 1.0 |
| S1-9 | 1.8 | 64.0 | 12.4 | 19.6 | 1.6 |
| Average | 46.5 | 8.6 | 2.4 | 19.0 | 4.9 |

*Data obtained petrographically from point counts of thin sections and acetate peels.

slightly dolomitic, partly recrystallized, brachiopod, echinoderm, trilobite, bryozoan, bivalve biomicrite. Skeletal grains are relatively abundant (20.4 percent of the rock) and reflect an increase in diversity of taxa from those observed at locality A. The dolomite is probably secondary. In addition, silt size quartz grains comprise 1.4 percent of the rock. (Sl-1, Appendix III).

At Section 2, south of Havensville, Kansas, the Brownville is a coarse calcarenite: immature, partly recrystallized, brachiopod, bryozoan, bivalve, echinoderm, biomicrite. Skeletal grains comprise 24.6 percent of the rock and terrigenous components make up less than one percent (0.8 percent) of the rock. (Sl-2, Appendix IV).

At Section 3, the Brownville Limestone Member is a coarse calcarenite: immature, slightly silty, slightly dolomitic, partly recrystallized, brachiopod, bivalve, gastropod, foraminiferid, echinoderm biomicrite. Skeletal grains represent 18.4 percent of the rock and fossil diversity is relatively high. The dolomite, because it replaces skeletal grains, is probably secondary in origin. Terrigenous grains of quartz and opaques comprise 2.0 percent of the rock (Sl-3, Appendix III).

At Section 4, the Brownville limestone is a fine calcarenite: immature, brachiopod, bivalve, bryozoan fossiliferous micrite. Only 4.6 percent of the rock consists of skeletal grains and the diversity is low. Quartz silt makes up 9.0 percent of the rock. (Sl-4, Appendix IV)

Southward, at Section 5 near St. Marys, Kansas, the Brownville is a coarse calcarenite: immature, partly recrystallized, brachiopod, bivalve, bryozoan, echinoderm biomicrite). Skeletal grains are relatively abundant (24.8 percent of the rock) and diverse. Less than two percent (1.6 percent) of the rock consists of quartz silt. (S1-5, Appendix IV)

The Brownville Limestone Member at Section 6, south of Maple Hill, Kansas, is a coarse calcarenite: immature, partly recrystallized, brachiopod, bivalve, encrusting alga, echinoderm biomicrite. Skeletal grains represent 20.0 percent of the rock; 2.2 percent of the rock consists of terrigenous components (S1-6, Appendix III). Plate 1 (figure 2) is a photomicrograph of the Brownville from Section 6 and illustrates the diversity of taxa at this locality.

At Section 7, also south of Maple Hill, Kansas, the Brownville is a coarse calcarenite: immature, brachiopod, bivalve, bryozoan, echinoderm, biomicrite. Skeletal grains are abundant (32.4 percent of the rock) and diverse. Only 0.4 percent of the rock consists of quartz silt. (S1-7, Appendix IV)

At Section 8, along Eskridge Road, the Brownville limestone is a coarse calcarenite: immature, brachiopod, bivalve, bryozoan, echinoderm biomicrite. It consists of 13.8 percent skeletal grains. The rock contains one percent terrigenous components. (S1-8, Appendix IV)

Lastly, at Section 9, near Admire Junction, Kansas, the Brownville Limestone Member is a medium calcarenite: immature recrystallized, brachiopod, bivalve, bryozoan, echinoderm, trilobite, gastropod, foraminiferid biomicrite. Sixty-four percent of the rock is microspar indicating that recrystallization from micrite to microspar is nearly complete. Many skeletal grains are completely recrystallized and have lost their original texture thus making identification difficult. The

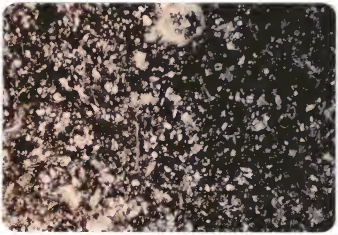


Figure 1. Photomicrograph of Brownville Limestone Member (Sample S1-A, X10, crossed nicols). Note low diversity of taxa and abundance of quartz grains.

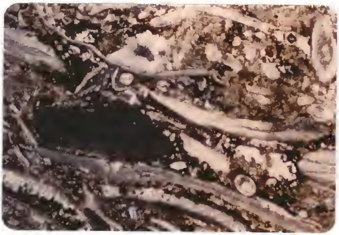


Figure 2. Photomicrograph of Brownville Limestone Member (Sample S1-6, X10, crossed nicols). Note increase in diversity of taxa and decrease in quartz grains.

rock contains 19.6 percent skeletal grains and 1.6 percent terrigenous components. (S1-9, Appendix III)

Figure 6 shows the relative diversity of taxa in the Brownville Limestone Member. Contours are based on the number of major taxa observed at each locality and reflect an increase in fossil diversity eastward (see allochems section in Appendix III).

Towle Shale Member.--The Towle Shale Member, named after the Towle farm in Richardson County, Nebraska, was first described by Moore (1932). Thickness of the unit as well as its fossil content are significantly different at the different exposures. In most parts of the study area the Towle is a sparsely fossiliferous, silty (quartz and muscovite), gray mudstone. Bryozoan fragments and productacean and chonetid brachiopod fragments are the most common fossils and are usually found only in the lower few feet of the interval.

Several differences in the lithology of the Towle Shale Member occur throughout the study area. North of Havensville, Kansas, the unit grades vertically into a reddish-brown mudstone that contains abundant caliche nodules (see Section 1, Appendix I). Here, the upper part of the Towle probably represents a paleosol. East of St. Marys, Kansas, the Towle shale is a channel sand which rests disconformably on the underlying Brownville Limestone Member (see Section 5, Appendix 1). This sand contains subangular to subround quartz grains, is well sorted, and shows evidence of bioturbation. Near Maple Hill, Kansas, the unit is a thinly laminated mudstone, containing interbedded limestone. Some of the limestone beds contain gastropods and bivalve fragments (see Section 6, 7, Appendix I).

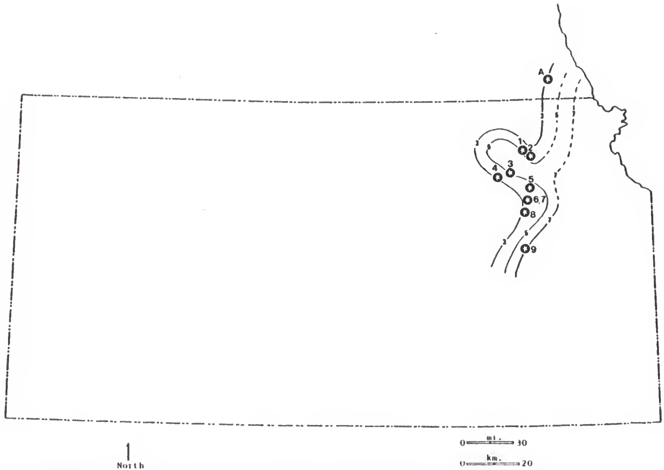



Figure 6. Relative diversity of taxa in the Brownville Limestone Member. Contours based on number of major taxa (refer to allochems section, Appendix III) present at each locality.

The Towle, in the study area, ranges in thickness from 148 cm (4.9 ft) at South Havensville (Section 2) to 657 cm (21.6 ft) east of St. Marys, Kansas (Section 5).

Aspinwall Limestone Member.--Condra and Bengston (1915, p. 17) named the Aspinwall limestone for exposures near Aspinwall, Nebraska. Five exposures of Aspinwall were identified in the study area and were measured and described for this investigation (see Sections 1, 2, 4, 6, 8, Appendix I).

At most localities, the Aspinwall Limestone Member is a platy (algal-laminated), yellowish-gray, micritic limestone (see Sections 1, 2, 6, Appendix I). It contains numerous clay ball inclusions up to 1 cm in diameter and a few fragments of brachiopods, bivalves, and echinoderms. At these localities the Aspinwall ranges in thickness from 29 cm (.95 ft) to 35.6 cm (1.2 ft).

At Section 4, near Flush, Kansas, the Aspinwall consists of two blocky, micritic limestone beds separated by a 1.3 m thick olive-gray mudstone parting. The limestone beds contain an abundant fossil assemblage of productacean brachiopods, crinoids, bivalves (myalinids and pectens), and gastropods. Most of the fossils are fragmented and disarticulated. The mudstone separating the two limestone beds contains only productacean brachiopod fragments and crinoid columnals. At this locality the Aspinwall is 174 cm (5.7 ft.) thick.

Hawxby Shale Member.--The Hawxby Shale Member, named by Moore and Condra (1932) after exposures in Nemaha County, Nebraska, was observed at only one section in the study area (see Section 8, Appendix I). At this locality, south of Interstate 70, the unit is a brown, sparsely fossiliferous, calcareous mudstone. Washed residues of this unit contain brachiopod and gastropod fragments, which are the only fossils observed. Sedimentary structures were not observed in the 139 cm (4.3 ft) of the Hawxby exposed at Section 8.

## DEPOSITIONAL AND ENVIRONMENTAL HISTORY OF THE WOOD SIDING FORMATION AND THE ONAGA SHALE

Across the Pennsylvanian-Permian outcrop belt the Wood Siding Formation and the Onaga Shale represent a variety of depositional environments that indicate the effects of several Late Paleozoic geologic events. The Wood Siding Formation and the Onaga Shale were deposited in Late Virgilian-Early Gearyan time in a shallow epicontinental sea which spread over a shelf-like basin in southern Nebraska, Kansas, and northern Oklahoma. The cyclicity of these sedimentary packages reflects eustatic sea level changes brought about by episodes of Mississippian to Permian glaciation in Gondwanaland (Crowell, 1978).

Cyclic sedimentary packages of the fifth-order (cyclothems) of about 400,000 to 500,000 years duration are relatively easy to distinguish within the Wood Siding Formation and the Onaga Shale (Bisby, 1985). Results of this study indicate that the boundaries between fifth-order cyclic events usually correspond to, within a few centimeters, the bases of members of any given formation, and thus, reflect major lithologic changes (eg. limestone to shale). Limestone members represent maximum marine events while shale members can be categorized as "outside shales" and represent relatively nonmarine events (Heckel and Baesemann, 1975 and Heckel, 1977).

Although portions of the Wood Siding Formation can be classified using the terminology of Heckel and Baesemann (1975), use of their model for interpretations of the depositional environments of these rocks is inappropriate for several reasons. First, many rocks contained within the two formations represent only incomplete development of the Heckel and Basemann (1977) cyclothem. Core shales were not observed at any of the measured sections and thus, distinction between upper and middle limestone members was impossible. Only detailed petrographic study of the limestones at closely spaced intervals within the rock can provide this type of information and was beyond the scope of this study. Finally, small variations, particularly within shale members, are not accounted for by Heckel and Baesemann's fifth-order level of interpretation. For example, thin limestone beds within predominantly mudstone sequences are classified as parts of an outside shale and are interpreted by Heckel (1979) as mere localized geologic events.

Moore's (1936) Wabaunsee cyclothems provide the closest analogy for a fifth-order level of interpretation of cyclicity within the Wood Siding Formation and Onaga Shale. Cyclothems of the Wabaunsee group, as noted by Moore (1936) are characterized by a core of carbonate and marine mudstones which rests conformably between sequences of nonmarine shales and sandstones. It should, however, be noted that many of the members of Moore's (1936) Wabaunsee cyclothems are not recognizeable (ie. molluscan limestones and shales) within the Wood Siding Formation and the Onaga Shale.

Cyclic events of the sixth-order are much more difficult to discern. Nevertheless, within the Wood Siding Formation and the Onaga

Shale there are several indications of smaller sixth-order events of about 100,000-225,000 year periodicities (Bisby, 1985). The Pony Creek and Towle shales both contain intervals that probably represent small-scale oscillations within major cyclothem sequences. Using the Brownville Limestone Member as a datum, cycles above and below the datum have been differentiated by the presence of transgressive or climate change surfaces, or both. For example, in Section 1, five different sixth-order cycles have been identified below the Brownville Limestone Member and are assigned negative numerical values. In addition, two cycles above the Brownville Limestone Member have been differentiated and are assigned positive numerical values. The Brownville limestone itself also constitutes a sixth-order cycle and is labeled cycle (0). Using this method minus 5 (-5) represents the oldest cycle at Section 1 while positive 2 (2) represents the youngest cycle at this locality. Note that the boundaries between these cycles do not necessarily correspond exactly to the boundaries between stratigraphic members. The boundary between the (-4) cycle and (-5) cycle at Section 1 is a climate change surface, above which is a coal seam. The boundaries between the remaining cycles at Section 1 are transgressive surfaces and usually reflect an abrupt increase in fossil abundance and diversity or a change from terrigenous to carbonate facies, or both. Figure 7 is a graphic illustration of Section 1 showing the boundaries between sixth-order cycles. Some sixth-order boundaries are also boundaries for fifth-order units as are the bases of the Aspinwall, Brownville, and Grayhorse limestones at Section 1 (see figure 7.).

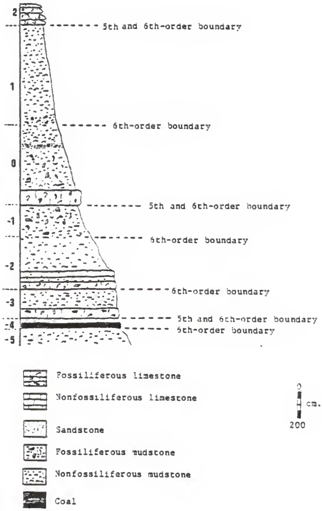


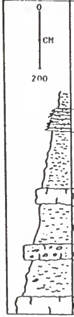

Figure 7. North Havensville Locality (Section 1) showing placement of fifth and sixth-order T-R units.

In addition to eustatic changes in sea level, late Paleozoic structural features contributed significantly to variations within the Wood Siding Formation and the Onaga Shale. Results of this study indicate that the Nemaha Anticline, a tectonically active structure in the late Paleozoic (Steeples, 1982), caused the deposition of terrestrial sediments in the northern portion of the study area. Supporting field evidence shows that rocks in the northern part of the outcrop belt contain a greater percentage of terrigenous particles (eg. quartz and muscovite) than their southern counterparts. The development of channel facies (Section 4) indicates downcutting followed by shallow marine deposition as evidenced by glauconite and marine fossils. Swamp deposits (coal seam at section 1) suggest marshy and swampy conditions in the northern part of the study area. Further evidence of a euxinic environment includes the presence of pyrite in the Brownville limestone as documented in this study and others (Twiss, 1955). Southward, the Wood Siding Formation and Onaga Shale become thicker in association with the Forest City and Cherokee Basins (figure 5).

Figure 8 is a generalized stratigraphic section of the Wood Siding Formation and the Onaga Shale illustrating probable depositional environments.

## PALAEOGEOGRAPHIC RECONSTRUCTIONS

Palaeogeographic reconstructions of the study area involve the correlation of smaller sixth-order cycles across the outcrop belt. Determination of the most transgressive phase of each cycle allows for correlation of basin-wide (allocyclic) events across the study area.




| GENERALIZED STRATIGRAPHIC SECTION | | | | |
|---|---|---|---|---|
| **MEMBER** | **DESCRIPTION** | **FOSSILS** | **DEPOSITIONAL ENVIRONMENT** | **LITHOLOGY** |
| HAWXBY SHALE | Brown mudstone; calcareous | Very sparesely foss. w/ brach's. | Nonmarine to very shallow marine | |
| ASPINWALL LS | Platy, yellowish gray skeletal calcilutite | Algal laminations; brach's, bivalves | Shallow marine-intertidal | |
| TOWLE SHALE | Olive gray mudstone; silty; often contains sandstone beds | Very sparsely fossiliferous w/ brach's, bivalves, ostracodes | Nonmarine to very shallow marine | |
| BROWNVILLE LS | Massive, gray, skeletal calcilutite | Brach's: many others | Marine-subtidal | |
| PONY CREEK SH | Gray mudstone w/ numerous limestone beds | Fossiliferous in zones; brach's, bivalves, snails | Nonmarine to marine | |
| GRAYHORSE LS | Gray, blocky, conglom. | Abundant bivalves | Shallow marine-intertidal | |
| PLUMB SHALE | Dark gray, blocky mudstone | Coalified and pyritized plants | Nonmarine | |
| NEBR. CITY LS | Massive, gray calcilutite | Abun. brachiopods | Marine-subtidal | |

Figure 8. Generalized stratigraphic section of Wood Siding Formation and Onaga Shale and probable depositional environments. Limestone-shale couplets are fifth-order T-R units. Four such units are contained within this sequence.

Correlation (figure 9) and comparison of facies for identical cycles then gives a relative indication of a locality's distance from shore and hence an approximate location of the palaeoshoreline. Reconstruction of the (-1) cycle reveals that rocks at Sections 4,5, and 6/7 contain abundant carbonate facies and marine fossils and were probably deposited in more marine conditions than were rocks deposited at Sections 1,2, and 3 where terrigenous sediments dominate the cycle (figure 10). The (0) cycle contains abundant carbonates across the study area (the Brownville Limestone Member is traceable across the entire state) and represents a major marine transgressive event (figure 10). Although consistent in its lithology, variations in the number of major taxa at various localities across the Brownville outcrop belt also provide evidence of a northeast-southwest trending shoreline (figure 6). The (1) cycle marks a return to depositional conditions similar to those associated with the (-1) cycle. Terrigenous sediments dominate at Sections 1,2, and 3 while Sections 4,5 and 6/7 contain rocks with marine fossils and carbonate facies. Nevertheless, Sections 5, and 6/7 appear to represent areas of deposition further from shore than during the (-1) cycle because of the increased occurrence of carbonates within the cycle (figure 10).

Because of the factors previously discussed, any transect across the Wood Siding Formation-Onaga Shale outcrop belt will exemplify a mosaic of depositional environments, both temporally and spatially, which represents a variety of geologic conditions. Thus, the occurrence of a climate change surface (coal) at one locality may correlate with a transgressive event (marine limestone) at another locality. Studies of

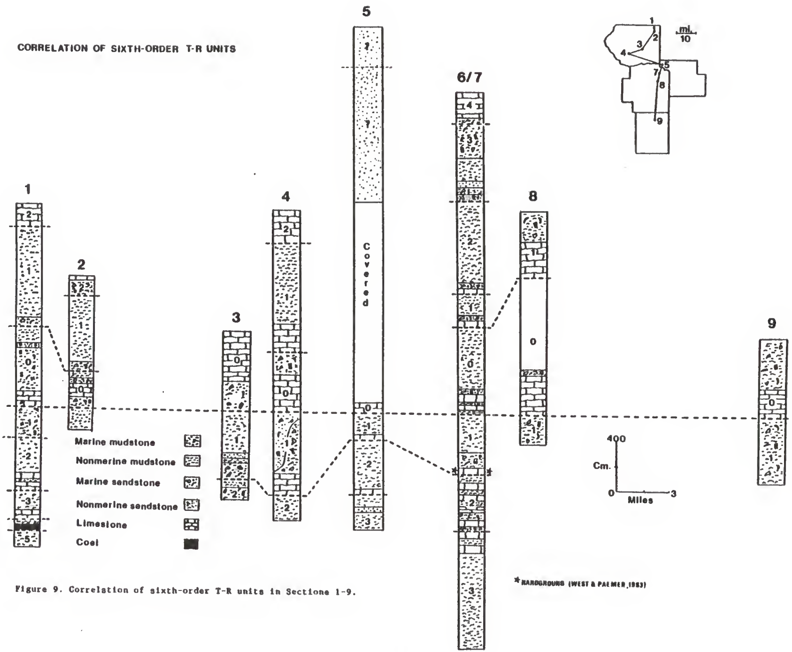



Figure 9. Correlation of sixth-order T-R units in Sections 1-9.

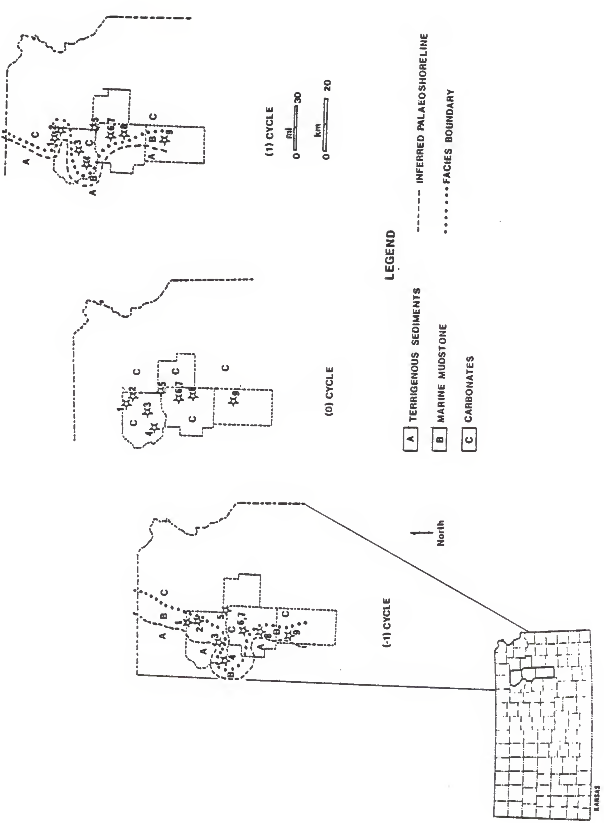



Figure 10. Probable facies deposition and location of palaeoshoreline during (-1), (0), and (1) cycles.

ichnofacies along the Georgia coast by Pemberton and Frey (1985) provide a modern analogue with which such a mosaic of depositional conditions can be compared. The authors note that at many localities along the Georgia coast exhumation of older deposits, such as paleosols, often has placed semiconsolidated substrates in a geographic and facies position normally occupied only by sand beaches. Similarly, the migration of streams has exposed old marsh deposits which are now occupied by estuarine animals. The end result of these processes is a "relict soft-substrate assemblage of diverse origins, overprinted by a firm-substrate suite" (Pemberton and Frey, 1985, pg. 257). Such a situation could easily explain, for example, the lack of lateral continuity of the hardground in the Pony Creek Shale Member documented by West and Palmer (1983).

In summary, paleogeographic reconstructions at three intervals during Wood Siding and Onaga time reveal a northeast-southwest trending shoreline. During pre- and post-Brownville time open marine conditions existed to the east of the Wood Siding Formation-Onaga Shale outcrop belt, while to the west, swampy and terrigenous sediments were deposited. Near Flush, Kansas, an inlet or bay must have existed to allow the accumulation of more marine sediments further to the west than at other outcrops.

During Brownvile time the entire study area was inundated by marine waters. Differences in fossil diversity and abundance in the Brownville indicate open marine conditions to the south and east. Conversely, the northern portion of the Brownville limestone outcrop belt reflects the influence of terrigenous sediments and a corresponding decrease in fossil abundance and diversity (see figure 6). It is quite likely that most suspension-feeding marine organisms (eg. brachiopods, bivalves) would have been unable to survive in an environment which was periodically flooded with terrigenous sediments.

## CONCLUSIONS

At least four major transgressive-regressive phases of sedimentation (cyclothems) occur within the Wood Siding Formation and Onaga Shale. Major marine transgressions, in order of their occurrence, are associated with the Nebraska City, Grayhorse, Brownville, and Aspinwall limestone members. Based on their relative thicknesses these cyclic sedimentary packages probably represent fifth-order events of about 400,000 to 500,000 years duration. Eustatic sea level changes, and to a lesser degree late Paleozoic structural features, controlled late Pennsylvanian-Early Permian sedimentation in Kansas.

More subtle lithologic variations, indicated by laterally persistent, fossiliferous beds or by climate-change surfaces represent smaller cycles in the "normal" sedimentary sequence (sixth-order cyclic events) with periodicities of 100,000-225,000 years or less. At least two possible sixth-order cycles have been differentiated in the Towle Shale Member while three possible sixth-order cycles have been identified in the Pony Creek Shale Member (see measured sections, Appendix I). It must be emphasized that the placement of sixth-order boundaries between lithologies described in this report is tentative; more detailed study is needed. Nevertheless, the persistent occurrence of these beds within the Pony Creek and Towle members suggests that small scale oscillations of sea level occurred during Late Pennsylvanian--Early Permian time with some regularity.

Palaeogeographic reconstructions, based on the correlation of sixth-order cycles, provide strong evidence for a northeast-southwest trending shoreline during Wood Siding-Onaga time. The most marine sedimentary rocks are associated with Forest City and Cherokee Basins and contain a fossil assemblage of marginiferid, chonetoid, and orthotetid brachiopods; crinoid columnals; and fenestrate bryozoans. Channel facies with pyritized and coalified plant fossils are more common in the northern portion of the study area and suggest marshy to swampy depositional conditions.

With regard to the stratigraphic position of the Pennsylvanian-Permian boundary in Kansas, no evidence of a laterally persistent hiatus exists in the units described in this investigation.

Results of this study indicate the importance of careful and detailed field work. Certainly, future stratigraphic investigations within the Mid-Continent must concentrate on the recognition of transgressive and climate change surfaces in the rock record. Variations within predominantly mudstone or carbonate sequences should be analyzed in detail and their significance evaluated. Continued stratigraphic observations at the sixth-order level will refine our understanding of these smaller cyclic events and may be useful in reconstructing, in detail, the palaeogeography of the Mid-Continent.

## ACKNOWLEDGMENTS

The financial support of the Kansas Geological Survey (thanks to the efforts of Dr. W. Lynn Watney) and AMOCO (thanks to Dr. G. A. Sanderson) is gratefully acknowledged.

The help of the following individuals is also gratefully acknowledged. Dr. W. Lynn Watney, Kansas Geological Survey, was helpful in the field studies. Dr. Page C. Twiss and Dr. Richard M. Busch, Kansas State University, reviewed the measured sections. Dr. Joseph L. Graf, Jr., Kansas State State University, assisted in thin section preparation. Dr. George Clark II, Kansas State University, also assisted in the thin section study as well as in preparation of the photomicrographs. Professors T. M. Barkley, Page C. Twiss, and Joseph L. Graf of Kansas State University, reviewed the manuscript. I am also indebted to Ms. Sylda Nichols who helped in preparation of the manuscript. Special thanks to Dr. Ronald R. West, Kansas State University, who supervised and critically reviewed the study.

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# APPENDIX I

## Meaured Sections

This appendix contains descriptions of the nine measured sections identified for this study. The measured sections include descriptions of all lithology changes, thickness of beds, and the location of each outcrop. In addition, the boundaries between fifth-order T-R units and sixth-order T-R units are differentiated.

**State:** KS **County:** Pottawatomie **Quadrangle:** Havensville

**Locality Description:**

NW¼ SE¼ sec. 16, T. 6 S, R. 12 E. Section 1

Roadcut north of Havensville, Kansas

Section measured 7-22-84

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | UNIT DESCRIPTIONS<br>Transgressive Surface —— - - - Climate Change Surface | Unit Thicknesses ft | in | m |
|---|---|---|---|---|---|
| | 2 | 24. Aspinwall Limestone: skeletal calcilutite; platy; pale yellowish brown (10YR 6/2), weathers to moderate yellowish brown (10YR 4/2); contains rounded clay fragments (1-3 mm); sparsely fossiliferous with productacean brachiopod fragments, echinoid spines, and other fragments of skeletal debris | 1± | 0 | .29 |
| | 1 | 23. Covered: | 0 | 9 | .23 |
| | | 22. Towle Shale: mudstone; no bedding; grayish olive (10Y 4/2), weathers to yellowish gray (5Y 7/2); soft; calcareous; contains abundant caliche nodules; no fossils observed | 3 | 10 | 1.17 |
| | | 21. Towle Shale: mudstone; no bedding; pale olive (10Y 6/2), weathers to pale greenish yellow (10YR 6/6); iron stained in parts; very silty with quartz and muscovite grains; sparsely fossiliferous with brachiopod fragments (chonetid and productaceans), ostracodes | 1 | 3 | .38 |
| | 0 | 20. Towle Shale: sandstone; no bedding; light gray (N7), weathers to yellowish gray (5Y 8/1); poorly consolidated; micaceous (muscovite); very fine grained, grains subangular to subround and very well sorted; no fossils observed | 0 | 6 | .15 |
| | | 19. Towle Shale: sandstone; no bedding; light gray (N7), weathers to yellowish gray (5Y 8/1); well consolidated, cemented with $CaCO_3$; very fine grained, grains subangular to subround and very well sorted; no fossils observed | 0 | 2 | .037 |
| | | 18. Towle Shale: mudstone; no bedding; light olive gray (5Y 6/1), weathers to yellowish gray (5Y 8/1); soft; calcareous; no fossils observed | 0 | 5 | .12 |
| | | 17. Towle Shale: sandstone; no bedding; moderate brown (5YR 4/4), weathers to light olive gray (5Y 6/1); iron stained, very fine grained, grains subangular to subround and very well sorted; some small unidentifiable fossil fragments | 0 | 1 | .04 |
| | | 16. Towle Shale: mudstone; no bedding; moderate brown (5Y 3/4), weathers to pale brown (5YR 5/2); soft, calcareous; slightly silty with quartz and muscovite grains, sparsely fossiliferous with brachiopod fragments (productaceans) | 2 | 5 | .74 |
| | | 15. Brownville Limestone: skeletal calcilutite; blocky; light gray (N7), weathers to grayish yellow (5Y 8/4); abundant limonite inclusions; silty; fossiliferous with brachiopods (marginiferids), bivalves (pectens), horn corals, echinoderm fragments, and gastropods | 1 | 2 | .35 |
| | | 14. Pony Creek Shale: mudstone; no bedding; light olive gray (5Y 5/2), weathers to yellowish gray (5Y 7/2); soft, slightly micaceous (muscovite); sparsely fossiliferous productacean brachiopod spines, ostracodes | 0 | 6 | .16 |
| | -1 | 13. Pony Creek Shale: calcilutite; no bedding; dark gray (N3), weathers to pale brown (5YR 5/2) and light brown (5YR 5/6); occurs as clast (1.7 cm in diameter); bored; iron stained; no fossils observed | | | |
| | | 12. Pony Creek Shale; calcilutite; finely laminated; medium dark gray (N4), weathers to medium gray (N5); forms persistent limestone bed; no fossils observed | 0 | | .01 |
| | | 11. Pony Creek Shale; calcilutite; no bedding; medium gray (N5), weathers to light gray (N7); occurs as clasts up to 8.5 cm. in diameter; no fossils observed | | | |

Section 1 continued

| | | | | |
|---|---|---|---|---|
| | 10. Pony Creek Shale: mudstone; no bedding; moderate brown (5YR 3/4), weathers to pale brown (5YR 5/2); soft; noncalcareous, micaceous (muscovite); very sparsely fossiliferous with brachiopod fragments | 2 | 3 | .69 |
| ? | 9. Pony Creek Shale: mudstone; no bedding; olive gray (5YR 4/1), weathers to light olive gray (5Y 6/1); soft, noncalcareous; lower 15.5 cm. shows evidence of oxidation; no fossils observed | 2 | 9 | .83 |
| | 8. Pony Creek Shale: calcilutute; medium dark gray (N4), weathers to olive gray (5Y 4/1); occurs as thin, laterally persistent bed; no fossils observed | 0 | | .01 |
| -2 | 7. Pony Creek Shale: mudstone; no bedding; olive gray (5YR 4/1), weathers to light olive gray (5Y 6/1); soft; noncalcareous; very slightly micaceous (muscovite); no fossils observed | 0 | 4 | .1 |
| | 6. Pony Creek Shale: skeletal calcirudite; blocky; light gray (N7), weathers to light olive gray (5Y 6/1); forms thin irregular bed; conglomeritic in part with clasts up to 1.5 cm. in diameter; fossiliferous with brachiopod fragments, crinoid columnals, gastropods, bored in parts | 0 | 1 | .03 |
| ? | 5. Pony Creek Shale: mudstone; no bedding; dark reddish brown (10YR 3/4), weathers to grayish red (10YR 4/2); soft; noncalcareous, slightly micaceous (muscovite); no fossils observed | 1 | 7 | .49 |
| -3 | 4. Grayhorse Limestone?: skeletal calcirudite; platy; light brownish gray ((5YR 6/1), weathers to light gray (N7); with numerous medium gray (N5), platy, mud inclusions up to 5 mm in size, also with small brownish gray (5YR 4/1) sandy inclusions; extremely fossiliferous with brachiopods (<u>Meekella</u>, <u>Derbyia</u>, chonetids), and bivalve steinkerns, fossils disarticulated and at random orientations | 1 | 0 | .30 |
| | 3. Plumb Shale?: mudstone; blocky; medium gray (N5), weathers to light olive gray (5Y 6/1), noncalcareous, very slightly micaceous (muscovite); oxidized in part; no fossils observed | 0 | 4 | .10 |
| -4 | 2. Plumb Shale?: coal; finely laminated; black (N1), no fossils observed | 0 | 5 | .14 |
| ? -5 | 1. Plumb Shale?: mudstone; no bedding; dark gray (N3), weathers to medium gray (N5); calcareous; very slightly micaceous (muscovite); no fossils observed | 0 | 11 | .29 |

**State:** KS **County:** Pottawatomie **Quadrangle:** Havensville

**Locality Description:**

N½ SW¼ sec. 28, T. 6 S., R. 12 E. Section 2

South of Havensville, Kansas

Section measured 3-4-84

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | UNIT DESCRIPTIONS (Transgressive Surface —— ---Climate Change Surface) | ft | in | m |
|---|---|---|---|---|---|
| | 2 | 9. Aspinwall Limestone: skeletal calcilutite; platy; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); limonite and "clay ball" inclusions up to .50 cm. in size; fossil fragments of echinoid plates and spines, also some disarticulated brachiopod valves | .5± | 0 | .15 |
| | 1 | 8. Towle Shale; mudstone; no bedding; dark grayish red (5R 4/2), weathers to light grayish red (10R 4/2); slightly silty with quartz and muscovite grains; sparsely fossiliferous with fragments of brachiopods, bryozoans; some ostracodes also present | 1 | 10 | .56 |
| | ? | | | | |
| | 0 | 7. Towle Shale: mudstone; finely laminated; dark grayish red (5R 4/2), weathers to light grayish red (10R 4/2); slightly silty with quartz and muscovite grains; iron stained; no fossils observed | 0 | 2 | .62 |
| | | 6. Towle Shale: mudstone; finely laminated; dark grayish red (5R 4/2), weathers to light grayish red (10R 4/2); part mottled pale olive (10Y 6/2); sl. silty with quartz and muscovite grains, no fossils observed | 0 | 1 | .38 |
| | | 5. Towle Shale: mudstone; no bedding; pale olive (10Y 6/2), weathers to yellowish gray (5Y 7/2); very slightly silty with quartz and muscovite grains; no fossils observed | 0 | 1 | .25 |
| | | 4. Towle Shale: mudstone; no bedding; dark grayish red (5R 4/2), weathers to light grayish red (10R 4/2), slightly silty with muscovite grains, sparsely fossiliferous with brachiopod and echinoderm fragments | 1 | 5 | .43 |
| | | 3. Towle Shale: mudstone; finely laminated; light olive gray (5Y 5/2), weathers to pale olive (10Y 6/2), iron stained, sparsely fossiliferous with brachiopod and echinoderm fragments | 1 | 3 | .37 |
| | | 2. Brownville Limestone: skeletal calcilutite; blocky; yellowish gray (5Y 7/2), weathers to pale brown (5YR 5/2); with limonite inclusions; abundantly and diversely fossiliferous with chonetid and marginiferid brachiopods, bryozoans, crinoid columnals | 1 | 11 | .59 |
| | -1 | 1. Pony Creek Shale: mudstone; no bedding; grayish olive green (10Y 4/2), weathers to pale olive green (10Y 6/2), silty with quartz and muscovite grains; sparsely fossiliferous with brachiopod, echinoderm fragments; some ostracodes also present | 1 | 4 | .42 |

**State:** KS **County:** Pottawatomie **Quadrangle:** Louisville

**Locality Description:**

Southern edge of sec. 35, T. 8 S., R. 10 E. Section 3
Roadcut southeast of Westmoreland, Kansas

Section measured 7-21-84

# UNIT DESCRIPTIONS

Transgressive Surface —— - - - Climate Change Surface

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | Unit Descriptions | ft | in | m |
|---|---|---|---|---|---|
| | | 19. Brownville Limestone: skeletal calcilutite; blocky; medium light gray (N6), weathers to moderate yellowish brown (10YR 5/4); limonite inclusions; abundantly and diversely fossiliferous with marginiferid brachiopods, crinoid columnals, bryozoans, bivalve fragments, gastropods, and horn corals | 1± | 0 | .31 |
| | | 18. Covered: | 0 | 6 | .14 |
| | 0 | 17. Brownville Limestone; skeletal calcilutite; blocky; medium light gray (N6), weathers to moderate yellowish brown (10YR 5/4); limonite inclusions; abundantly and diversely fossiliferous with marginiferid brachiopods, crinoid columnals, bryozoans, bivalve fragments, gastropods and horn corals | 1 | 7 | .49 |
| | | 16. Pony Creek Shale: mudstone; no bedding; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); very hard; slightly calcareous; sparsely fossiliferous with brachiopod and bivalve fragments | 1 | 10 | .56 |
| | | 15. Pony Creek Shale: mudstone; no bedding; dark yellowish orange (10YR 6/6); oxidized zone; no fossils observed | 0 | 1 | .025 |
| | | 14. Pony Creek Shale: calcilutite; medium dark gray (N4), weathers to light olive gray (5Y 5/2); occurs as unfossiliferous clasts up to 2.0 cm. in diameter | | | |
| | | 13. Pony Creek Shale: mudstone; no bedding; dark yellowish brown (10YR 4/2), weathers to light olive gray (5Y 5/2); no fossils observed | 2 | 7 | .80 |
| | | 12. Pony Creek Shale: mudstone; no bedding; dark yellowish orange (10YR 6/6); oxidized zone; no fossils observed | 0 | .5 | .01 |
| | | 11. Pony Creek Shale: sandstone; finely laminated; medium gray (N5), weathers to dark yellowish brown (10YR 4/2); very fine grained, well sorted, micaceous (muscovite); cemented with calcium carbonate; rare brachiopods | 0 | 1 | .02 |
| | -1 | 10. Pony Creek Shale: mudstone; no bedding; dark yellowish brown (10YR 4/2), weathers to light olive gray (5Y 5/2); slightly calcareous, no fossils observed | 0 | 4 | .09 |
| | | 9. Pony Creek Shale: mudstone; no bedding; dark yellowish orange (10YR 6/6); oxidized zone; no fossils observed | 0 | 1 | .025 |
| | | 8. Pony Creek Shale: mudstone no bedding; dark yellowish brown (10YR 4/2), weathers to light olive gray (5Y 5/2)' slightly micaceous (muscovite); mottled with iron stains; sparsely fossiliferous with brachiopod fragments, ostracodes, bivalves | 1 | 4 | .40 |
| | —?— | 7. Pony Creek Shale: mudstone; no bedding; dark yellowish orange (10YR 6/6); oxidized zone; no fossils observed | 0 | 1 | .025 |
| | | 6. Pony Creek Shale: mudstone; no bedding; moderate brown (5YR 3/4), weathers to pale yellowish brown (10YR 6/2); slightly micaceous (muscovite); no fossils observed | 0 | 2 | .05 |
| | -2 | 5. Pony Creek Shale: calcilutite; finely laminated; dark yellowish brown (10YR 4/2), weathers to pale yellowish brown (10YR 6/2); slightly micaceous (muscovite); no fossils observed | 0 | .5 | .01 |
| | | 4. Pony Creek Shale: mudstone; no bedding; dark yellowish brown (10YR 4/2), weathers to light olive gray (5Y 5/2); sparsely fossiliferous with brachiopod fragments and ostracodes | 0 | 8 | .20 |

Section 3 continued

| | | | | | |
|---|---|---|---|---|---|
| | | 3. Pony Creek Shale: mudstone; no bedding; dark yellowish orange (10YT 6/6); oxidized zone; sparsely fossiliferous with brachiopods and ostracodes | 0 | 1 | .03 |
| | | 2. Pony Creek Shale: mudstone; no bedding; dark yellowish brown (10YR 4/2), weathers to light olive gray (5Y 5/2), soft, slightly micaceous (muscovite); mottled with iron stains; sparsely fossiliferous with brachiopods and ostracodes | 0 | 7± | .19 |
| | —?— -3 | 1. Covered: | | | |

**State:** KS **County:** Pottawatomie **Quadrangle:** Flush

**Locality Description:**

NW¼ NW¼ sec. 16, T. 9 S., R. 9 E.
Stream bank south of Flush, Kansas

Section 4

Section measured 7-14-84

Modified after Mudge and Yochelson (1962)

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | UNIT DESCRIPTIONS (Transgressive Surface —— ; - - - Climate Change Surface) | Unit Thicknesses ft | in | m |
|---|---|---|---|---|---|
| | 2 | 9. Covered: till, cherty gravel | 8± | 0 | 2.1 |
| | | 8. Aspinwall Limestone: skeletal calcilutite; blocky; grayish yellow (5Y 8/4), weathers to yellowish gray (5Y 7/2), slightly micaceous (muscovite); some limonite inclusions present; sparsely fossiliferous with crinoid columnals, productacean brachiopod fragments | 2 | 6 | .75 |
| | | 7. Aspinwall Limestone: mudstone; blocky; light olive gray (5Y 5/2), weathers yellowish gray (5Y 7/2); hard; very calcareous; very sparsely fossiliferous with brachiopod fragments | 4 | 3 | 1.3 |
| | 1 | 6. Aspinwall Limestone: skeletal calcilutite; blocky; light gray (N7), weathers to yellowish gray (5Y 8/1); some faintly visible laminae, fossiliferous with bivalve fragments and molds (myalinids and pectens), productacean brachiopod fragments (marginiferids), crinoid columnals, gastropods | 2 | 3 | .69 |
| | ? | | | | |
| | 0 | 5. Towle Shale: mudstone; finely laminated; greenish gray (5GY 6/1), weathers light gray (N8), soft, slightly silty with muscovite and quartz grains; very sparsely fossilifeerous with brachiopod fragments | 2 | 6 | .77 |
| | | 4. Brownville Limestone: skeletal calcilutite; massive; medium light gray (N6), weathers to very light gray (N7); slightly pyritic; very abundantly and diversely fossiliferous with marginiferid and chonetid brachiopods | 2 | 0 | .6 |
| | | 3A. Pony Creek Shale: sandstone; some laminar cross-bedding; medium gray (N5), weathers to green gray (5GY 6/1); very gine grained, grains subangular to subround, well sorted; portions very well cemented; contains sparse marine fossils, coalified and pyritized plant fossils; some glauconite present | truncates beds 1,2,3 | | |
| | ? | | | | |
| | -1 | 3. Pony Creek Shale: mudstone, no bedding, olive gray (5Y 3/2), weathers to light olive gray (5Y 5/2), soft, micaceous (muscovite), iron stained | 4 | 1 | 1.25 |
| | | 2. Grayhorse Limestone: skeletal calcirudite (conglomerate); blocky; medium dark gray (5Y 6/1), weathers to light olive gray (5Y 6/1); upper 25 cm. especially conglomeritic with limestone and clay ball clasts up to 8 cm. in size, most clasts are subangular; pyrite and marcasite inclusions common on upper surface; sparsely fossiliferous with bivalves (myalinids), brachiopods, crinoids, bryozoans | 2 | 0 | .6 |
| | -2 | 1. Plumb Shale: mudstone; blocky; medium dark gray (N4) weathers to medium light gray (N6); abundant limonite and puyrite inclusions up to 5 cm. in size, also with large well rounded limestone and sandstone clasts up to 15 cm. in size; noncalcareous; soft; fossiliferous with coalified and pyritized and plants, also some pyritized burrows. | 8± | 0 | 2.38 |

**State:** KS **County:** Shawnee **Quadrangle:** St. Marys

**Locality Description:**

SW¼ NW¼ sec. 13, T. 10 S., R. 12 E
Railroad cut just east of St. Mary's, KS Section 5

Section measured 7-31-85

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | UNIT DESCRIPTIONS<br>Transgressive Surface —— ---Climate Change Surface | ft | in | m |
|---|---|---|---|---|---|
| | ? | 16. Towle Shale: siltstone; platy; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1), micaceous (muscovite); finely laminated with some dark bands (limonite?) between laminae; very fine grained, grains mostly subrounded and very well sorted; poorly consolidated; some coalified plant fragments | 2 | 6 | .78 |
| | --?-- | | | | |
| | | 15. Towle Shale; siltstone; blocky; moderate yellowish brown (10YR 5/4), weathers to pale yellowish brown (10YR 6/2); micaceous (muscovite); also contains iron minerals (hematite and limonite?); very well consolidated; very grained, grains mostly subround to subangular and very well sorted; contains burrows | 1 | 3 | .39 |
| | | 14. Towle Shale: siltstone; finely laminated and platy; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1), micaceous (muscovite); finely laminated with some dark bands (limonite?); mostly poorly consolidated but some well-cemented zones; very fine grained, grains mostly subrounded and very well sorted; some coalified plant fragments | 8 | 5 | 2.6 |
| | 0 | 13. Cover: | 9 | 3 | 2.8 |
| | | 12. Brownville Limestone: skeletal calcilutite; blocky to massive; light gray (N7), weathers to pale brown (5YR 5/2); iron stained; abundantly and diversely fossiliferous with brachiopods (marginiferids and chonetids), crinoids, horn corals, bryozoans | 0 | 9 | .24 |
| | | 11. Pony Creek Shale: mudstone; no bedding; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1), hard and calcareous; very sparsely fossiliferous with chonetid skeletal fragments | 2 | 2 | .67 |
| | | 10. Pony Creek Shale: mudstone; no bedding; yellowish gray (5Y 8/1) weathers to pale brown (5YR 5/2) and pale yellowish brown (10YR 6/2); very slightly micaceous (muscovite); very hard and calcareous; | 0 | 4 | .095 |
| | | 9. Pony Creek Shale: calcilutite; platy; light gray (N7), weathers to light olive gray (5Y 6/1), has mudstone partings at about 2 cm. intervals; iron stained; locally persistent but variable in thickness; very slightly micaceous (muscovite); no fossils observed | 0 | 6 | .16 |
| | -1 | 8. Pony Creek Shale: mudstone; no bedding; light olive gray (5Y 6/1), weathers to yellowish gray (5Y 8/1), slightly micaceous (muscovite), very slightly calcareous, with oxidized zones; very sparsely fossiliferous with some thin-shelled brachiopods | 0 | 10 | .25 |
| | --?-- | | | | |
| | | 7. Pony Creek Shale: calcilutite; platy; brownish gray (5Y 4/1), weathers to yellowish gray (5Y 8/1), slightly micaceous (muscovite), with oxidized iron zones; no fossils observed | | | |
| | | 6. PonyCreek Shale: mudstone; no bedding; light olive gray (5Y 6/1), weathers to yellowish gray (5Y 8/1) , slightly micaceous (muscovite), very calcareous; | 1 | 3 | .40 |
| | -2 | 5. Pony Creek Shale: mudstone; no bedding; dark reddish brown (10YR 3/4), weathers to grayish red (10R 4/2); slightly micaceous (muscovite); slightly calcareous in parts; with some hematite(?) inclusions; no fossils observed. | 2 | 2 | .62 |

| | | | | | |
|---|---|---|---|---|---|
| | | 4. Pony Creek Sbale: calcilutite; thinly bedded; brownish gray (5YR 4/1), weathers to grayish red (10R 4/2), slightly micaceous (muscovite); with oxidized iron zones; no fossils observed | 0 | 1 | .02 |
| | | 3. Pony Creek Shale: mudstone; no bedding; dark reddisb brown (10R 3/4), weathers to grayish red (10R 4/2), slightly micaceous (muscovite), slightly calcareous in parts; with some hematite(?) inclusions; no fossils observed | 0 | 5 | .12 |
| | -2 | 2. Pony Creek Sbale: sandstone; thinly bedded; light gray (N7), weatbers to yellowish gray (5Y 8/1), very fine grained, very well sorted, grains subangular to subround, slightly micaceous (muscovite); calcareous; witb oxidized iron zones; no fossils observed | 0 | 3 | .065 |
| | | 1. Pony Creek Sbale: mudstone; no bedding; dark reddish brown (10YR 3/4), weathers to grayish red (10R 4/2); sligbtly micaceous (muscovite); slightly calcareous; witb some hematite (?) inclusions; no fossils observed | 2± | 0 | .80 |

**State:** KS **County:** Wabaunsee **Quadrangle:** Maple Hill

**Locality Description:**

NE¼ NW¼ sec. 26, T. 11 S., R 12 E.
Roadcut along Interstate 70

Composite section of
Localities 6,7

Sections measured 6-25-83 and 6-26-83

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | UNIT DESCRIPTIONS<br>Transgressive Surface —— ---Climate Change Surface | Unit Thicknesses ft | in | m |
|---|---|---|---|---|---|
| | 4 | 40. Aspinwall Limestone: calcilutite; platy and finely laminated; yellowish gray (5Y 8/1), weathers to very light gray (N8), contains numerous "clay ball" inclusions up to 1 cm. in size; very sparsely fossiliferous with unidentifiable skeletal fragments (present on north side only) | 1± | 0 | .36 |
| | | 39. Towle Shale: mudstone; blocky; olive gray (5Y 3/2), weathers to light olive gray (5Y 5/2); contains some carbonate (caliche?) nodules; no fossils observed | 0 | 6 | .15 |
| | 3 | 38. Towle Shale: mustone; with some thin laminae; olive gray (5Y 3/2), weathers to yellowish gray (5Y 8/1); micaceous (muscovite); very sparsely fossiliferous with brachiopod and bryozoan fragments | 2 | 2 | .66 |
| | | 37. Towle Shale: siltstone; blocky; light olive gray (5Y 6/1), weathers to yellowish gray (5Y 8/1); grains subangular to subround and very well sorted; also some silt size iron inclusions present; sparsely fossiliferous with unidentifiable skeletal fragments | 0 | 7 | .18 |
| | ? | 36. Towle Shale: mudstone; no bedding; yellowish gray (5Y 7/2); weathers to grayish Yellow (5Y 8/4); slightly micaceous (muscovite); slightly calcareous; no fossils observed | 0 | 4 | .11 |
| | | 35. Towle Shale: siltstone; blocky; yellowish gray (5Y 7/2), weathers to very pale orange (10YR 8/2); resembles bed no. 33; no fossils observed | 0 | | .04 |
| | | 34. Towle Shale: mudstone; no bedding; grayish yellow (5Y 8/4), weathers to pale greenish yellow (10Y 8/2); fossiliferous with brachiopod and bivalve fragments, crinoid columnals, other unidentifiable fragments | 0 | 2 | .05 |
| | 2 | 33. Towle Shale: siltstone; blocky; yellowish gray (5Y 7/2), pale orange (10YR 8/2); grains subangular to subround and very well sorted; also some silt size iron inclusions present; calcareous; sparsely fossiliferous with unidentifiable skeletal fragments | 0 | 2 | .06 |
| | | 32. Towle Shale: calcilutite; no bedding; light olive gray (5Y 6/1); weathers to light gray (N7); occurs as clasts up to 7 cm. in size; some iron inclusions present; sparsely fossiliferous with forams? | | | |
| | | 31. Towle Shale: mudstone: no bedding; grayish yellow (5Y 8/4), weathers to pale greenish yellow (10Y 8/2); lower 15 cm. fossiliferous with ostracodes and forams | 5 | 2 | 1.58 |
| | | 30. Towle Shale: calcilutite; very thinly bedded; yellowish gray (5Y 7/2), weathers to light gray (N7); irregular in thickness; iron stained; fossiliferous with gastropods (high-spired), and bivalves | 0 | | .02 |
| | ? | 29. Towle Shale: mudstone; no bedding; grayish yellow (5Y 8/4) weathers to pale greenish yellow (10Y 8/2); some iron staining; slightly micaceous (muscovite); very slightly calcareous; no fossils observed | 0 | 9 | .22 |
| | 1 | 28. Towle Shale: mudstone; no bedding; blocky; pale brown (5YR 5/2), weathers to pale yellowish brown (10YR 6/2), slightly micaceous (muscovite); with some iron staining; hard; very calcareous; no fossils observed | 0 | 9 | .25 |
| | | 27. Towle Shale; mudstone; no bedding; grayish red (10R 4/2), weathers to grayish red (5YR 4/2); similar to bed no. 25; sparsely fossiliferous with brachiopod? shell fragments, bryozoans | 0 | 4 | .10 |
| | ? | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | | 26. Towle Shale: calcilutite; thinly bedded; light gray (N7), weathers to very light gray (N8); iron stained; irregular in thickness but laterally persistent; no fossils observed | 0 | 2 | .06 |
| | | 25. Towle Shale: mudstone; blocky; grayish red (10R 4/2), weathers to grayish red (5R 4/2); with some iron (limonite?) conceretions; slightly micaceous (muscovite); hard but noncalcareous; no fossils observed | 4 | 5 | 1.35 |
| | 0 | 24. Towle Shale: mudstone; no bedding; greenish gray (5GY 6/1), weathers to light greenish gray (5GY 8/1); very calcareous and hard; with small iron (limonite?) inclusions; fossiliferous with fragments of bryozoans, brachiopods, crinoids, and bivalves, trilobites, encrusting forams | 0 | 2 | .05 |
| | | 23. Brownville Limestone: skeletal calcilutite; massive; light gray (N7), weathers to light brown (5Y 6/4); with numerous iron (limonite?) inclusions; abundantly and diversely fossiliferous with brachiopods (chonetids and marginiferids), crinoids, fenestrate bryozoans, and bivalves | 0 | 10 | .25 |
| | | 22. Brownville Limestone: mudstone; no bedding; pale greenish yellow (10Y 8/2) weathers to grayish yellow (5Y 8/4), sparsely fossiliferous with skeletal fragments? | 0 | 1 | .03 |
| | | 21. Brownville Limestone: skeletal calcilutite; massive; light gray (N7), weathers to light brown (5Y 6/4); with numerous iron (limonite?) inclusions; abundantly and diversely fossiliferous with brachiopods (chonetids and marginiferids), crinoids, fenestrate bryozoans, and bivalves | 1 | 6 | .46 |
| | | 20. Pony Creek Shale: mudstone; no bedding; light gray (N7), weathers to light olive gray (5Y 6/1), with some iron stains and inclusions (limonite?); noncalcareous but very hard; slightly micaceous (muscovite); no fossils observed | 2 | 4 | .51 |
| | | 19. Pony Creek Shale: mudstone; no bedding; grayish red (10R 4/2); weathers to pale red (5R 6/2); iron stained, slightly calcareous; sparsely fossiliferous with brachiopod fragments | 2 | 2 | 1.66 |
| | -1 | 18. Pony Creek Shale: mudstone; thinly laminated; medium gray (N5), weathers to light gray (N7), very slightly calcareous, contains limonite inclusions, iron stained | 1 | 3 | 2.17 |
| | | * 17. Pony Creek Shale: calcilutute; thinly bedded; medium dark gray (N4), weathers to light olive gray (5Y 6/1); discontinuous; bored; encrusted with bryozoan holdfasts, <u>Spirorbis</u> | 0 | 1 | .03 |
| | —?— | 16. Pony Creek Shale: mudstone; thinly laminated; medium dark gray (N4), weathers to light olive gray (5Y 6/1); silty with quartz and muscovite grains; hard and slightly calcareous; no fossils observed | 0 | 6 | .15 |
| | | 15. Pony Creek Shale: calcilutite; thinly bedded; light olive gray (5Y 6/1), weathers to yellowish gray (5Y 8/1); laterally persistent; no fossils observed | 0 | 1 | .04 |
| | | 14. Pony Creek Shale: mudstone; finely laminated; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); silty with quartz and muscovite grains; very hard; no fossils observed | 0 | 2 | .05 |
| | -2 | 13. Pony Creek Shale: calcilutite; finely laminated; light olive gray (5Y 6/1), weathers to yellowish gray (5Y 8/1); laterally peristent; no fossils observed | 0 | 1 | .03 |
| | | 12. Pony Creek Shale: mudstone; thinly laminated; olive gray (5Y 4/1), weathers light olive gray (5Y 6/1); very silty with quartz and muscovite grains; calcareous; no fossils observed | 0 | 1 | .03 |
| | | 11. Pony Creek Shale: calcilutite; finely laminated; medium dark gray (N4), weathers to light olive gray (5Y 6/1); laterally persistent; no fossils observed | 0 | 1 | .04 |
| | | 10. Pony Creek Shale: mudstone; no bedding; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); slightly silty with quartz and muscovite grains; no fossils observed | 0 | | .01 |

* denotes hardgroud documented by West and Palmer, 1983

Composite section of Locations 6,7 continued

| | | | | |
|---|---|---|---|---|
| | 9. Pony Creek Shale: calcilutite; thinly bedded; medium dark gray (N4), weathers to light olive gray (5Y 6/1); some secondary sparry calcite present in fractures; locally persistent; no fossils observed | 0 | 2 | .05 |
| -2 | 8. Pony Creek Shale: mudstone; very thinly laminated; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); hard; slightly silty with quartz and and muscovite grains; very slightly calcareous; skeletal fragments | 0 | 1 | .03 |
| | 7. Pony Creek Shale: calcilutite; finely laminated; dark gray (N3), weathers to light olive gray (5Y 6/1); laterally persistent; no fossils observed | 0 | 1 | .03 |
| | 6. Pony Creek Shale: mudstone; very finely laminated; olive gray 5Y 4/1), weathers to light olive gray (5Y 6/1); slightly micaceous (muscovite); hard but only slightly calcareous; very sparsely fossiliferous with productacean brachiopod fragments | 0 | 6 | .15 |
| ? | | | | |
| | 5. Pony Creek Shale: calcilutite; thinly bedded; dark gray (N3), weathers to light olive gray (5Y 6/1); no fossils observed | 0 | 3 | .08 |
| | 4. Pony Creek Shale: mudstone; very finely laminated; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); slightly micaceous (muscovite); hard and slightly calcareous; no fossils observed | 0 | 3 | .08 |
| -3 | 3. Pony Creek Shale: calcilutite; finely laminated; medium dark gray (N4), weathers to olive gray (5Y 4/1), laterally persistent; no fossils observed | 0 | 6 | .15 |
| | 2. Pony Creek Shale; mudstone; no bedding; dark gray (N3), weathers to moderate brown (5Yr 4/4); no fossils observed | | | |
| | 1. Grayhorse Limestone: calcirudite; blocky; light gray (N7), weathers to yellowish gray (5Y 7/2); clasts mostly subangular up to 2.0 cm. in size; sparsely fossiliferous with brachiopod and bivalve fragments, and crinoid columnals (present on north side only) | 0 | 3 | .08 |

**State:** KS **County:** Wabaunsee **Quadrangle:** Maple Hill

**Locality Description:**

NE¼ SE¼ sec. 13 T. 12 S., R. 12 E. Section 8

Roadcut south of Interstate 70 - Eskridge Rd/

Section measured 8-13-84

## UNIT DESCRIPTIONS

Transgressive Surface —— ---Climate Change Surface

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | Unit Descriptions | Unit Thicknesses ft | in | m |
|---|---|---|---|---|---|
| | | 7. Hawxby Shale: mudstone; no bedding; pale brown (5YR 5/2), weathers to pale yellowish brown (10YR 6/2), very calcareous; slightly silty with quartz and muscovite grains; sparsely fossiliferous with brachiopod fragments, ostracodes | 5± | | 1.39 |
| | 1 | 6. Aspinwall Limestone! skeletal calcilutite; platy and finely laminated (algal); light gray (N7), weathers to very light gray (N8); sparsely fossiliferous with brachiopod fragments, crinoids, echinoid spines, bryozoans, ostracodes | 2 | 10 | .86 |
| | | 5. Towle Shale: calcilutite; no bedding; brownish gray (5YR 4/1), weathers to light olive gray (5Y 6/1); occurs as clasts up to 9.0 cm. in diameter; no fossils obaerved | | | |
| | | 4. Towle Shale: mudstone; no bedding; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); very hard and calcareous, rare brachiopods and bivalves | 6 | 0 | 1.84 |
| | | 3. Towle Shale: mudstone; no bedding; olive gray (5Y 4/1) weathers to pale yellowish orange (10YR 8/6) and light olive gray (5Y 6/1); forms distinct iron-stained zone; very hard and calcareous; sparsely fossiliferous with brachiopod and bryozoan fragments, ostracodes | 0 | 3 | .08 |
| | 0 | 2. Brownville Limestone: skeletal calcilutite; blocky; light gray (N7), weathers to yellowish gray (5Y 7/2) and pale yellowish brown (10YR 6/2); with limonite inclusions; abundantly and diversely fossiliferous with productacean brachiopods (marginiferids), crinoid columnals, fenestrate bryozoans, horn corals, bivalve fragments (pectens), fossils randomly oriented and disarticulated | 2 | 11 | .90 |
| | | 1. Pony Creek Shale: mudstone; no bedding; moderate brown (5YR 3/4) , weathers to pale brown (5YR 5/2); slightly micaceous (muscovite), soft, sparsely fossiliferous with echinoderms | 2± | 0 | .65 |

**State:** KS **County:** Lyon **Quadrangle:** Admire

**Locality Description:**

NE¼ NE¼ sec. 21, T. 16 S., R. 12 E. Section 9

Stream cut at Admire Junction

Section measured 8-21-84

| 5th order T-R units/boundaries | 6th order T-R units/boundaries | UNIT DESCRIPTIONS<br>Transgressive Surface —— ---Climate Change Surface | Unit Thicknesses ft | in | m |
|---|---|---|---|---|---|
| | | 6. Cover: gravel and soil | 2± | 0 | .70 |
| | | 5. Towle Shale: mudstone; no bedding; olive gray (5Y 4/1), weathers to light olive gray (5Y 6/1); soft; sparsely fossiliferous with brachiopod and echinoid fragments, bryozoans, bivalve fragments, ostracodes | 0 | 4 | .09 |
| | | 4. Brownville Limestone: skeletal calcilutite; massive; light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1); bioturbated; abundantly and diveresly fossiliferous w/productacean brachiopod fragments, crinoid columnals and plates, bryozoans; some fossils concentrated in "nests"; fecal(?) pellets also present | 0 | 10 | .27 |
| | 0 | 3. Brownville Limestone: mudstone; no bedding; light olive gray (5Y 6/1), weathers to yellowish gray (5Y 8/1); discontinuous; possible weathered zone; no fossils observed | 0 | 0-2 | 0-.04 |
| | | 2. Brownville Limestone: skeletal calcilutite; massive; light olive gray (5Y 6/1), weathers yellowish gray (5Y 8/1); distinctly jointed; abundantly fossiliferous with productid brachiopod fragments (marginiferids), piriferid and chonetid brachiopods, crinoid columnals, bryozoans; most shells disarticulated and randomly oriented | 1 | 7 | .47 |
| | -1 | 1. Pony Creek Shale: mudstone; laminated; grayish olive green (5GY 3/2), weathers to pale olive (10Y 6/2), mottled with brownish black (5YR 2/1); slightly micaceous (muscovite); fossiliferous with bivalve molds (pectens), brachiopods (<u>Orbiculoidea</u>), ostracodes, conodonts | 6 | 4 | 1.94 |

# APPENDIX II

## U.S.G.S. Checklist for Field Description of Sedimentary Rocks

This appendix contains the U.S.G.S. checklist for field description of sedimentary rocks.

U.S.G.S. CHECKLIST FOR FIELD DESCRIPTION OF SEDIMENTARY ROCKS: 

Note: Describe first the largest units recognized, then those of the next order, and so on down to the smallest.

A. External form of the rock unit. Lenticular, persistent, very regular in thickness, etc.; dimensions; relation to overlying or underlying units.

B. Color. Color of unit as a whole, wet or dry. Color of individual particles.

C. Bedding.

1. How manifested: Sharp, by partings, by difference in texture, color, etc.; transitional; shaly.

2. Shape of bedding surfaces: Plane, undulating, ripple-marked, etc.; irregular; if not plane, record details of form and dimensions of features.

3. Thickness of beds: Comparative thicknesses; different orders. Relation of thicknesses; rhythmic; random. If variable, relation between thickness and composition, bedding, etc.

4. Attitude and direction of bedding surfaces: Horizontal, inclined, curved. Relation to each other: parallel, intersecting, tangential; angles between different attitudes and directions; dips, strikes; dimensions; relation of size, composition, shape, etc., to attitude and direction; relation of composition to different types of beddings.

5. Markings of bedding surfaces: mud cracks, rain prints, bubble impressions, ice-crystal impressions, trails, footprints, etc.

6. Disturbances of bedding: Edgewise or intraformational conglomerates, folding or crumpling of individual beds before consolidation, etc.

D. Composition.

1. Inorganic constituents.

a. Mineralogy or lithology of principal constituents; approximate percentages; vertical and lateral variations

b. Size: Prevailing size if fairly uniform; range in sizes if no proportions of different sizes as determined by sieving where feasible; distribution of sizes with relation to other features; vertical and lateral variations in size.

c. Shape: Crystalline, angular, subangular, subrounded, rounded; relation of shape to size, material, position in beds, etc. For quantitative results on pebbles, etc., estimate or measure radius of curvature of sharpest edge, mean radius, and maximum and minimum diameter.

d. Surface textures: Glossy, smooth, mat, pitted, etc.

e. Orientation: If not equidimensionsl, direction of greater dimensions with respect to bedding, to each other, etc.

f. Chemical and internal physical condition: Fresh, weathered, decomposed, cracked, etc.

g. Packing: Closeness and manner.

h. Pore space.

i. Cement: Present or absent; proportion; composition; variations in composition vertically and laterally and in relation to other characters; disposition with respect to bedding, fractures, etc.

j. Color: Wet or dry; location, inherent or as a stain in constituents or cement; variations and their relation to other factors such as composition, porosity, bedding, fracturing, fossils.

2. Organic constituents.

a. Kinds; relative abundance.

b. Size: Does the distribution of sizes show effects of mechanical deposition?

c. Condition: Entire, fragmented, wholly or partly dissolved; means of preservation (silicified, replaced by calcite, etc. relation to kinds).

d. Distribution: With respect to character of beds, kinds of organisms, bedding, evidence of burrowing, etc.

e. Orientation: With respect to bedding; with respect to life habits, possible manner of death, etc.

E. Concretions.

1. Form, size, color, composition and their variations.

2. Internal structure; central nucleus, organic or inorganic; central or hollow; homogeneous; bended horizontally, concentrically, etc.; radial; compace; vesicular.

3. Boundary against country rock: Sharp, transitional.

4. Relation of bedding to concretions: Continous through concretion, deflected above, below, or both; thinned above, below, etc.

5. Distribution: Random; regular; if regular, intervals between growths (layers), vertically and horizontally; differences between characters of concretions in different groups (layers). Relation of distribution to other characters, as mechanical, chemical, or organic composition of country rock; jointing, fissuring, folding, etc., topo graphy, groundwater level; etc.

F. Hardness and structure: firmness, friabiliity, jointing, ease of fracturing along bedding or joints.

# APPENDIX III

## Thin Section Descriptions and Point Count Data

Using Chaye's (1949) method, five hundred points were counted on each of five thin sections. Orthochemical, allochemical, and terrigenous components were identified and their abundance (in percent) determined. In addition, a rock name was assigned to each sample designating grain size and composition. These data are in the following appendix.

S1-A

| Type of Particle | Number of points | Percent of points | Percent skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 244 | 48.8 | ----- |
| Microspar | 33 | 6.6 | ----- |
| Spar | 8 | 1.6 | ----- |
| Allochems (grains) | | | |
| Brachiopods | 26 | 5.2 | 45.6 |
| Bivalves | 2 | 0.4 | 3.5 |
| Echinoderms | 19 | 3.8 | 33.3 |
| Unidentifiable skeletal fragments | 10 | 2.0 | 17.5 |
| Terrigenous Components | | | |
| Quartz silt | 129 | 25.8 | ----- |
| Plagioclase | 1 | 0.2 | ----- |
| Opaques | 15 | 3.0 | ----- |
| Porosity | 13 | 2.6 | ----- |
| Total | 500 | 100.0 | 99.9 |

Rock Name:

Fine calcarenite: immature, silty, partly recrystallized, brachiopod, echinoderm, bivalve biomicrite

S1-1

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 220 | 44.0 | ----- |
| Microspar | 143 | 28.6 | ----- |
| Spar | 12 | 2.4 | ----- |
| Dolomite | 0 | trace | ----- |
| Allochems (grains) | | | |
| Brachiopods | 60 | 12.0 | 58.8 |
| Bivalves | 1 | .2 | 1.0 |
| Bryozoans | 9 | 1.8 | 8.8 |
| Echinoderms | 5 | 1.0 | 4.9 |
| Trilobites | 5 | 1.0 | 4.9 |
| Unidentifiable skeletal fragments | 22 | 4.4 | 21.6 |
| Terrigenous Components | | | |
| Quartz silt | 7 | 1.4 | ----- |
| Porosity | 16 | 3.2 | ----- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Coarse calcarenite: immature, slightly silty, slightly dolomitic, partly recrystallized, brachiopod, echinoderm, trilobite, bryozoan, bivalve biomicrite

S1-3

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 236 | 47.2 | ----- |
| Microspar | 150 | 30.0 | ----- |
| Spar | 7 | 1.4 | ----- |
| Dolomite | 0 | trace | ----- |
| Allochems (grains) | | | |
| Brachiopods | 36 | 7.2 | 35.6 |
| Bivalves | 24 | 4.8 | 26.1 |
| Echinodoerms | 2 | 0.4 | 2.2 |
| Gastropods | 11 | 2.2 | 11.9 |
| Foraminifera | 7 | 1.4 | 7.6 |
| Unidentifiable skeletal fragments | 12 | 2.4 | 13.0 |
| Terrigenous Components | | | |
| Quartz silt | 8 | 1.6 | ----- |
| Opaques | 2 | 0.4 | ----- |
| Porosity | 5 | 1.0 | ----- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Coarse calcarenite: immature, partly recrystallized, slightly dolomitic, gastropod, brachiopod, bivalve, echinoderm, foraminiferid biomicrite

S1-6

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 338 | 67.6 | ----- |
| Microspar | 38 | 7.6 | ----- |
| Spar | 5 | 1.0 | ----- |
| Allochems (grains) | | | |
| Brachiopods | 72 | 14.4 | 72.0 |
| Bivalves | 10 | 2.0 | 10.0 |
| Echinoderms | 5 | 1.0 | 5.0 |
| Algae | 6 | 1.2 | 6.0 |
| Unidentifiable skeletal grains | 7 | 1.4 | 7.0 |
| Terrigenous Components | | | |
| Quartz silt | 5 | 1.0 | ----- |
| Opaques | 6 | 1.2 | ----- |
| Porosity | 8 | 1.6 | ---- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Coarse calcarenite: immature, partly recrystallized, brachiopod, bivalve, encrusting algae, echinoderm biomicrite

S1-9

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 9 | 1.8 | ----- |
| Microspar | 320 | 64.0 | ----- |
| Spar | 62 | 12.4 | ----- |
| Allochems (grains) | | | |
| Brachiopods | 36 | 7.2 | 35.6 |
| Bivalves | 18 | 3.6 | 17.8 |
| Bryozoans | 20 | 4.0 | 19.8 |
| Echinoderms | 11 | 2.2 | 10.9 |
| Trilobites | 11 | 2.2 | 10.9 |
| Gastropods | 1 | 0.2 | 1.0 |
| Foraminifera | 1 | 0.2 | 1.0 |
| Unidentifiable skeletal fragments | 3 | 0.6 | 3.0 |
| Terrigenous Components | | | |
| Glauconite | 1 | .2 | ----- |
| Collophane ? | 6 | 1.2 | ----- |
| Opaques | 1 | 0.2 | ----- |
| Porosity | 0 | 0.0 | ----- |
| Total | 500 | 100.0 | ----- |

Rock Name:

Medium calcarenite: immature, recrystallized, brachiopod, bivalve, bryozoan, echinoderm, trilobite, foraminiferid biomicrite

# APPENDIX IV

## Acetate Peel Descriptions and Point Count Data

Using Chaye's (1949) method, five hundred points were counted on each of five mounted acetate peels. Orthochemical, allochemical, and terrigenous components were identified and their abundance (in percent) determined. In addition, a rock name was assigned to each sample designating grain size and composition. These data are in the following appendix.

| Type of Particle | Number of points | Percent of points | Percent skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 349 | 69.8 | ----- |
| Microspar | 20 | 4.0 | ----- |
| Spar | ----- | ----- | ----- |
| Allochems (grains) | | | |
| Brachiopods | 85 | 17.0 | 69.1 |
| Bryozoans | 4 | 0.8 | 3.3 |
| Bivalves | 3 | 0.6 | 2.4 |
| Echinoderms | 5 | 1.0 | 4.1 |
| Unidentifiable skeletal fragments | 26 | 5.2 | 21.1 |
| Terrigenous Components | | | |
| opaques? | 4 | 0.8 | ----- |
| Porosity | 4 | 0.8 | ----- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Coarse calcarenite: immature, partly recrystallized, brachiopod, bryozoan, bivalve, echinoderm biomicrite

S1-4

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 432 | 86.4 | ----- |
| Microspar | ----- | ----- | ----- |
| Spar | ----- | ----- | ----- |
| Allochems (grains) | | | |
| Brachiopods | 6 | 1.2 | 26.1 |
| Bivalves | 3 | .6 | 13.0 |
| Bryozoans | 2 | .4 | 8.7 |
| Unidentifiable skeletal fragments | 12 | 2.4 | 52.2 |
| Terrigenous Components | | | |
| Quartz silt | 45 | 9.0 | ----- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Fine calcarenite: immature, brachiopod, bivalve, bryozoan fossiliferous micrite

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 308 | 61.6 | ----- |
| Microspar | 40 | 8.0 | ----- |
| Spar | 18 | 3.6 | ----- |
| Allochems (grains) | | | |
| Brachiopods | 92 | 18.4 | 74.2 |
| Bivalve | 6 | 1.2 | 4.9 |
| Bryozoan | 20 | 4.0 | 16.1 |
| Echinoderms | 3 | 0.6 | 2.4 |
| Unidentifiable skeletal grains | 3 | 0.6 | 2.4 |
| Terrigenous Components | | | |
| Quartz silt | 8 | 1.6 | ----- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Coarse calcarenite: immature, partly recrystallized, brachiopod, bryozoan, echinoderm biomicrite

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
| --- | --- | --- | --- |
| Orthochems (matrix) | | | |
| Micrite | 336 | 67.2 | ----- |
| Microspar | ----- | ----- | ----- |
| Spar | ----- | ----- | ----- |
| Allochems (grains) | | | |
| Brachiopods | 72 | 14.4 | 44.4 |
| Bivalve | 16 | 3.2 | 9.9 |
| Bryozoan | 4 | 0.8 | 2.5 |
| Echinoderm | 1 | 0.2 | .6 |
| Unidentifiable skeletal fragments | 69 | 13.8 | 42.6 |
| Terrigenous Components | | | |
| Quartz silt | 2 | 0.4 | ----- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Coarse calcarenite: immature, brachiopod, bivalve, bryozoan, echinoderm biomicrite

| Type of Particle | Number of points | Percent of points | Percent of skeletal grains |
|---|---|---|---|
| Orthochems (matrix) | | | |
| Micrite | 414 | 82.8 | ----- |
| Microspar | 4 | 0.8 | ----- |
| Spar | 8 | 1.6 | ----- |
| Allochems (grains) | | | |
| Brachiopods | 26 | 5.2 | 37.7 |
| Bivalves | 6 | 1.2 | 8.7 |
| Bryozoans | 8 | 1.6 | 11.6 |
| Echinoderms | 6 | 1.2 | 8.7 |
| Unidentifiable skeletal fragments | 23 | 4.6 | 33.3 |
| Terrigenous Components | | | |
| Opaques? | 5 | 1.0 | ----- |
| Total | 500 | 100.0 | 100.0 |

Rock Name:

Coarse calcarenite: immature, brachiopod, bivalve, bryozoan, echinoderm biomicrite

# APPENDIX V



## Washed Residue Data

This appendix contains the data from washed residues of mudstone and shale samples from the study area. Taxa observed are listed by section and bed number for each locality.

# WASHED RESIDUE DATA

| Sample | Taxa |
|---|---|
| **Section 1** | |
| 22 | brachiopods, crinoids, Spirorbis |
| 21 | chonetids, productaceans, bivalves, gastropods, ostracodes, crinoids |
| 16 | productaceans |
| 14 | productaceans, ostracodes |
| 13 | ----- |
| 11 | productaceans, chonetid, crinoids |
| 10 | productaceans |
| 5 | ----- |
| 1 | ----- |
| **Section 2** | |
| 8 | productaceans, fusulinids, fenestrate bryozoans |
| 7 | productaceans |
| 5 | ----- |
| 4 | productaceans, echinoids |
| 3 | productaceans, echinoids |
| **Section 3** | |
| 16 | productaceans |
| 13 | ----- |
| 11 | brachiopods, bivalves, crinoids |
| 8 | brachiopods, bivalves, ostracodes |
| 4 | brachiopods, ostracodes |
| 2 | brachiopods, ostracodes |
| **Section 4** | |
| 7 | brachiopods |
| 3a | coalified and pyritized plant fossils |
| 3 | brachiopods, bryozoans, echinoids |
| 1 | coalified and pyritized plant fossils |
| **Section 5** | |
| 16 | coalified plant fragments |
| 14 | plant debris |
| 11 | productaceans, crinoids |
| 8 | chonetids |
| 6 | ----- |
| 5 | ----- |

Section 6/7

| | |
|---|---|
| 37 | unidentifiable skeletal fragments |
| 33 | unidentifiable skeletal fragments, crinoids |
| 24 | fenestrate bryozoans, spiriferids, holothurian sclerites, trilobite spines crinoids, echinoids, encrusting foraminiferids |
| 19 | brachiopods |
| 18 | brachiopods |
| 17 | productaceans |
| 5 | productaceans |
| 3 | carbonaceous debris |

Section 8

| | |
|---|---|
| 7 | brachiopods, gastropods |
| 4 | brachiopods, bivalves, ostracodes |
| 3 | brachiopods, bryozoans, ostracodes, crinoids, gastropods |
| 1 | echinoderms |

Section 9

| | |
|---|---|
| 5 | brachiopods, bryozoans, bivalves, echinoids |
| 1 | orbiculoids, pectens, bryozoans, ostracodes, conodonts, fish scales |

# DEPOSITIONAL ENVIRONMENTS OF THE WOOD SIDING FORMATION AND THE ONAGA SHALE (PENNSYLVANIAN-PERMIAN) IN NORTHEAST KANSAS

by

CURTIS G. BISBY

B.S., Kansas State University, 1982

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Geology

KANSAS STATE UNIVERSITY
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1986

ABSTRACT

The northeastern Kansas sedimentary deposits of the Wood Siding Formation and the Onaga Shale are recognized as products of Late Pennsylvanian-Early Permian cyclic sedimentation. Reconstruction of the depositional events associated with the units is important in understanding cyclic sedimentation in Kansas.

Studies of 26 measured sections (nine measured and described in detail) utilizing stratigraphic, sedimentologic, and palaeontologic observations provide the basis for interpretation of the depositional environments of the Wood Siding Formation and the Onaga Shale. Results of this study indicate that variations in water depth/distance from shore, controlled by Late Palaeozoic structural features and eustatic sea level changes, were the major factors controlling sedimentation.

On the basis of lithologic and palaeontologic characteristics, four fifth-order cycles of sedimentation (cyclothems), of about 400,000-500,000 years duration, have been identified within the Wood Siding Formation and the Onaga Shale. At least five sixth-order cycles of sedimentation, with periodicities of 100,000-225,000 years or less, have also been identified within the two formations. The boundaries between sixth-order cycles are represented by thin, laterally persistent fossiliferous limestone beds or by climate change surfaces.

Sediments deposited in the southern part of the study area, along the western edge of the Forest City Basin, exhibit distinct differences from their northern counterparts which accumulated along or near the Nemaha Anticline. The thickest, most marine sediments are

associated with the Forest City and Cherokee Basins. Typical marine fossils include marginiferid, chonetoid, and orthotetid brachiopods; crinoid columnals; and fenestrate bryozoans. Channel facies with pyritized and coalified plant fossils are more common in the northern portion of the study area and suggest marshy to swampy depositional conditions.