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STRATIGRAPHY AND SEDIMENTOLOGY OF THE  
UPPER MARMATON GROUP AND THE PLEASANTON  
GROUP (PENNSYLVANIAN) OF SOUTHEASTERN KANSAS

by

Margo Jean Sutton

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STRATIGRAPHY AND SEDIMENTOLOGY  
OF THE UPPER MARMATON GROUP AND THE PLEASANTON GROUP  
(PENNSYLVANIAN)  
OF SOUTHEASTERN KANSAS

by  
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A thesis submitted in partial fulfillment  
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CERTIFICATE OF APPROVAL

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M.S. THESIS

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## ABSTRACT

Cyclothemic carbonate-shale deposition dominated Pennsylvanian sedimentation in the Midcontinent region of the United States during late Desmoinesian and early Missourian time. Five periods of deltaic sedimentation during regressive phases of cyclic sedimentation account for the deposition of five sandstone units within the interval from the Lake Neosho Shale to the Mound City Shale in southeastern Kansas. In ascending order these sandstones occur (1) within the Nowata Shale, (2) between the lower (Norfleet) Member and the upper (Idenbro) Member of the Lenapah Formation, (3) within the newly proposed Mound Valley Formation, (4) at the base of the Seminole Formation (base of the Missourian stage), and (5) within the Tackett Formation.

The two sandstone units just below the Desmoinesian-Missourian boundary have been incorrectly mapped as "Hepler" sandstones within the outcrop belt of southeastern Kansas. The sandstone unit at the base of the Seminole Formation is in the stratigraphic position accorded the Hepler elsewhere in Kansas and Missouri. Evidence from geophysical well logs indicates that the sandstone at the base of the Seminole

Formation is the thickest and cleanest of the sandstones mapped as "Hepler" in southeastern Kansas.

Isopach and isolith maps of the stratigraphic interval that contains the two upper sandstones, the Hepler and Knobtown sandstones, show that these units occupy positions within lobate sedimentary thickness trends. The overall geometries and sedimentary characteristics observed in outcrops and interpreted from well-log signatures suggest that these units were deposited in deltaic environments during regressive phases of cyclic sedimentation.

As the delta prograded into the study area, the first sediments associated with the Hepler Sandstone were fine-grained prodeltaic muds. With continued regression the delta prograded in response to continued sediment supply, and coarser-grained delta-front, marine bar, and channel sands were deposited under higher energy conditions.

The Knobtown Sandstone was deposited under alternating energy conditions. The alternation that resulted in the interbedding of shales and sandstones possibly involved suspension deposition during low-flow stages and sand transport during flood time in a delta-front environment, or the shifting of channels across the delta plain. Seaward of the Knobtown Sandstone, a thick carbonate formed along a transitional slope away from detrital influx or perhaps on local topographic highs.

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## INTRODUCTION

### Geologic Setting

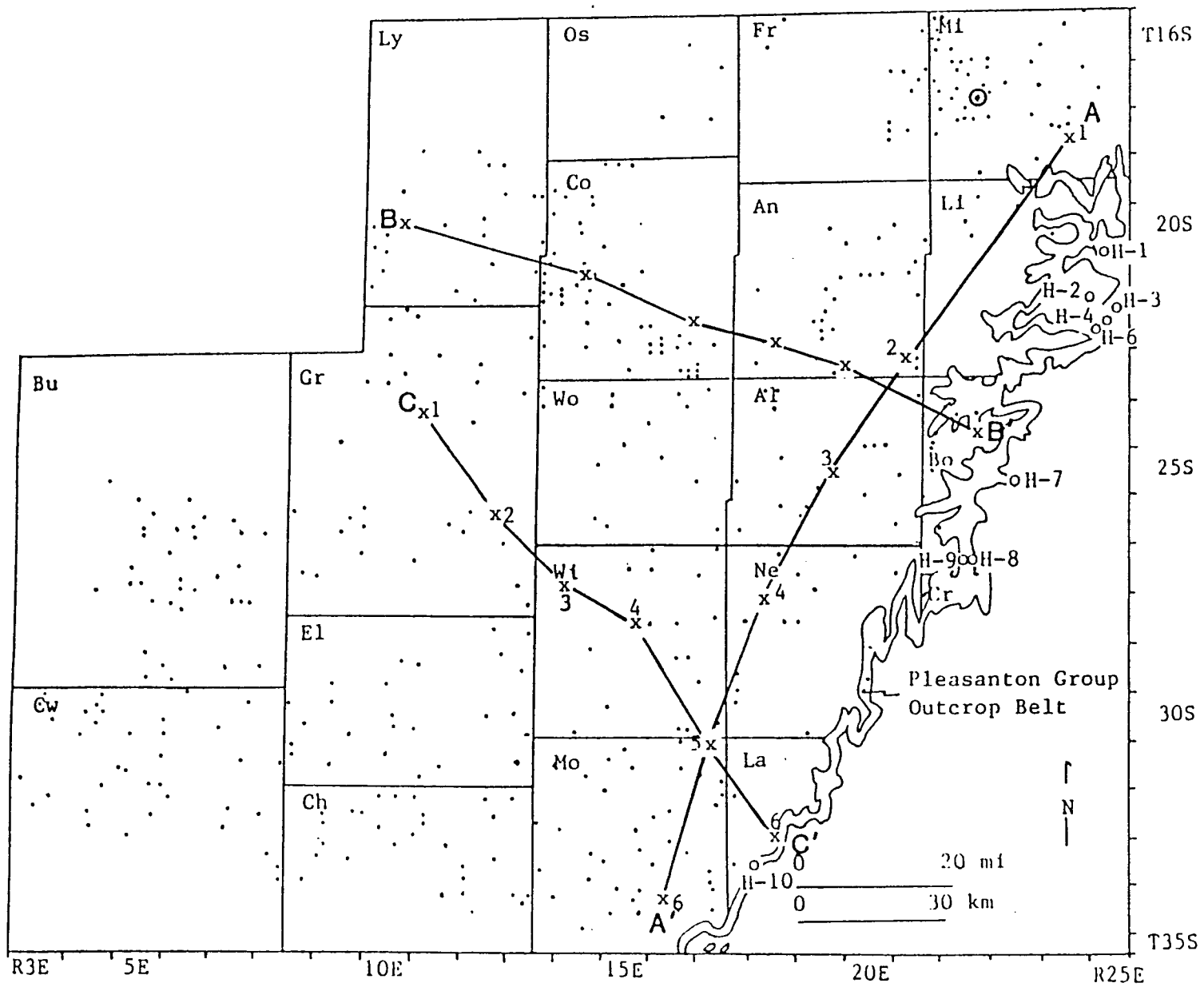
#### Location of Study Area

The study area is located in southeastern Kansas, covering a twenty-county area (Fig. 1). The Pleasanton Group outcrop belt trends across southeastern Kansas, through parts of Montgomery, Labette, Neosho, Crawford, Bourbon, Linn, and Miami Counties, with many geophysical logs and a core from wells located west of the outcrop belt (Fig. 1).

#### Tectonic Features

During the Late Mississippian and Early Pennsylvanian, the Midcontinent east of the ancestral Rocky Mountains was subjected to rapid and intense deformation (Kluth and Coney, 1981). Five stages recognized in the Pennsylvanian System in ascending order are: Morrowan, Atokan, Desmoinesian, Missourian, and Virgilian. During Morrowan and Atokan time, all or most of eastern Kansas was a low-lying positive area that exposed Mississippian and older Paleozoic rocks. South of Kansas, the Arkoma and Anadarko basins were developing, possibly in response to the continental suturing to the

Figure 1. Location of study area in southeastern Kansas. Pleasanton Group outcrop belt, distribution of well logs, core, and cross sections locations are shown. Open circles correspond to outcrop localities where exposures were measured, described, and sampled. Dots correspond to well log locations. X's refer to well logs used in cross section construction. Circled dot corresponds to well log with core. Counties: Mi=Miami; Li=Linn; Bo=Bourbon; Fr=Franklin; An=Anderson; Al=Allen; Ne=Neosho; La=Labette; Os=Osage; Co=Coffey; Wo=Woodson; Wi=Wilson; Mo=Montgomery; Ly=Lyon; Gr=Greenwood; El=Elk; Ch=Chautauqua; Bu=Butler; Cw=Cowley; Cr=Crawford.

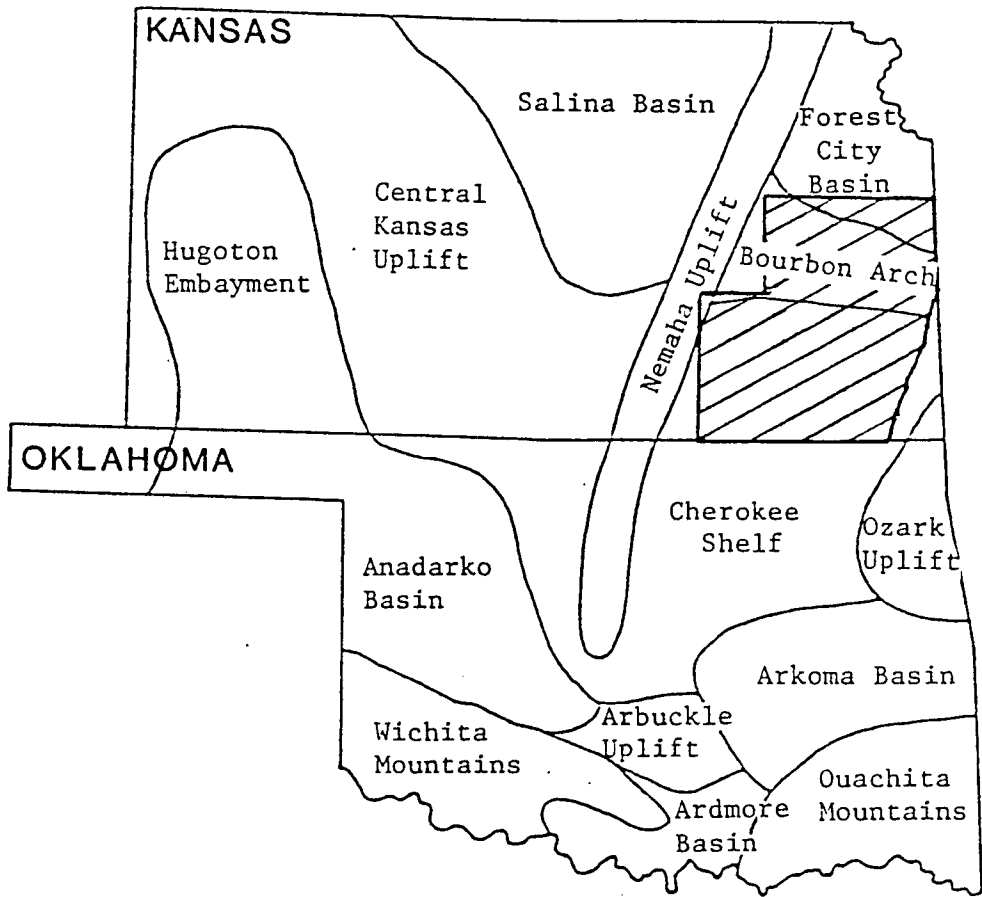


south resulting from the collision between the North American and South American-African plates (Kluth and Coney, 1981). The main structural features produced at this time in eastern Kansas were the Nemaha Uplift and the Bourbon Arch (Merriam, 1963) (Fig. 2).

The Nemaha Uplift trends NNE to SSW and divides the older North Kansas Basin into two regions, the Salina Basin to the west and the Forest City Basin and Cherokee Shelf to the east (Merriam, 1963; Moore, 1979). The Bourbon Arch, which separates the Cherokee Shelf from the Forest City Basin, was a positive feature at various times during the Pennsylvanian and trends WNW to ESE through east-central Kansas and into Missouri (Merriam, 1963). The Ozark Uplift forms the eastern boundary of the Cherokee Shelf and the southeastern boundary of the Forest City Basin (Fig. 2). The Cherokee Shelf, a shallow northward extension of the Arkoma Basin of Oklahoma was a low-lying, stable area during Middle and Late Pennsylvanian time.

The cyclic nature of the Pennsylvanian deposits has been recognized in Kansas and other areas of the Midcontinent (Weller, 1930, 1931, Moore, 1936, 1949). Eustatic sea level fluctuations resulting from Gondwanan glaciation have been suggested to account for cyclothem development and lateral distribution of lithofacies (Wanless and Shepard, 1936, Heckel, 1980). During periods of

Figure 2. Middle-Late Pennsylvanian structural features of eastern Kansas. Study area diagonally lined. Modified from Moore, 1979.



transgression, the Cherokee Sea advanced northward from Oklahoma, inundating the Cherokee Shelf, and creating marine conditions. During periods of regression deltaic sediments prograded across the Cherokee Shelf. Periods of deltaic progradation added second-order modifications to eustatic cyclothem development (Boardman, et al., 1984).

### Stratigraphic Overview

Moore and Jewett (1932) originally designated the strata between the top of the Marmaton Group and the base of the Hertha Limestone as the Bourbon Group. In 1947 the geological surveys of Iowa, Kansas, Nebraska, and Missouri concurred that this interval should be designated the Pleasanton Group.

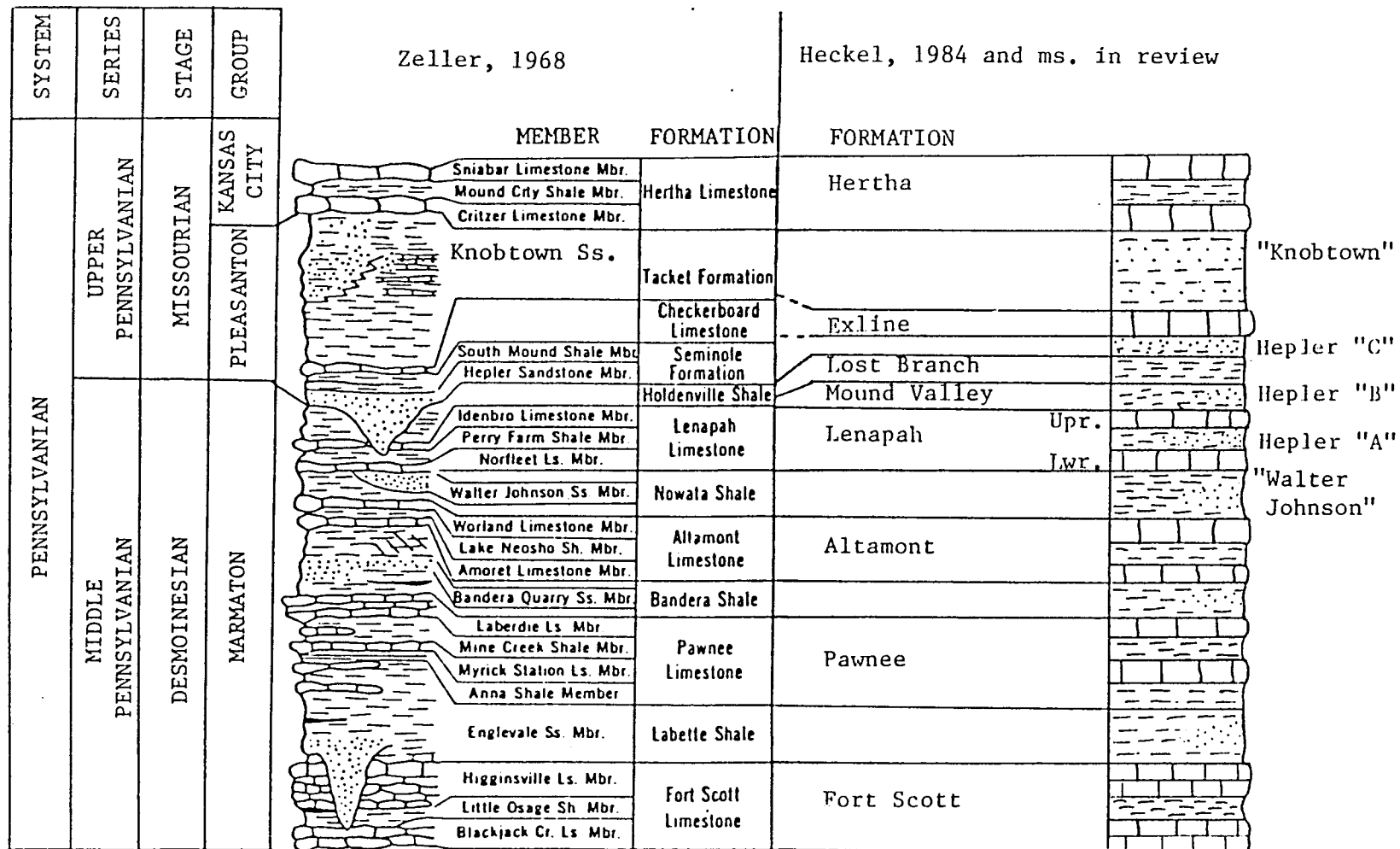
Stratigraphic studies of the Pleasanton Group in Kansas were conducted by Hatcher (1961) and Emery (1962) and summarized by Jewett et al. (1965). The Pleasanton Group consists of sandstone, shale, carbonate, and coal, of Missourian (early Late Pennsylvanian) age. In Kansas this group has been divided in ascending order into (Fig. 3): the Seminole Formation, Checkerboard Limestone, and Tackett Formation (Jewett, et al., 1965). "The basal Missourian sandstone" (Jewett, 1937, p.37) of eastern Kansas was designated as the Hepler Sandstone by Jewett (1940), with its type section in Bourbon County, Kansas, just north of

the town of Hepler. In Kansas, the Hepler is currently recognized as the basal sandstone member of the Seminole Formation, and is overlain by the South Mound Shale Member (Jewett, et al., 1965). The lower boundary of the Hepler Sandstone Member has been defined as the disconformable surface that truncates the underlying Desmoinesian rocks (Jewett, 1940).

The Hepler Sandstone in Kansas is a fine to very fine-grained, micaceous, calcite-cemented sandstone (Jewett et al., 1965). Hatcher (1961) noted that in the northern part of the outcrop belt a concentration of calcium carbonate occurs in the middle of the Hepler Sandstone. Jewett et al. (1965) reported that the Hepler is thicker (maximum reported 26 ft (7.8 m)) in the northern part than in the southern part (maximum reported 12 ft (3.7 m)) of the outcrop belt, while the average thickness throughout the outcrop belt is 4 ft (1.2 m). Emery (1962) noted that a marked decrease in grain size accompanies the general southward thinning.

The Pleasanton Group is underlain by the Marmaton Group, which consists of sandstone, shale, and carbonate, of Desmoinesian (upper Middle Pennsylvanian) age. Eight formations currently recognized in the Marmaton Group in ascending order are (Zeller, 1968): Fort Scott Limestone, Labette Shale, Pawnee Limestone, Bandera Shale, Altamont Limestone, Nowata Shale, Lenapah Limestone, and Holdenville Shale (Fig. 3).

Figure 3. Stratigraphic column of Marmaton, Pleasanton, and Kansas City groups in Kansas. Stratigraphic positions of proposed Lost Branch Formation, proposed Mound Valley Formation, and Hepler "A", "B", and "C" sandstones. Modified from Zeller, 1968 and Heckel, 1984 and ms. in review. Exline Limestone has not been definitely recognized in Kansas.



The work of Bennison, et al. (1981) in Oklahoma has shown that the term "Holdenville" is inappropriate for the uppermost Desmoinesian unit north of the Tulsa area. Heckel (1984; ms. in review) proposes that this term should be abandoned in northern Oklahoma, Missouri, and Kansas. The highest Desmoinesian unit is currently referred to as the Lost Branch Formation (Fig. 3) (Heckel, 1984). The Lost Branch is a sequence of marine shales with thin limestones that includes most of the strata formerly contained in the Holdenville Formation north of Oklahoma (Heckel, ms. in review). The Nuyaka Creek shale bed (Bennison, et al., 1981) is a black shale bed within the lower portion of the Lost Branch Formation. Recent biostratigraphic data strongly suggests that the Desmoinesian-Missourian boundary is correctly placed at the base of the Seminole Formation, which is the top of the newly proposed Lost Branch Formation (Heckel, ms. in review), and is marked by the sandstone generally considered to be Hepler.

Between the Lenapah Limestone and the Lost Branch Formation (Fig. 3), a new unit is recognized and is referred to provisionally as the Mound Valley Formation (Heckel, ms. in review). This unit consists of the Dawson Coal, its underclay, and equivalent detrital rocks many of which were formerly included in the Holdenville Formation, and some referred to as Hepler (Heckel, ms. in review).

When Jewett originally named the Hepler at its type section in southwestern Bourbon County, Kansas, he was actually describing a sandstone now considered to be within the Mound Valley Formation, below the Nuyaka Creek black shale bed, rather than above it, as the Hepler is considered to be (Heckel, ms. in review). This error, in combination with limited outcrop exposure and limited stratigraphic control on outcrop caused subsequent workers to call any sandstone near the Desmoinesian-Missourian boundary Hepler. Thus, earlier workers assumed that all sandstone units exposed near the Desmoinesian-Missourian boundary were at the same stratigraphic horizon. The apparent variations in the stratigraphic positions of the Hepler sandstone units were explained as being due to erosion in places into the underlying beds (Heckel, ms. in review).

At least three sandstone units occupying different stratigraphic horizons have been called Hepler in Kansas (Fig. 3) within the interval between the lower (Norfleet) Member of the Lenapah Limestone (below the Lost Branch) and the Hertha Limestone (above the Pleasanton) (Heckel, pers. commun., 1983). For the purpose of this discussion, each of these sandstones in ascending order will be referred to as Hepler "A", "B", and "C". Hepler "A" is recognized between the upper (Idenbro) and lower (Norfleet) Lenapah Members, Hepler "B" is recognized within the Mound Valley Formation,

and Hepler "C" occupies the originally recognized stratigraphic position at the base of the Missourian Pleasanton Group (Heckel, pers. commun., 1983) (Fig. 3).

The Walter Johnson Sandstone Member of the Nowata Shale, below the Lenapah Limestone, is a thin-bedded to massive sandstone and occurs locally in southeastern Kansas (Zeller, 1968). The Knobtown Sandstone Member in the top of the Pleasanton Group occurs from Kansas City southward to Linn County (Greene, 1933). On outcrop in southern Linn County and northern Bourbon County, the upper part of the Pleasanton Group contains a unit of repetitive thin, dark-gray, silty, micaceous shales and dark-gray argillaceous, sublithographic, unfossiliferous limestone informally called the Bourbon flags. The Bourbon flags crop out along a narrow belt averaging 5 to 6 km wide and nearly 40 km long, trending southwest-northeast (Underwood, 1984).

The Kansas City Group overlies the Pleasanton Group. The Hertha Limestone, the lowest formation in the Kansas City Group is divided into three members. In ascending order the members are: Critzer Limestone, Mound City Shale, and Sniabar Limestone (Fig. 3). Underwood (1984) showed that the Critzer Limestone is closely associated with the Bourbon flags, and that the Mound City Shale thickens southward to become the top of the Pleasanton Group in Bourbon County, and to the south.

### Purpose of Study

Previous geologic studies concerning Late Desmoinesian and Early Missourian strata in eastern Kansas have left aspects of stratigraphy and stratigraphic nomenclature regarding this interval problematic. The interval of focus in this study was from the Lake Neosho Shale Member of the Altamont Limestone upward to a black shale facies that appears in the Mound City Shale south of Linn County (Fig. 3). The primary purpose of this investigation was to determine the number and stratigraphic positions of sandstone units designated as "Hepler" and to determine the lithologic characteristics of each unit called "Hepler" in this interval. Two sandstone units at stratigraphic positions that possibly are the Knobtown and Walter Johnson sandstones, which are similar to the "Hepler" sandstones, were also considered for comparative purposes. The "Hepler" and Knobtown sandstones were analysed to (1) determine the lateral and vertical extent of each sandstone unit, (2) determine the siliciclastic sediment source(s), and (3) suggest depositional environments for these sandstone units.

### Methods of Study

#### Physical Analyses

Nine surface sections were measured, described, and sampled (Appendix A). One available core was described and

sampled. Petrographic analysis was conducted on the sandstone samples collected from surface sections and from the core. The sandstone samples were impregnated with a blue-dyed epoxy resin prior to the cutting of thin-sections. The thin-sections were etched and stained by the Boone and Wheeler (1968) Method to determine the presence of potassium feldspar. The thin-sections were stained with alizarin red-S to distinguish dolomite from calcite and with potassium ferricyanide to distinguish ferroan calcite and dolomite from non-ferroan calcite and dolomite. Petrographic analysis was used to determine the composition of the grains, cements, and fine-grained materials in order to determine the siliciclastic provenance and the compositional and textural variations that exist among the "Hepler" sandstones. Modal analyses of nine thin-sections from four localities were conducted, using 250 grid points per thin-section and classified according to Folk's classification scheme (1974).

Outcrop analyses were used for interpreting lithologies and to help correlate geophysical well-log signatures of the various lithologies within the study interval. In addition, a gamma-ray-neutron log of the cored interval was compared with the core lithologies to determine the gamma-ray log response to the various lithologies.

## Geophysical Analysis

Geophysical well-log signatures are direct physical responses to variation in lithologic characteristics and interstitial fluid chemistry. This often enables the delineation of lithologic boundaries of subsurface units.

Gamma ray-neutron logs were used to determine the lithologies. Gamma-ray logs respond to the gamma rays produced in the process of radioactive decay of naturally occurring earth materials. Most of the radiation encountered is the result of the gamma rays produced by Potassium 40 and the decay daughter products in the uranium and thorium series, which occur in clay minerals that are commonly found in large quantities in fine-grained mudrocks. For example, the response to phosphatic black shales is a high gamma-ray count, which is recorded as a strong deflection to the right. In contrast, limestones generally record low gamma-ray counts indicated by a strong deflection to the left. Moderate gamma-ray counts are generally recorded for light-gray, siltier shales. Sandstones generally have gamma-ray counts that are intermediate between those of shale and limestone. The gamma-ray log was used as an indicator of shaliness or, conversely, to delineate shale-free zones. Since grain size and shaleness of the sandstone reflect the energy of environment of deposition, the gamma-ray log was used to interpret

continuous grain-size profiles sequences penetrated by the wells studied. These relationships enable lithologic interpretations to be made from well-log signatures.

Well-log signatures were compared with outcrop and core descriptions of lithologies so that depositional and stratigraphic relationships of lithofacies could be interpreted. Within the interval of study four different types of lithologies are identifiable on the gamma-ray-neutron log: black shale, limestone, shale, and sandstone. West of the outcrop belt, lithologic interpretations were based on knowledge of the stratigraphy and on interpretations made from well-log signatures. Figure 4 shows a "type" gamma-ray and neutron log with interpreted lithologies for the interval of study for the northern portion of the study area. Figure 5 shows a "type" gamma-ray and neutron log with interpreted lithologies for the interval of study in the southern portion of the study area.

The stratigraphic relationships of the Hepler "C" and Knobtown sandstones were established using the geophysical well logs. The well-log data were used to determine the lateral and vertical extent of the various sandstone units, through the construction of isopach and isolith maps and cross sections. The Lake Neosho, Nuyaka Creek, and Mound City black shales are each laterally continuous in the study area, and easily recognizable on the well logs. For these

Figure 4. "Type" gamma-ray and neutron signatures and interpreted lithologies of study interval in northern portion of study area. Note that black shales bounding the study interval are recognized in subsurface by abrupt, high gamma-ray deflection. Well log from sec. 5, T23S, R21E.

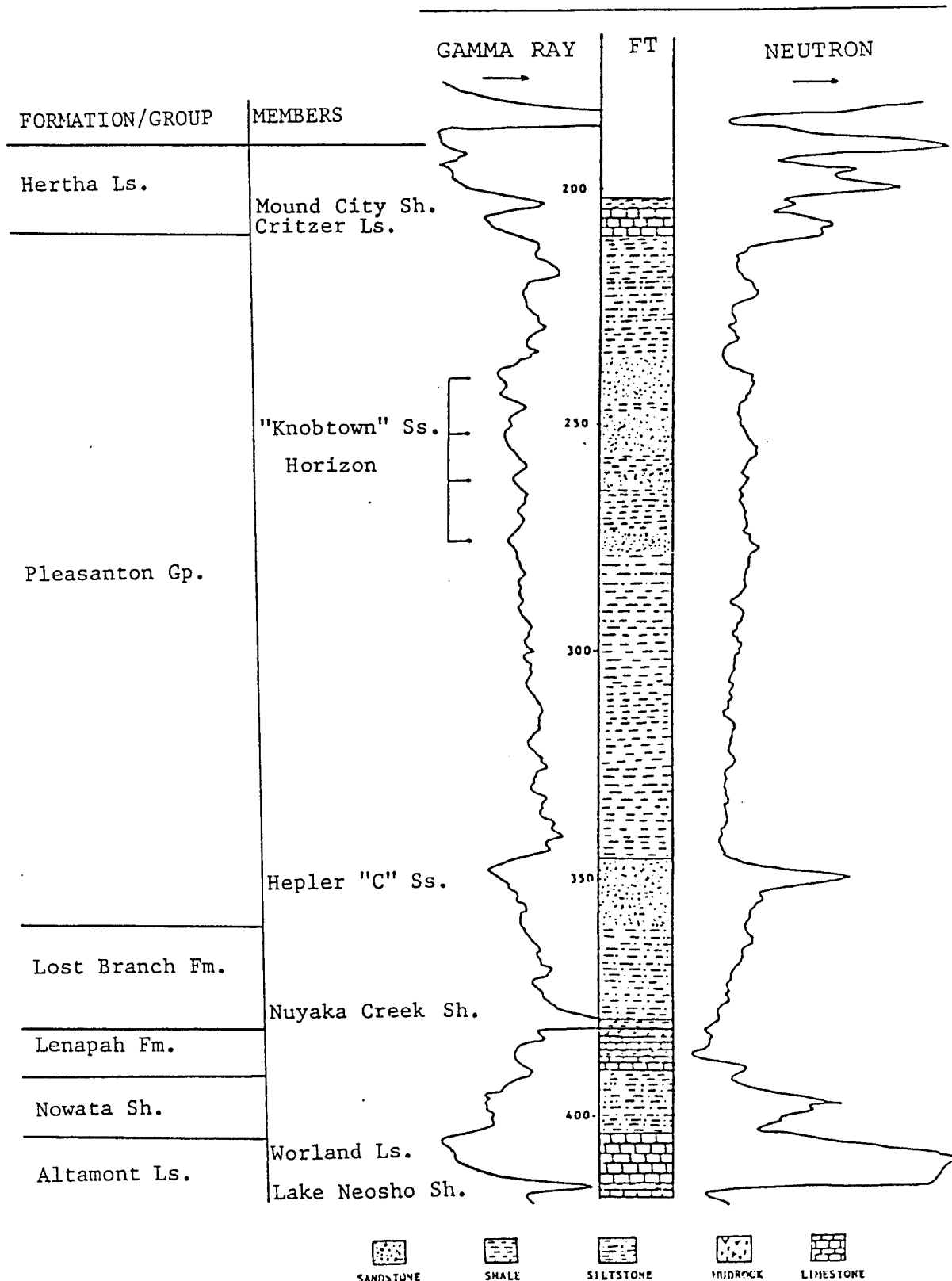
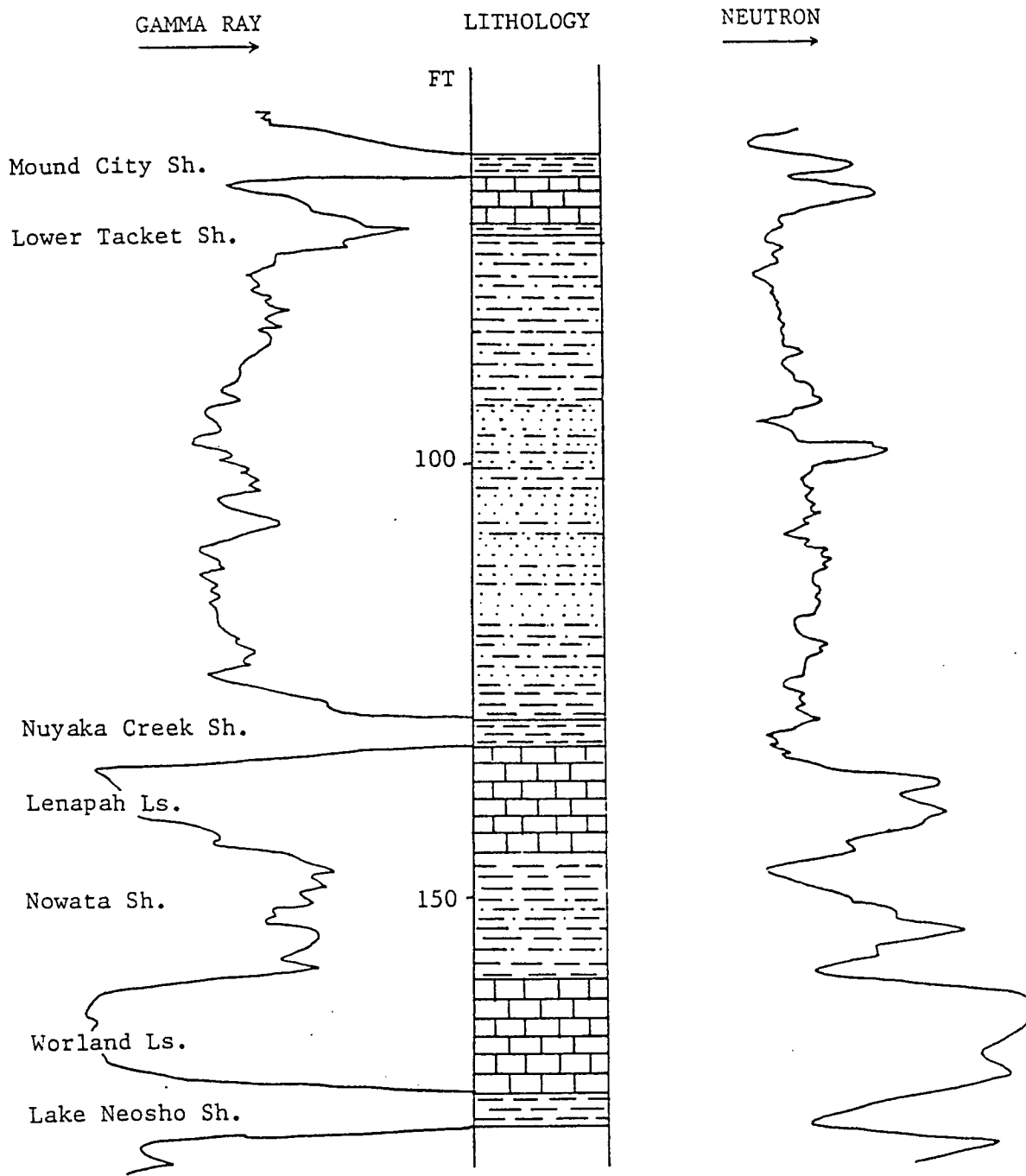


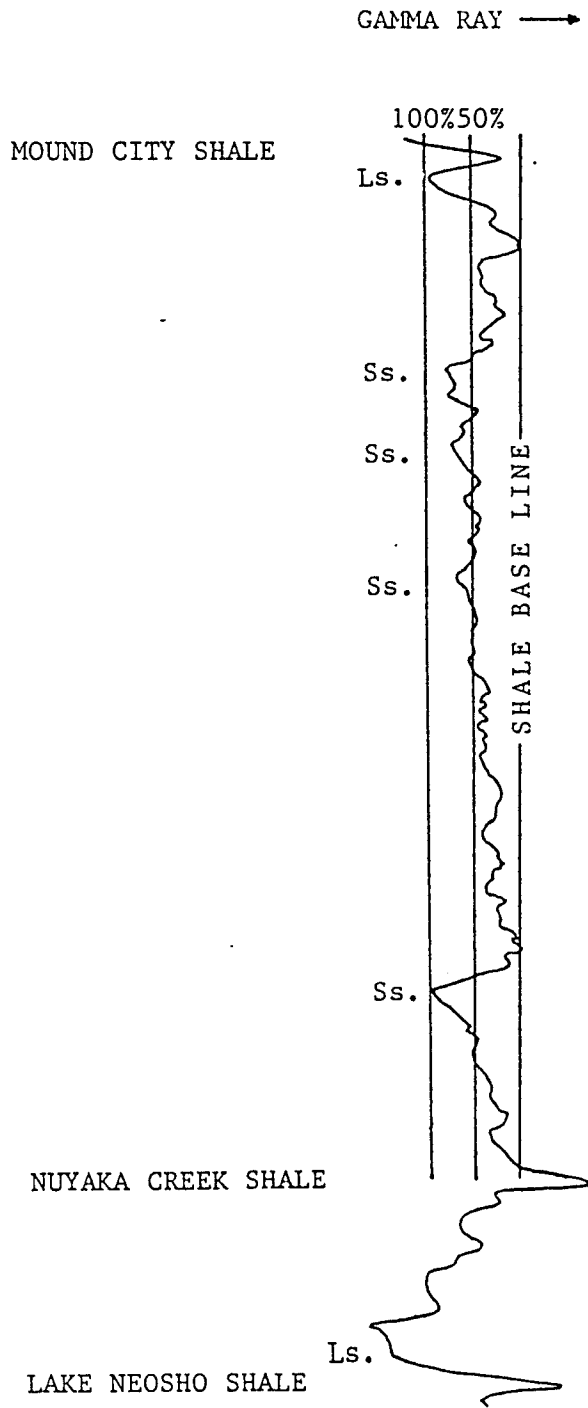
Figure 5. "Type" gamma-ray and neutron signatures and interpreted lithologies of study interval in southern portion of study area. In southern portion of study area the lower Tacket shale is present. Well log from sec. 34, T32S, R16E.



reasons they were used as marker horizons (Figures 4 and 5). The key marker horizons made well-to-well stratigraphic correlations possible. These marker horizons provided the framework for isopach and isolith maps and cross-section construction. The Nuyaka Creek Shale served as the datum bed from which cross sections were hung. Three detailed stratigraphic cross sections were constructed across parts of the study area to permit correlation, to illustrate the stratigraphic relationships and variation in the well-log signatures, and to aid in lithologic and depositional history interpretations. Tracing the Hepler "C" and Knobtown sandstones in the subsurface was accomplished using approximately 450 geophysical well logs.

In order to generate sandstone isolith maps, a shale base-line was constructed at gamma-ray values that relate to gray shales, and a clean sand line was constructed at gamma-ray values that relate to clean sandstone units (Fig. 6). A 50% sand line bisecting the number of gamma-ray units between the shale base line and the clean sand line was constructed. The portion of the gamma-ray curve to the left of the 50% sand line has been interpreted as being composed of greater than 50% sand-sized material. The thicknesses of the sandstone units along this line were recorded and used to construct sandstone isolith maps.

Figure 6. Method used to determine thickness of individual sandstone horizons within interval from Nuyaka Creek Shale to Mound City Shale. Non-black shale, clean sand, and 50% sand lines were constructed for each log. Thicknesses were recorded along 50% line for sandstone distribution maps.



Sandstone isolith maps were constructed for the sandstones between the Nuyaka Creek and the Mound City shales. This interval was divided into upper and lower units since each contains sandstone units and the two sandstone units appear to represent separate depositional phases. In the northern portion of the study area, a thickness of shale was used to separate the lower sandstone from the upper sandstone. The lower Tacket shale, a black shale present in the southern portion of the study area, was used to separate the upper sandstone from the lower sandstone when the lower Tacket shale is present (Fig. 5). The lower sandstone in this interval occupies the stratigraphic position of the Hepler "C" sandstone, while the upper sandstone in this interval occupies the stratigraphic position of the Knobtown Sandstone. There is stratigraphic uncertainty between the type Knobtown Sandstone and a sandstone observed at the top of the Pleasanton near Mound City, Kansas (Heckel, per. commun., 1985). Therefore, for purposes of this study the sandstones in the upper Pleasanton will be referred to as "Knobtown".

Synthesis of all the aforementioned analyses were used to interpret depositional environments for the Walter Johnson, each of the "Hepler", and the "Knobtown" sandstones.

## STRATIGRAPHIC ANALYSES

### Core-Well Log Analyses

The vertical sequence of lithologies cored in well OSH-1A (Miami County, Kansas) in ascending order consists of: (1) fossiliferous limestone, (2) mottled, medium-gray shale and very fine-grained sandstone, (3) interlaminated medium-gray shale and very fine-grained sandstone, (4) medium-gray shale with regular parallel laminations with some lenticular very fine-grained sandstone, and (5) fine-grained, massive, well-sorted, ferroan dolomite-cemented sandstone (Fig. 7).

The sandstone in this core was labeled by the Kansas Geological Survey as being "Hepler" sandstone. Figure 7 compares the gamma-ray log response to the lithologic characteristics of the cored interval. Analysis of the well log and core shows that the sandstone is actually at a stratigraphic horizon of the Nowata Shale and is possibly the Walter Johnson Sandstone (Fig. 7). The sandstone at this horizon will be referred to as "Walter Johnson" due to stratigraphic uncertainty between the type Walter Johnson in Montgomery County, Kansas and the sandstone in core OSH-1A. The "Walter Johnson" sandstone was not recognized in any

other well logs used in this study other than at the locality where the sandstone was cored. This can be attributed to it being thicker north or northeast of the study area and thinner than the bed resolution of gamma-ray logs elsewhere in the study area.

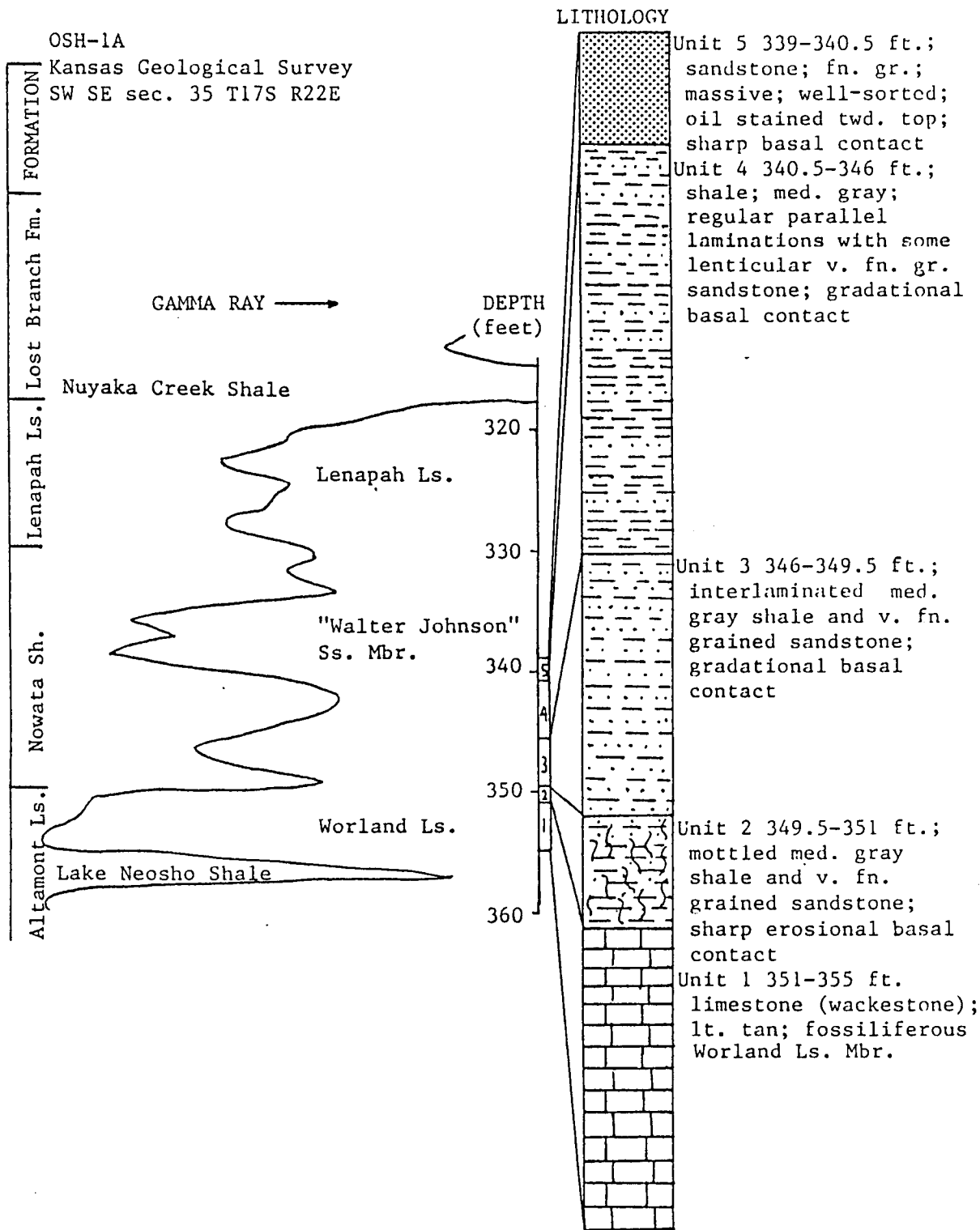
Cored samples of the "Hepler" and "Knobtown" sandstones were not available for this study.

#### Hepler "A" Sandstone

Hepler "A" was observed at the Uniontown East section (H-7) (Appendix A). The vertical sequence of lithologies at this locality in ascending order consists of: (1) dense calcarenite (Norfleet Limestone Member of the Lenapah Limestone) (Heckel, pers. commun., 1985), (2) very fine-grained sandstone interbedded with shale (mostly covered), (3) fine-grained sandstone with micaceous shale partings, (4) fine- to medium-grained, ripple-laminated sandstone and some large scale cross-stratification, (5) fossiliferous, sandy limestone (Idenbro Limestone Member of the Lenapah Limestone) (Heckel, pers. commun., 1985), (6) medium-gray shale, (7) very fine-grained sandstone, interbedded with micaceous shale, and (8) fine-grained micaceous sandstone.

The Hepler "A" sandstone comprises units 3 and 4 at this exposure. This sandstone lies between two limestones correlated with the Norfleet and Idenbro members of the

Figure 7. Gamma ray log with corresponding core description for core OSH-1A. The sandstone is at stratigraphic horizon of "Walter Johnson" Sandstone Member of Nowata Shale. Core OSH-1A is located in sec. 35, T17S, R22E.



Lenapah Limestone, which is the position of the Perry Farm Shale Member of the Lenapah Limestone. No sandstone as distinct as this was noted in this position on the subsurface well logs. Possible explanations for this include: (1) the sandstones may be too thin (less than 2 feet) to be resolved by the geophysical well logs, (2) the sandstone is not able to be differentiated from the overlying Idenbro and underlying Norfleet members of the Lenapah Limestone, and (3) the sandstone is local in occurrence, perhaps better developed north or northeast of the study area.

#### Hepler "B" Sandstone

Hepler "B" was observed both at the top of the Uniontown East section (H-7) and at the Prong Creek section (H-8) (Appendix A). The vertical sequence of lithologies at Prong Creek in ascending order consists of: (1) dense limestone (Lenapah), probably Norfleet (Heckel, pers. commun., 1985), (2) silty shale, (3) two very thin skeletal calcarenites separated by a thin shale, possibly the Idenbro Limestone (Heckel, pers. commun., 1985), (4) very fine-grained sandstone interbedded with micaceous shale, (5) very fine-grained sandstone, (6) very fine-grained sandstone interbedded with micaceous shale, and (7) fine-to medium-grained, gray, ripple-laminated sandstone with some micaceous partings.

The Hepler "B" sandstone comprises units 7 and 8 at Uniontown East (H-7), and probably units 3 through 8 at Prong Creek (H-8). The sandstone lies above the probable Idenbro Limestone and apparently below the Nuyaka Creek black shale, which is within the "Mound Valley Formation" of Heckel (ms. in review). No sandstone as distinct as this was detected in this position on the well logs. Possible explanations for this include: (1) the sandstones may be too thin (less than 2 feet) to be resolved by the geophysical well logs, (2) the sandstone is local in occurrence and may be thicker south or southeast of the study area, and (3) the sandstone is not able to be differentiated from underlying limestones.

#### Hepler "C" Sandstone

Hepler "C" is best exposed along the Marais des Cygnes River at Trading Post (H-1) (Appendix A). The vertical sequence of lithologies observed on outcrop in ascending order consists of: (1) black phosphatic shale (Nuyaka Creek black shale bed of the Lost Branch Formation), (2) medium-gray, clayey shale with layers of ironstone concretions with thin beds of very fine-grained sandstone toward the top (upper part of the Lost Branch Formation) (Heckel, ms. in review), (3) very fine-grained sandstone interbedded with shale, and (4) fine-grained, ripple-laminated sandstone.

Hepler "C" comprises units 3 and 4 at this section, and was identified on the geophysical well logs by its position not far above the Nuyaka Creek black shale bed, within the lower portion of the interval from the Nuyaka Creek to the Mound City Shale. The well-log signatures of this sandstone are variable and are characterized by three general types: (1) an upward coarsening shale-sandstone sequence with a gradational basal contact and an abrupt upper contact, (2) a thinner shale-sandstone sequence that is mostly sandstone and has both abrupt upper and lower contacts, and (3) two stacked type 2 well-log signatures, that are separated by a thickness of shale (Fig. 8).

#### "Knobtown" Sandstone Horizon

Outcrops of the "Knobtown" sandstone were not observed, hence all stratigraphic interpretations are based on subsurface information. The well-log signatures of the "Knobtown" sandstone are highly variable and suggest that the sandstone is lenticular, occupying various positions in the upper portion of the interval from the Nuyaka Creek Shale to the Mound City Shale. Alterations of high and low gamma-ray values indicate interbedding of shale and sandstone (Fig. 5). The lenticular nature of the sandstones and the variable well-log signatures are displayed in cross-section B-B' (Fig. 9).

Figure 8. Three well-log signatures characteristic of Hepler "C". Type 1 is an upward coarsening shale-sandstone sequence with a gradational basal contact and an abrupt upper contact. Type 2 is a thinner shale-sandstone sequence that is mostly sandstone and has both abrupt lower and upper contacts. Type 3 is two stacked type 2 well-log signatures separated by a thickness of shale.

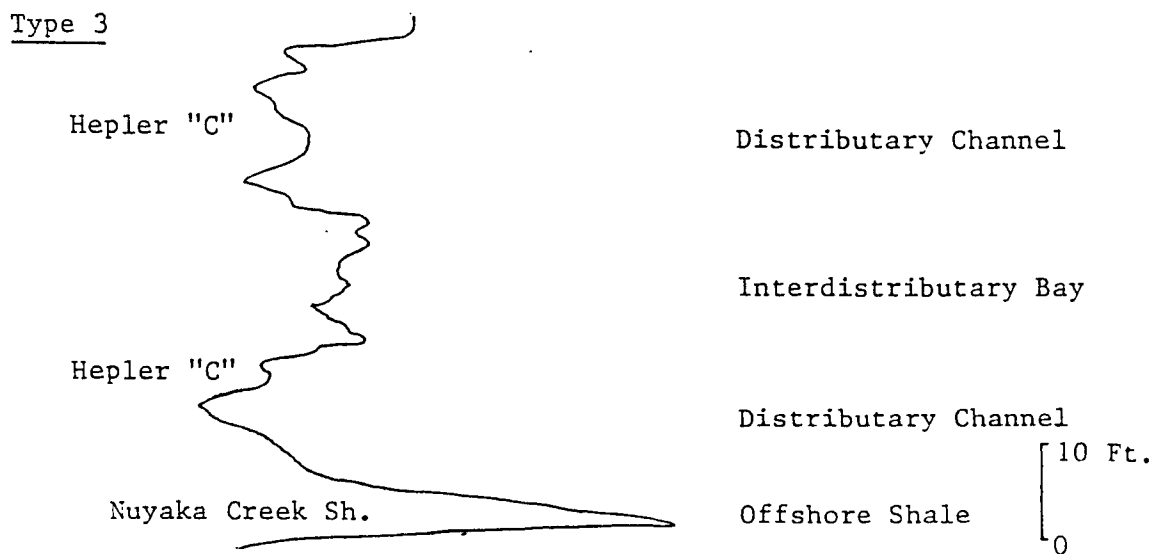
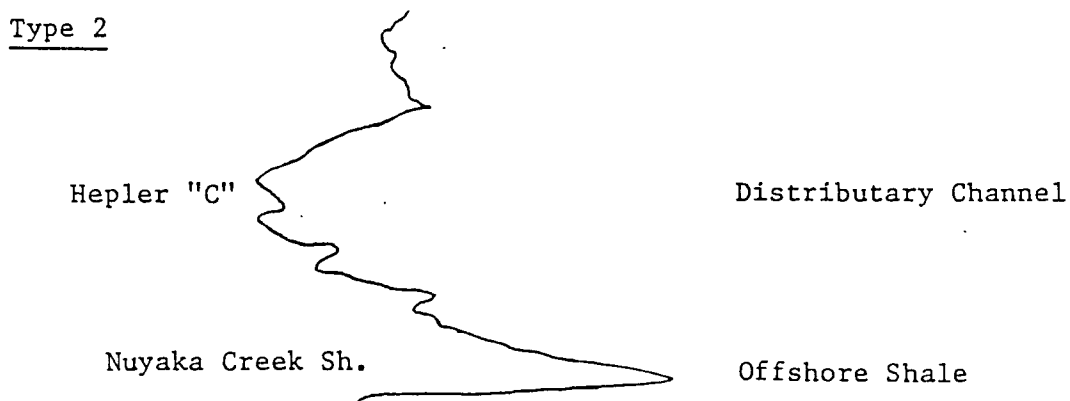
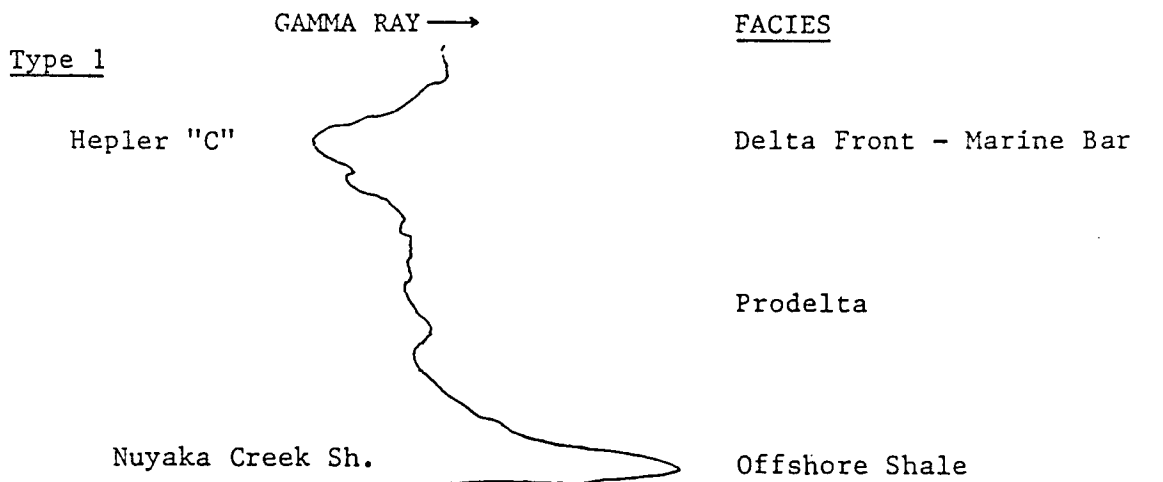


Figure 9. Cross-section B-B'. Lateral continuity of black shales and variation in well-log signatures and lithologies along this traverse are shown. Dashed line separates "Knobtown" sandstone (upper portion) from Hepler "C" sandstone (lower portion). See figure 1 for location.

B

NW

Lyons Co.

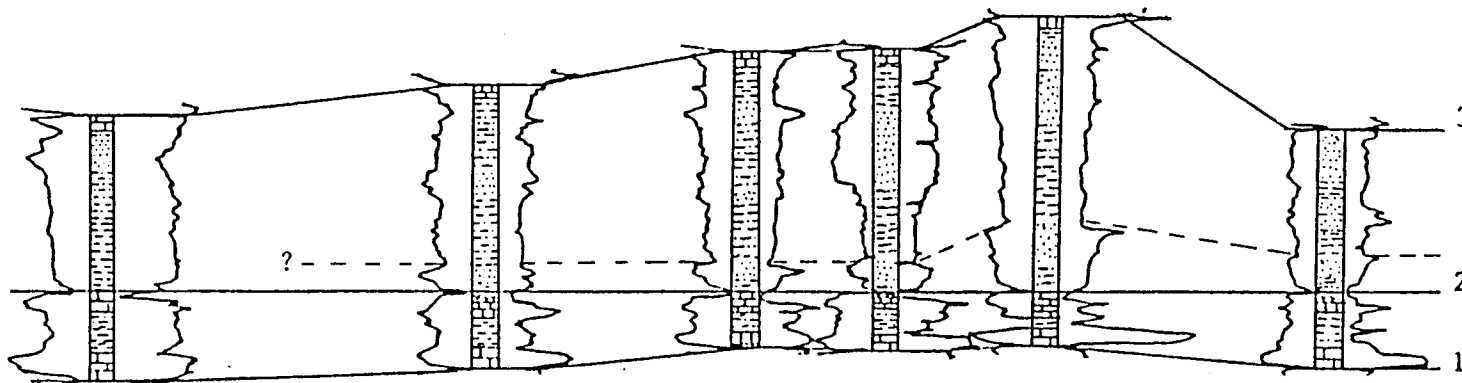
10-T20S-R10E

B'

SE

Bourbon Co.

10-T21S-R14E 11-T22S-R16E 28-T22S-R18E 12-T23S-R19E 14-T24S-R22E



50 Ft | 15 M

10 Mi

6.2 Km

- 1. Lake Neosho Sh.
- 2. Nuyaka Creek Sh.
- 3. Mound City Sh.

In the subsurface, a facies change occurs from north to south in the study area at the stratigraphic horizon of the "Knobtown" sandstone. A north-south cross section (A-A') has been constructed in the subsurface (Fig. 10). Well-log signatures in the three northern wells indicate that the sequence between the Nuyaka Creek Shale and the Mound City Shale is dominated by siliciclastic rocks, whereas in wells 4 and 5 only the sequence between the Nuyaka Creek Shale and the lower Tacket shale is dominated by siliciclastic rocks. In these wells, the low gamma-ray and high neutron values indicate that the sequence from the lower Tacket shale to the Mound City Shale is dominated by carbonate rocks. Well 6 shows a very thin low-gamma count unit in this interval, possibly calcareous shale or argillaceous limestone based on comparison to a nearby outcrop (Heckel, pers. commun., 1985).

#### Interval Thicknesses

Three isopach maps were generated for the interval of study. The maps show the variation in thickness from the (1) Lake Neosho Shale to the Nuyaka Creek Shale (Fig. 11), (2) Nuyaka Creek Shale to the Mound City Shale (Fig. 12), and (3) Lake Neosho Shale to the Mound City Shale (Fig. 13).

Figure 10. Cross-section A-A'. Lateral continuity of black shales and variation in well-log signatures and lithologies along north-south traverse are shown. Dashed line separates "Knobtown" sandstone (upper portion) from Hepler "C" sandstone (lower portion), where lower Tackett shale is not present. See figure 1 for location.

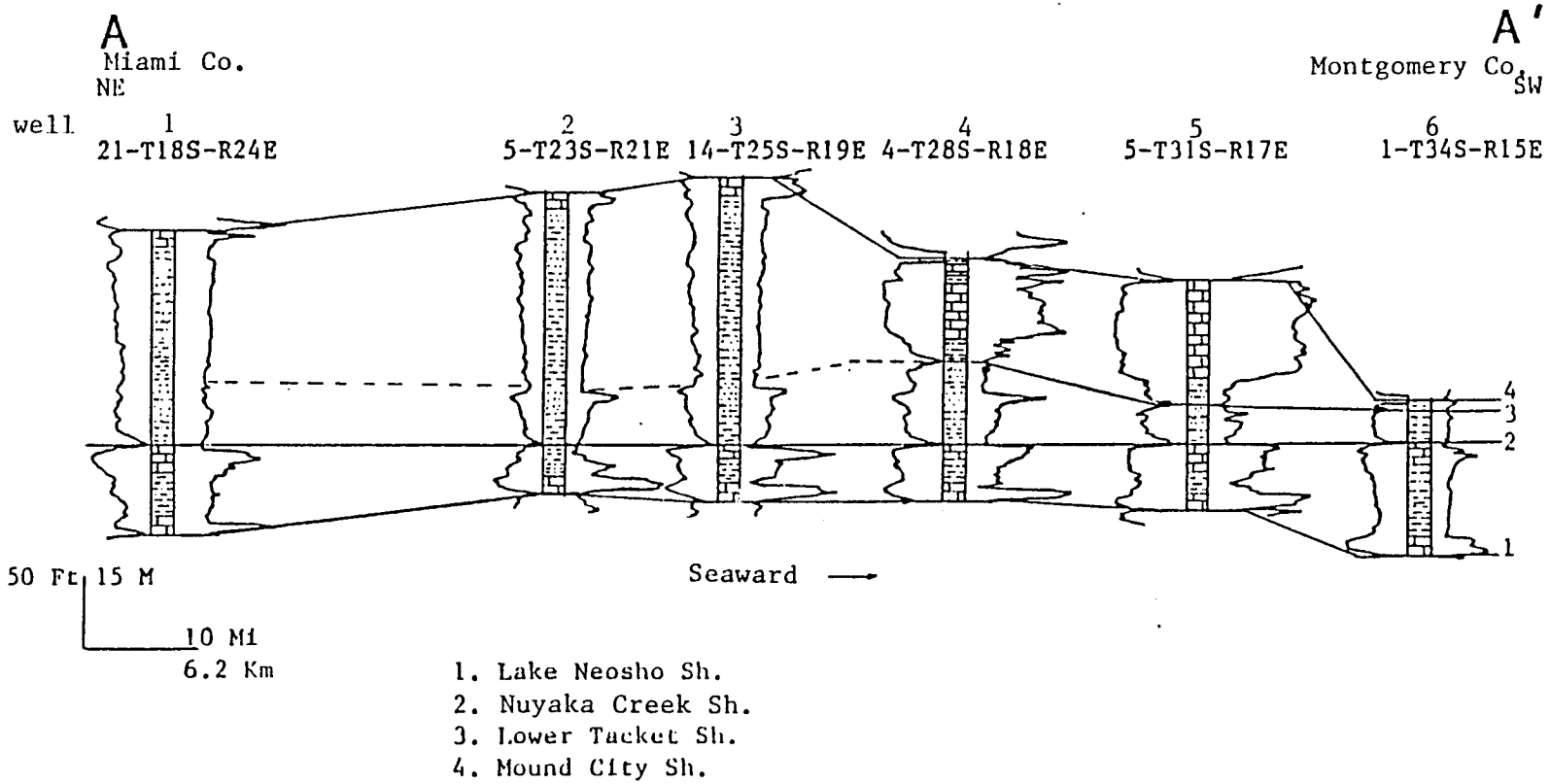


Figure 11. Isopach map of interval from Lake Neosho Shale to Nuyaka Creek Shale. Contour interval equals 10 feet.

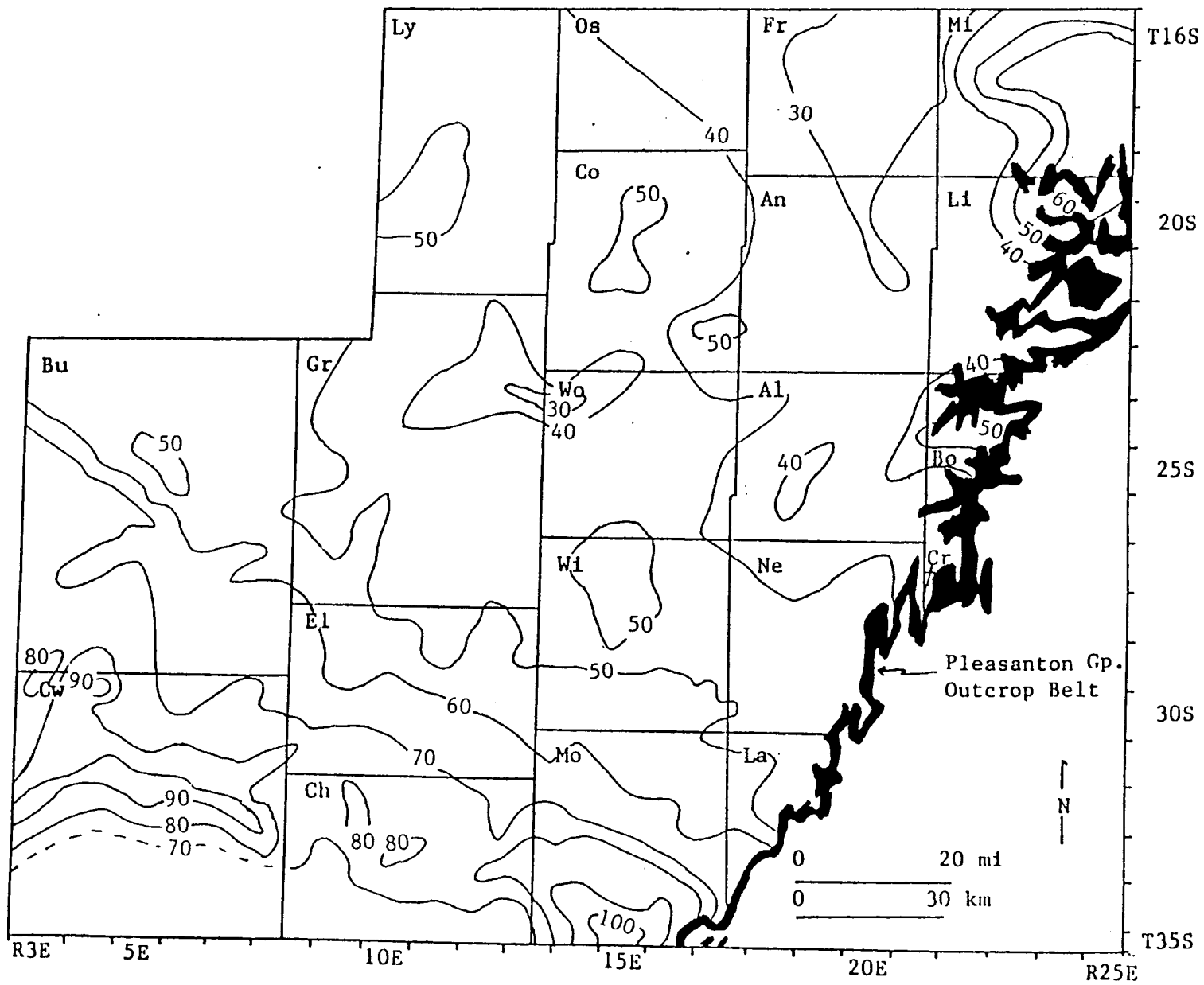


Figure 12. Isopach map of interval from Nuyaka Creek Shale to Mound City Shale. Contour interval equals 20 feet.

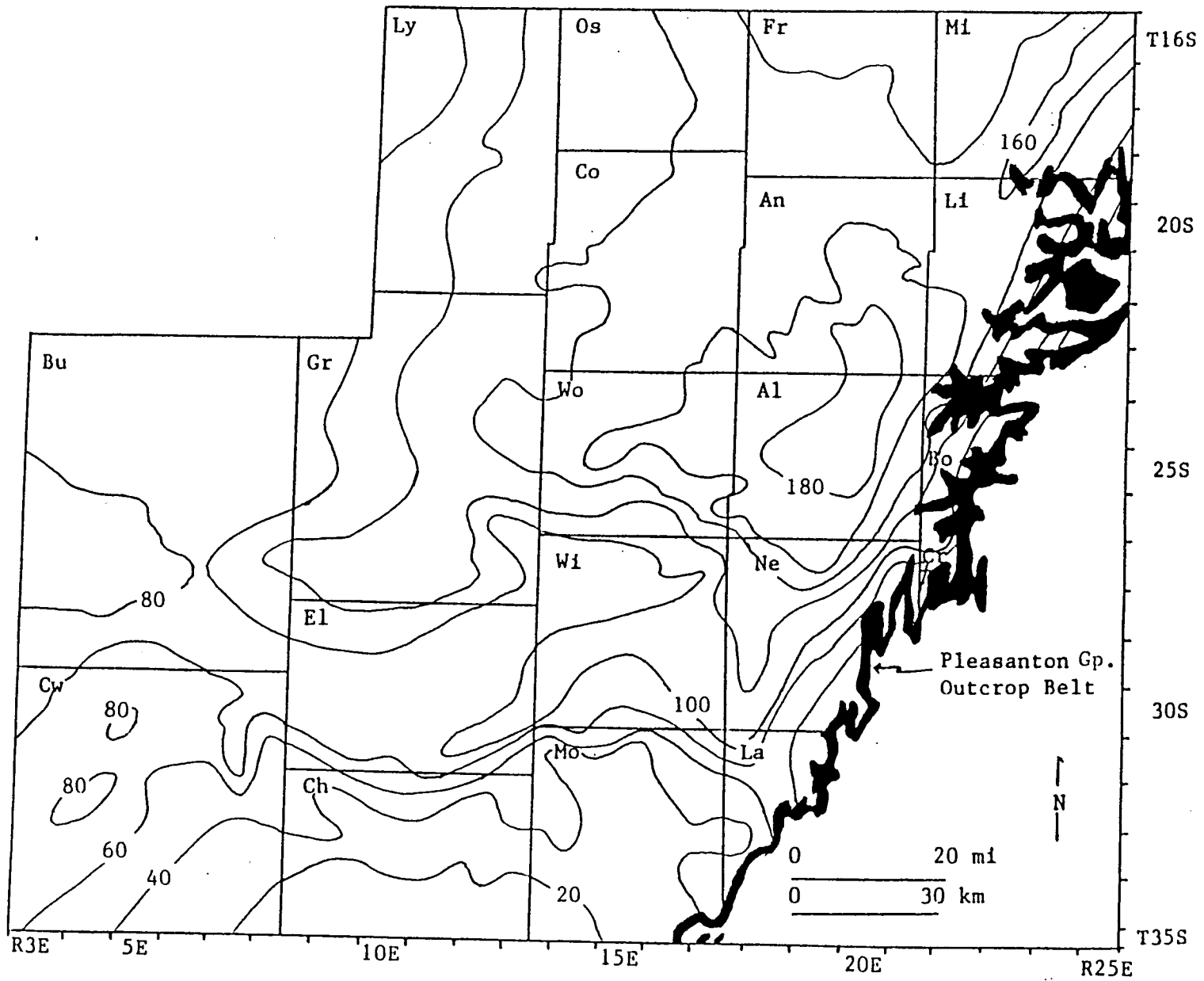
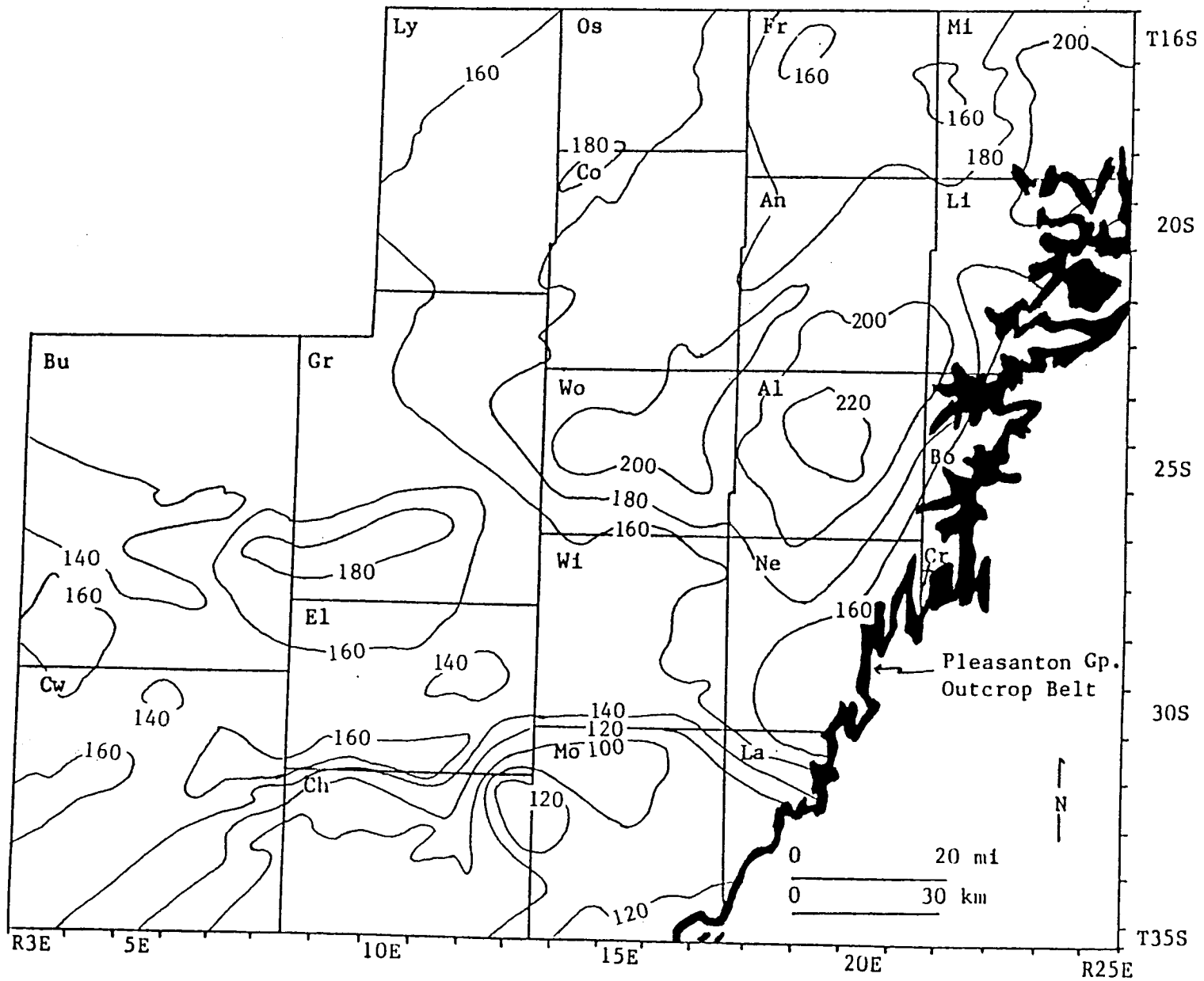


Figure 13. Isopach map of interval from Lake Neosho Shale to Mound City Shale. Contour interval equals 20 feet.



In the study area, the thickness of the interval from the Lake Neosho Shale to the Nuyaka Creek Shale (Fig. 11) ranges from a maximum of 100 feet (30 m) in southern Montgomery County to a minimum of 25 feet (7.5 m) in east-central Anderson County. In general, the rocks in this interval are thickest in the northeast and south and southwest portions of the study area.

The thickness of the interval from the Nuyaka Creek Shale to the Mound City Shale (Fig. 12) ranges from a maximum of 185 feet (55.5 m) in central Allen County and southern Anderson County to a minimum of 20 feet (6 m) in southern Chautauqua County. In general, the contour lines form a lobate shape. There is one distinct area of greater thickness, trending N25°E, extending from northern Neosho County to western Linn County. There is a trend of abrupt thinning that parallels the eastern side of this thickness trend from northern Bourbon County to northern Labette County. In northern Labette County, the thinning trend shifts direction and parallels the northern boundaries of Montgomery and Chautauqua counties.

The isopach map from the Lake Neosho Shale to the Mound City Shale (Fig. 13) shows a range in thickness from a maximum of 225 feet (67.5 m) in central Allen County to a minimum of 85 feet (25.2 m) in northern Montgomery County. Several distinct thickness areas are delineated on this map.

One trends N25°E, extending from southern Anderson County to southern Allen County, and is coincident with the thickness on the Nuyaka Creek to Mound City interval (compare figures 12 and 13). Another thickness trend extends N80°E from east-central Butler County to south-central Greenwood County. Several other local areas of thickening are present.

The thicknesses of the intervals are variable, probably as a result of paleotopography, lateral variations in depositional environments during the time the strata were being deposited, differential compaction, local subsidence, or a combination of several of these factors. Away from the thickest rocks in the interval from the Lake Neosho Shale to the Nuyaka Creek Shale, there appears to be a decrease in thickness of the shale sequence deposited within the Nowata Shale (Figures 10 and 9). This may indicate that this area was farther from the point source(s) of siliciclastics during both phases of detrital deposition. It does not appear that the Bourbon Arch was a positive feature during these time intervals as there is no pronounced thinning of the rock units over the area of the arch in Bourbon, Allen, and Coffey Counties.

## SEDIMENTOLOGICAL ANALYSES

Simons and Richardson (1961) suggested that hydraulic flow regimes are determined by the nature of the bed forms. Since stratification is the product of bed forms, flow regimes can be determined from the characteristics of stratification as outlined by Harms and Fahnestock (1965). Flow regimes can be determined from textures and sedimentary structures observed in cores and on outcrops, and can be interpreted from gamma-ray log signatures in the study area.

"Walter Johnson" Sandstone

The fossiliferous limestone at the base of the OSH-1A core in Miami County is the Worland Limestone Member of the Altamont Formation, which has been interpreted to have been deposited during a regressive phase of cyclic sedimentation (Schenk, 1967). The mottled, medium-gray shale and very fine-grained sandstone may have formed in a prodeltaic, nearshore, quiet-water environment from suspended sediments. The mottled appearance may have been produced by burrowing organisms or it may be a mottled soil horizon. The interlaminated medium-gray shale and the very fine-grained sandstone probably formed under alternating energy

conditions. The shale represents muds deposited from suspension under quiet-water conditions, while the sands were deposited under higher energy conditions. The medium-gray shale with regular parallel laminations probably was deposited in a quiet-water environment from suspended sediments. The lenticular, very fine-grained sandstone probably formed in the lower part of the upper flow regime under higher energy conditions. The fine-grained, massive, ferroan dolomite-cemented sandstone probably was deposited under higher energy conditions.

#### Hepler "A" Sandstone

The Norfleet Limestone below the Hepler "A" horizon has been interpreted to represent a relatively minor transgressive-regressive cycle (Parkinson, 1982). The Hepler "A" unit was deposited during the subsequent regression. Sandstone interbedded with shale (unit 2) was probably deposited under alternating energy conditions. The higher sandstones (units 3 and 4) probably formed in the lower part of the upper flow regime. The ripple-laminated sandstone (unit 4) was probably deposited in the lower part of the lower flow regime. The overlying fossiliferous, sandy Idenbro Limestone formed during a later minor period of transgression under low detrital influx. The gray shales were probably deposited in a quiet-water environment from suspension, possibly early in a subsequent regression. The

thin silty shale (unit 1) at Prong Creek (H-8) to the south may be the distal end of the Hepler "A" detrital influx.

#### Hepler "B" Sandstone

The interbedded sandstone and shale associated with the Hepler "B" sandstone (unit 7 at Uniontown East and unit 3 at Prong Creek) were deposited under alternating energy conditions during later regression closing the Idenbro marine interval. The shale was probably deposited in quiet water from suspended sediments, while the sandstone probably formed under higher energy conditions. The ripple-laminated sandstone (unit 8 at Prong Creek) probably formed in the lower part of the lower flow regime.

#### Hepler "C" Sandstone

The Nuyaka Creek black phosphatic shale below the Hepler "C" sandstone is interpreted to be deposited under quiet, offshore marine conditions during maximum transgression (Heckel, 1980). The overlying gray shale was probably deposited in a quiet-water environment from suspension during early regression. The sandstone interbedded with shale probably formed under alternating energy conditions. The sandstone probably formed in the lower part of the upper flow regime. The shale was probably deposited under lower energy conditions from suspension. The ripple-laminated sandstones were probably deposited in

the lower part of the lower flow regime. The coarsening-upwards sequence suggests that the shale was deposited in a quiet-water environment, such as in a prodelta, while the coarser sediments were deposited by a prograding delta that brought coarser sediments into the area. Higher energy conditions winnowed the fines from the sediments, leaving the coarser grained sediments closer to the source.

The lower portion of the type 1 log signature has high gamma-ray counts, indicating a fine-grained, clay-rich sedimentary lithology. This signature is interpreted to represent prodeltaic muds that were deposited under quiet water conditions. The prodeltaic muds are the first terrigenous sediments introduced into the area by the advancing delta. Upwards in the sequence the gamma-ray values progressively decrease, indicating the deposition of coarser-grained sediments. The coarser-grained sediments were deposited under higher energy conditions. These sediments are interpreted to represent delta-front or marine-bar sands that were deposited over the prodeltaic muds as a result of delta progradation. The type 2 log signature is interpreted to represent distributary channel cut-offs on the delta plain resulting from the migration of distributary channels. The type 3 log signature is interpreted to represent migration of distributary channels across the delta plain, resulting in stacking of channel

sequences. The two channel sequences are separated by a shale sequence that is interpreted to represent interdistributary bay deposits. Analysis of the distribution of the three type log signatures reveals that they commonly occur in close proximity of one another, and individual types do not form a distinctive pattern of occurrence.

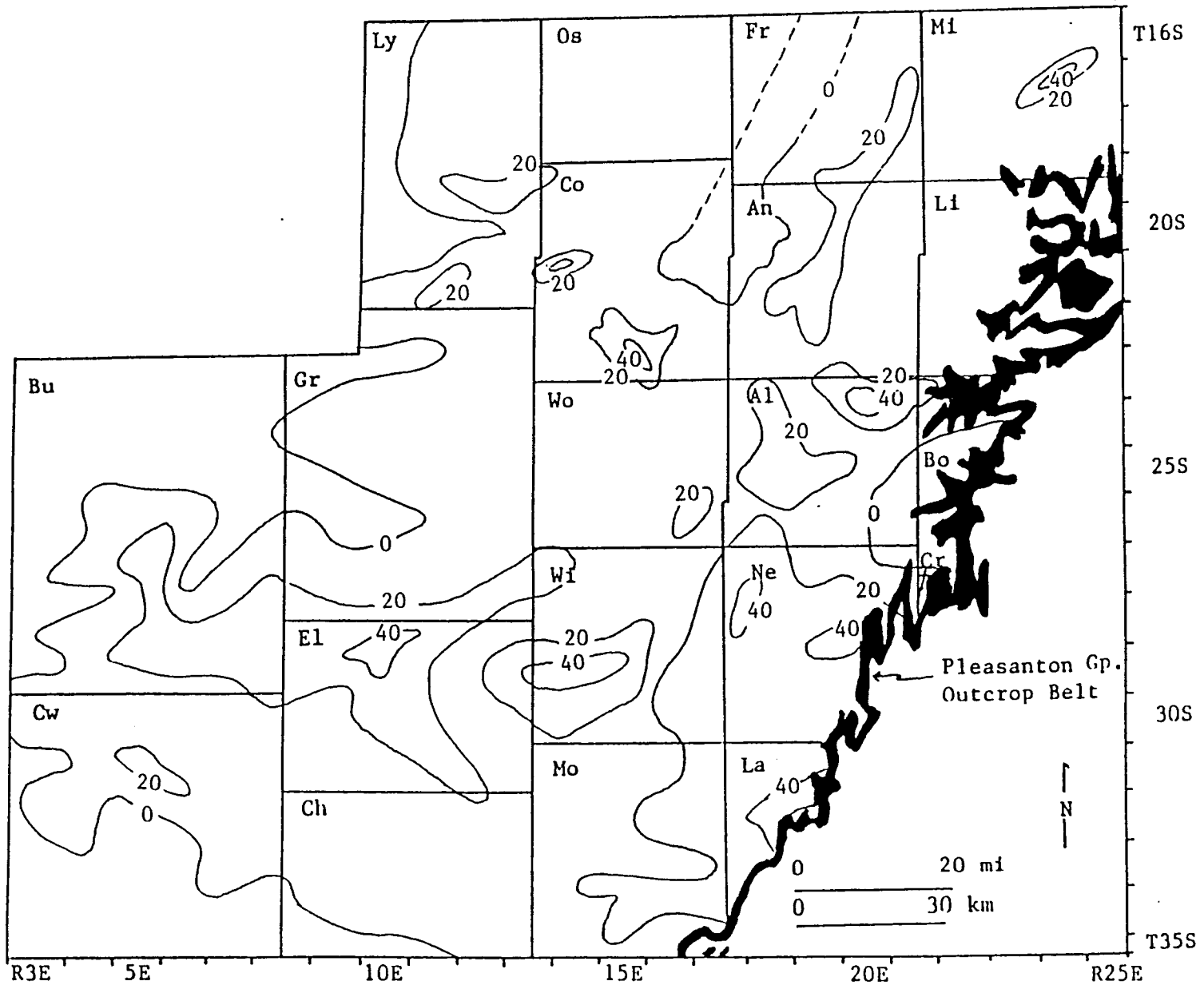
The general trend of decreasing gamma-ray values upward through Hepler "C" indicates a gradual coarsening of grains and an increase in energy through time. A net sandstone isolith map of the Hepler "C" indicates several distinct net sandstone thickness trends (Fig. 14). The areas of greatest thickness are located in the northeast, southeast, and southern portions of the study area. In general, the net sandstone thicknesses in the northern portion of the study area trend northeast to southwest, while the net sandstone thicknesses in the southern portion trend east to west. The sandstone thicknesses that trend northeast to southwest may have been deposited as marine bars and channel sandstones oriented approximately parallel to depositional strike, while the sandstone thicknesses that trend east to west may be delta-front sands that formed by waves or currents reworking the distal portion of the delta, orienting the sandstone thicknesses parallel to the shoreline. For this explanation to be valid, the siliciclastic point source would have been to the northeast of the study area. The

orientation of the net sandstone thickness may also be due to the deposition of sediments from more than one siliciclastic point source. Net sandstone thicknesses suggest that the point source(s) of siliciclastic sediments were either from the northeast, or the southeast, or both the northeast and southeast. The net sandstone isolith (Fig. 14) and cross-sections A-A' (Fig. 10) and B-B' (Fig. 9) all indicate that the amount of sandstone decreases toward the southwest and northwest portions of the study area. The sandstone thickness trends occupy positions within the lobate sedimentary thickness trends observed on the isopach map of the Nuyaka Creek Shale to Mound City Shale interval (compare figures 12 and 14).

#### "Knobtown" Sandstone Horizon

The interbedding of the shales and sandstones suggests that the two rock types were deposited under different energy conditions. The shales were probably deposited under quiet, low energy conditions, while the sandstones were deposited under higher energy conditions. The interbedding of the shale and sandstone might represent alternation between suspension deposition during low flow stages and sand transport during floodtime in a distal delta-front environment, or the shifting of channels across a delta plain. The thick carbonate sequence in the southern portion

Figure 14. Net sandstone isolith of Hepler "C" Sandstone horizon. Contour interval equals 20 feet.



of the study area (Fig. 15) formed away from the detrital influx.

The net sandstone thicknesses in the northern portion of the study area trend northeast to southwest, while the net "limestone" thicknesses in the southern portion of the study area trend east to west (Fig. 15). This can most likely be attributed to the facies change that occurs from north to south. The thickest sandstones occur in the northeastern and central portions of the study area. The net sandstone thickness trends suggest that the siliciclastic point source was northeast of the study area. The line separating the siliciclastic facies from the carbonate facies was based on interpretations of the well-log signatures. The carbonate rocks occur from approximately T27S southward (Fig. 15). Cross-section A-A' illustrates the facies change from a shoreline delta to a marine carbonate (Fig. 10). A series of thicknesses are present and are interpreted to represent carbonate mound build-ups that formed seaward of the delta, possibly along a transitional slope as discussed by Underwood (1984), or perhaps on local topographic highs. The carbonate build-ups were able to form away from detrital influx. The carbonates thin abruptly to the south (Fig. 10). Seaward of the carbonate build-ups very little if any siliciclastic sediment was deposited, probably due to distance from

detrital sources. Any carbonate sediments here were produced at very low rates, possibly due to low organic productivity, caused by water depths below the photic zone or below the thermocline at this particular stand of sea level.

The thick carbonate sequences in the subsurface may relate to the Bourbon flags phenomena described by Underwood (1984). Underwood (1984) reported that the Bourbon flags grade up into the algal Critzer Limestone, and were deposited along the slope of a deltaic lobe during stillstand and early regression after minor marine transgression. The thick carbonate sequences detected in the subsurface do not crop out in the southern portion of the study area, except possibly near South Mound in southeastern Neosho County, where there is a dense calcilutitic algal mound facies like the slope Critzer above the Bourbon flags (Heckel, pers. commun., 1985). Traverse C-C' illustrates the facies change that occurs westward from the outcrop belt (Fig. 16). Figure 17 shows well log 6 from cross-section C-C' compared with a nearby composite measured section, where sandstone is absent in more of a basinal sequence.

Figure 15. Net sandstone-limestone isolith map of "Knobtown" sandstone horizon. Dashed line separates siliciclastic facies to the north from carbonate facies to the south. Contour interval equals 30 feet.

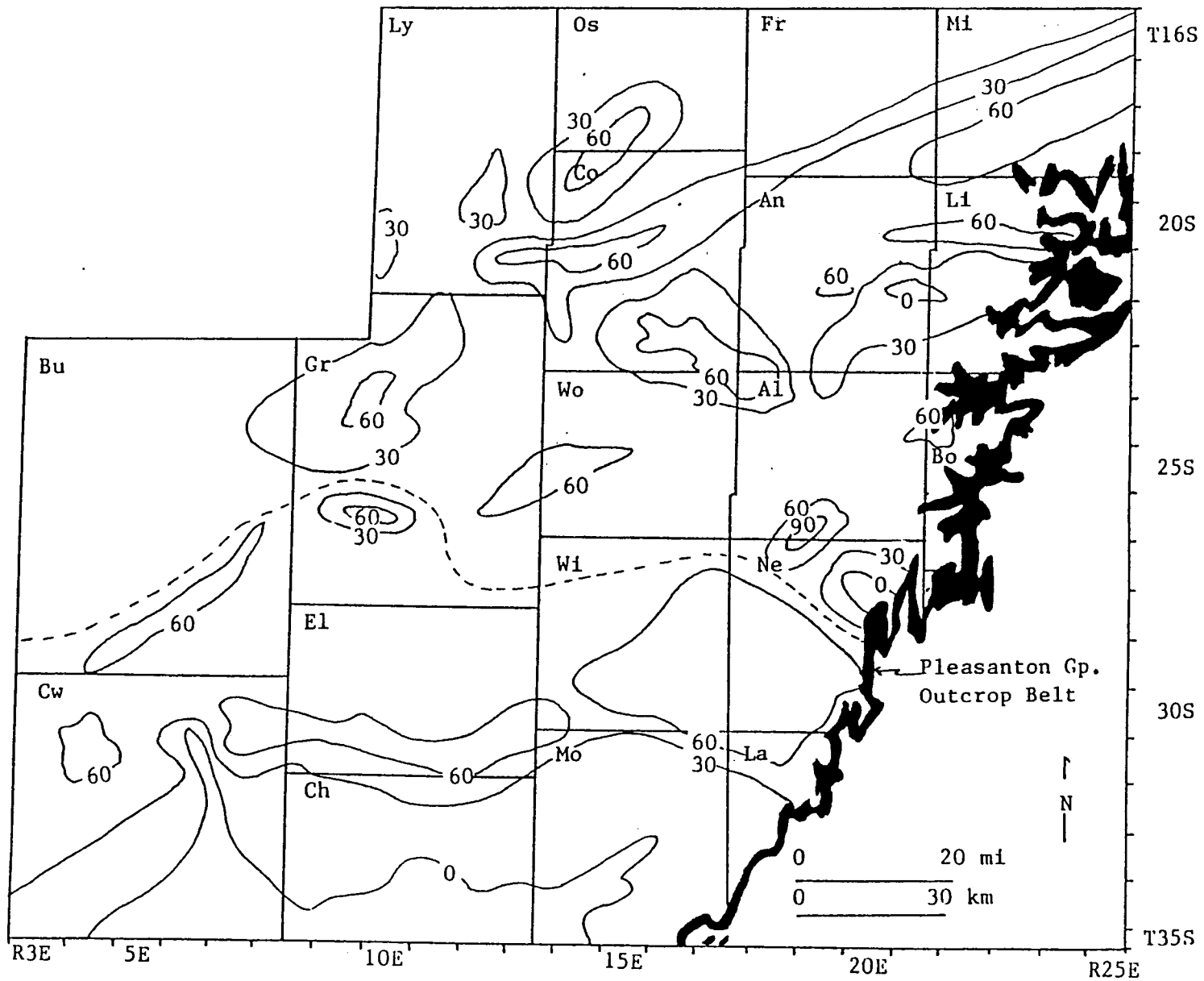
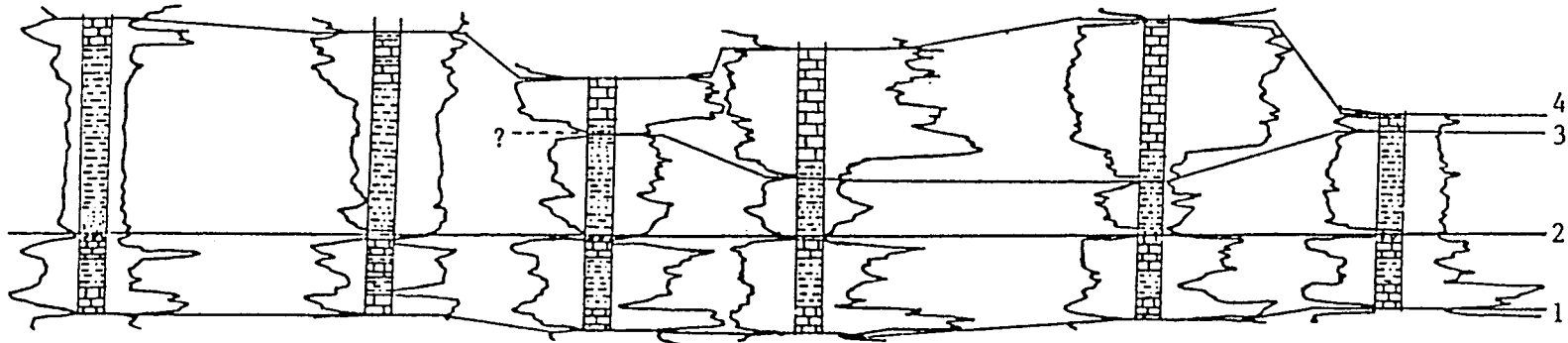


Figure 16. Cross-section C-C'. Lateral continuity of black shales and variation in well-log signatures along this traverse are shown. Facies change that occurs westward from outcrop belt is shown. See figure 1 for location.

C  
Greenwood Co.  
NW  
well 1

Labette Co. C'  
SE

8-T24S-R11E      2      3      4      5      6      34-T32S-R18E  
11-T26S-R12E    20-T27S-R14E    24-T28S-15E      5-T31S-R17E

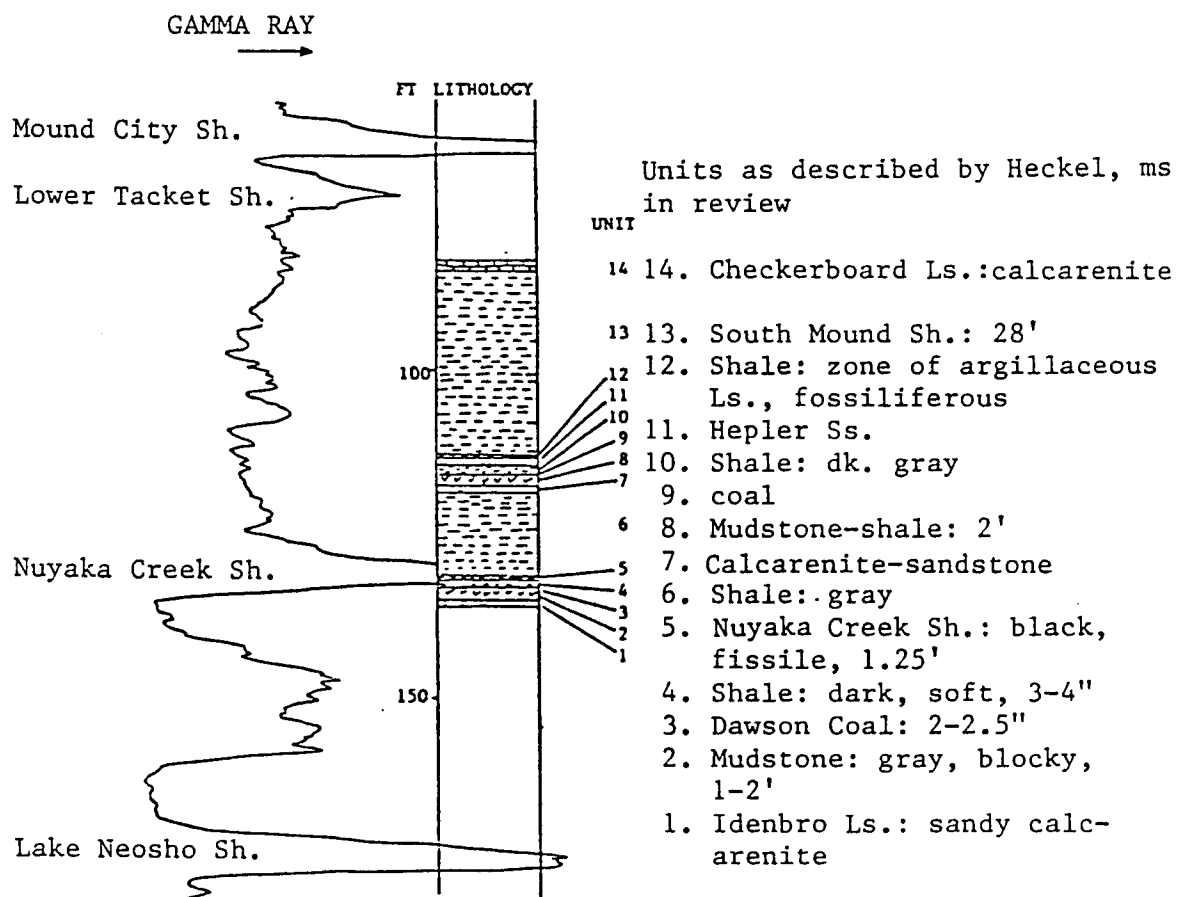


50Ft 15M  
10 MI  
6.2 Km

1. Lake Neosho Sh.
2. Nuyaka Creek Sh.
3. Lower Tacket Sh.
4. Mound City Sh.

Figure 17. Well log 6 (sec. 34, T32S, R18E) from cross-section C-C' and nearby composite detailed measured section in basinal sequence. Measured section MVSW, stratotype of Lost Branch Formation. Compositied in northeast quarter, sec. 10, T33S, R18E, along Lost Branch and Pumpkin creeks, Labette Co., KS. From Heckel, ms. in review.

Well 6  
sec. 34 T32S R18E

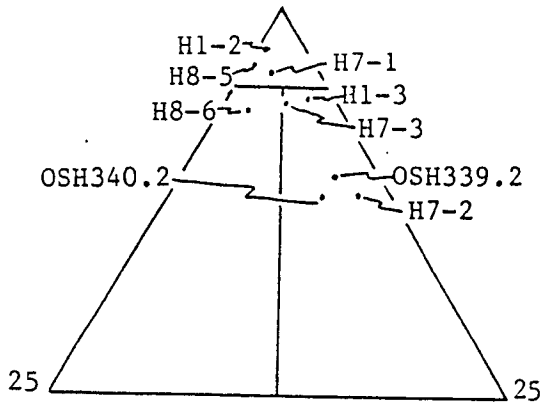


Lenapah Fm.: unit 1  
Mound Valley Fm.: units 2 and 3  
Lost Branch Fm.: units 4-7  
Hepler "C": units 8-11  
South Mound Sh.: units 12 and 13  
Checkerboard Ls.: unit 14

## PETROGRAPHIC ANALYSES

A total of nine thin-sections representing four different sandstone units were examined in detail. The thin-sections examined include: two from core OSH-1A, two from section H-1, three from section H-7, and two from section H-8. The thin-sections represent the "Walter Johnson", Hepler "C", "A", and "B" sandstones, respectively. Siliciclastic components of the rocks include: monocrystalline and polycrystalline quartz, plagioclase feldspar, muscovite, biotite, chlorite, rock fragments, zircon, and glauconite. Cements include ferroan dolomite, calcite, iron oxide, and silica. The grains are well-cemented, resulting in low porosity. This analysis shows that these sandstones are quartz arenites, subarkoses, and sublitharenites, according to the classification of Folk (1974) (Fig. 18). The percentages of detrital and authigenic components based on the point counts are recorded in table 1.

Figure 18. Ternary sandstone classification for the "Walter Johnson" sandstone (OSH) and the Hepler "A" (H-7), "B" (H-8), and "C" (H-1) sandstones. Based on data obtained from modal analysis of thin sections (Table 1). Classification scheme based on Folk, 1974. Quartz includes monocrystalline and polycrystalline quartz. Rock fragments include chert, siltstone, and metamorphic rock fragments. Feldspar is plagioclase feldspar.



QUARTZ

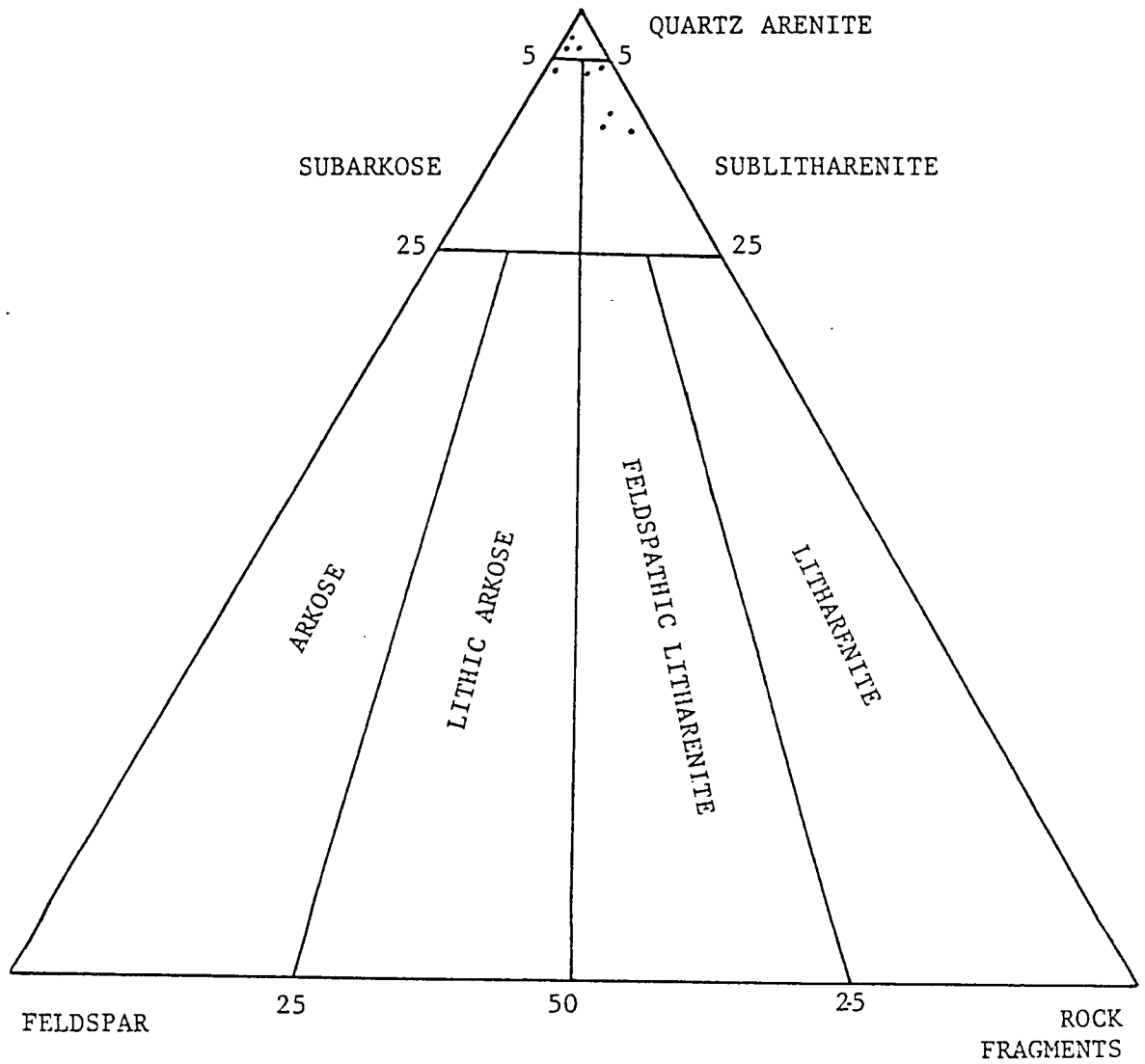


Table 1. Compositional percentages of "Walter Johnson" and Hepler "A", "B", and "C" sandstones.

column A: percentage of detrital and authigenic minerals

column B: percentage of detrital minerals

SAMPLE:	"Walter Johnson"				Hepler "C"				Hepler "A"						Hepler "B"			
	OSH339.2		OSH340.2		H1-2		H1-3		H7-1		H7-2		H7-3		H8-5		H8-6	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
<u>DETRITAL</u>																		
Quartz		89.2		88.8		97.9		94.4		96.1		88.1		94.3		96.5		93.9
Monocrystalline	51.8		47.4		30.9		37.6		51.1		45.0		50.4		44.7		49.0	
Polycrystalline	4.4				2.0		3.9		4.6		5.8		7.7		5.5		2.0	
Feldspar		2.1		3.8		2.1		1.1		2.4		1.7		2.6		3.5		5.0
Plagioclase	1.3		1.3		0.7		0.5		1.4		0.9		1.6		1.8		2.6	
Mica																		
Muscovite	0.4		1.3		5.3		5.8		6.4		6.8		6.9		11.0		2.6	
Biotite	0.4						3.4		1.8						4.1			
Chlorite	0.4						1.0		10.5		4.6		2.5					
Rock Fragments		8.7		7.4				4.4		1.6		10.2		3.1				1.1
Sedimentary	4.3		3.9				1.9		0.9		4.8		1.9					
Metamorphic											0.9						0.6	
Glauconite	1.2		0.5				1.0											
Zircon	tr						tr				tr							tr
<u>AUTHIGENIC</u>																		
Clays																		
Ferrous dolomite cement	31.1		40.3		13.8													
Carbonate cement					4.9		0.5				22.3		24.0		4.6		20.7	
Silica cement	3.8		4.0		42.4		7.3		10.8		8.9		3.8		4.7		7.1	
Iron oxide	0.9						21.0		3.7				1.2		22.2		15.2	
<u>Other</u>																		
Opagues									2.0						1.4			
Pore space							1.5											

## Detrital Minerals

### Monocrystalline Quartz

The most abundant mineral in the sandstones analyzed is monocrystalline quartz, composing between 31 and 52 percent of the bulk rock. Quartz grains are very-fine to fine-grained sand in size, ranging from 0.06 to 0.24 mm in maximum diameter in thin-section. The quartz grains commonly show slight undulose extinction (1 to 10 degrees) and a few display strong undulose extinction (greater than 10 degrees). The quartz grains commonly display overgrowths and commonly form an interlocking mosaic of grains (Fig. 19). Quartz overgrowths cause the outer edges of many of the quartz grains to have sharp, well-defined boundaries and cause the grains to appear to have angular to subangular roundness and low sphericity (Fig. 19). "Ghost" rims along quartz nuclei were observed (Fig. 19). Where calcite or ferroan dolomite cement are prevalent, etching along quartz grain rims is common (Fig. 20). Quartz grains commonly contain inclusions, suggesting a volcanic source. In general, quartz grain size increases toward the top of a section.

### Polycrystalline Quartz

Polycrystalline quartz grains (Fig. 21) are present in minor amounts ranging up to 8 percent of the bulk rock. The

Figure 19. Photomicrograph showing interlocking quartz overgrowths and "ghost" rim around original quartz nuclei (arrows). Dark areas are iron oxide. Crossed polarizers. Sample H7-2.

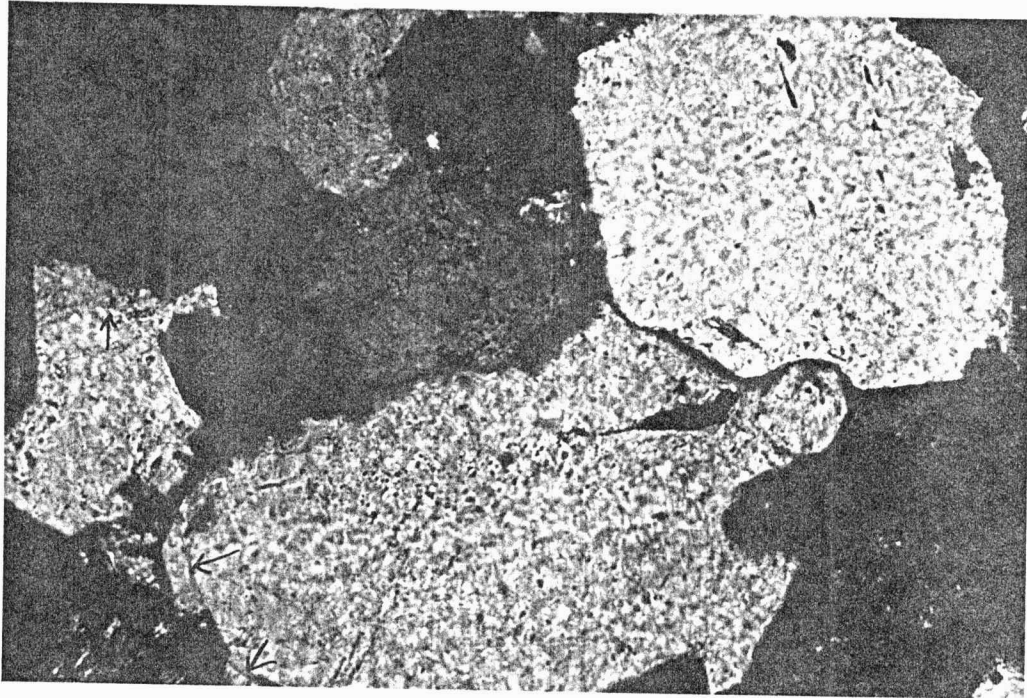
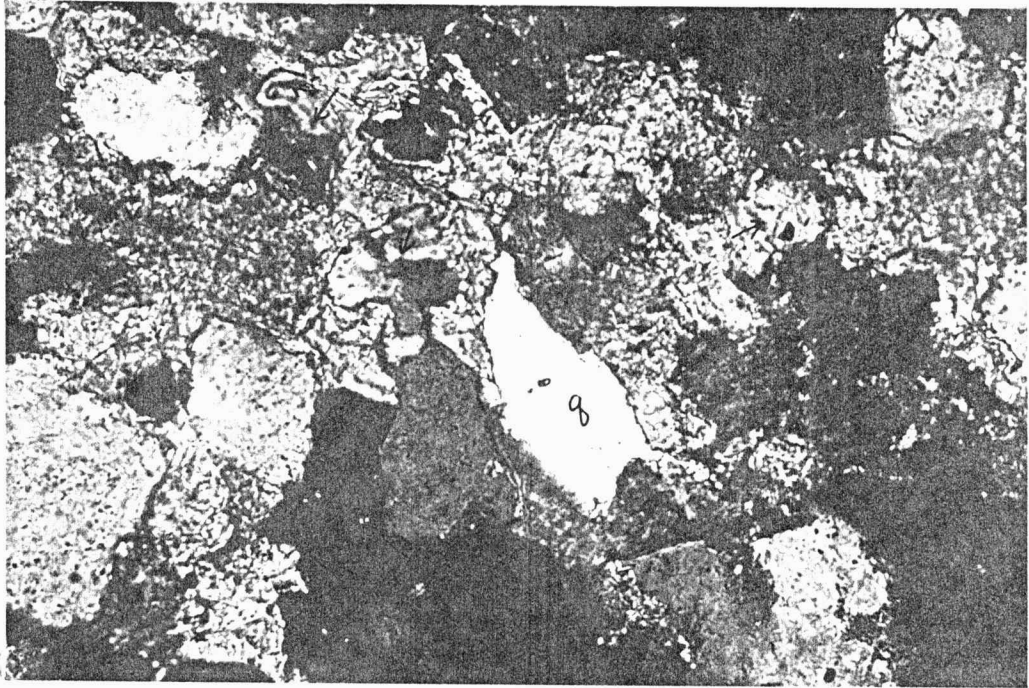


Figure 20. Photomicrograph showing subangular to angular quartz grains etched by ferroan dolomite (arrows) and quartz grains (q) "floating" in ferroan dolomite cement. Crossed polarizers. Sample OSH-340.1.



grains are subround to angular, have low sphericity, and range in size from coarse silt (0.05 mm) to fine sand (0.12 mm). Within the polycrystalline quartz grains individual quartz crystals exhibit slight undulose extinction.

#### Feldspar

Etching and staining of the thin sections by the Boone and Wheeler (1968) Method revealed the absence of potassium feldspar. Plagioclase feldspar identified by albite twinning (Fig. 22) is present in minor amounts, composing up to 2.6 percent of the bulk volume. These grains range in size from coarse silt (0.05 mm) to fine sand (0.15 mm). Roundness is subangular and sphericity is low. Measurement of the extinction angles by the Michael-Levy Method vary between 15 and 21 degrees, indicating that the grains are of albite composition.

#### Muscovite

Muscovite is the most common mica mineral, occurring as an accessory mineral, composing between 0.4 and 11 percent of the bulk rock. Muscovite occurs as elongate colorless laths and displays moderate birefringence in crossed polarized light (Fig. 23). The laths range in size from coarse silt (0.05 mm) to coarse sand (0.76 mm) in maximum diameter. The grains are commonly arranged roughly parallel to stratification. Some grains are bent around quartz

Figure 21. Photomicrograph showing polycrystalline quartz grain (q) with sharp outer boundaries. Crossed polarizers. Sample H7-2.

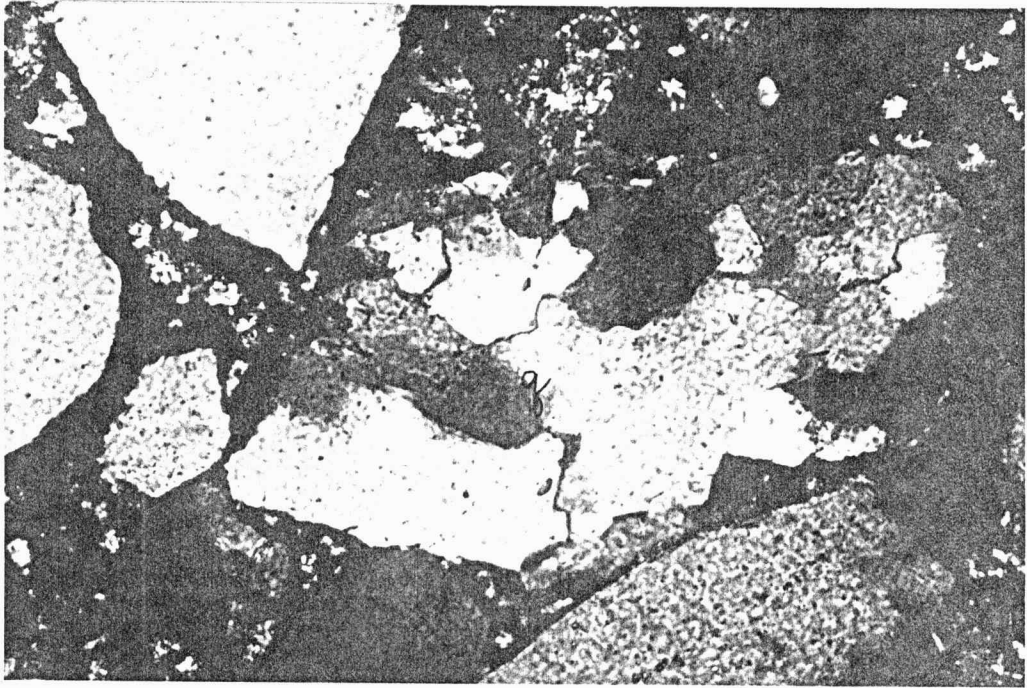
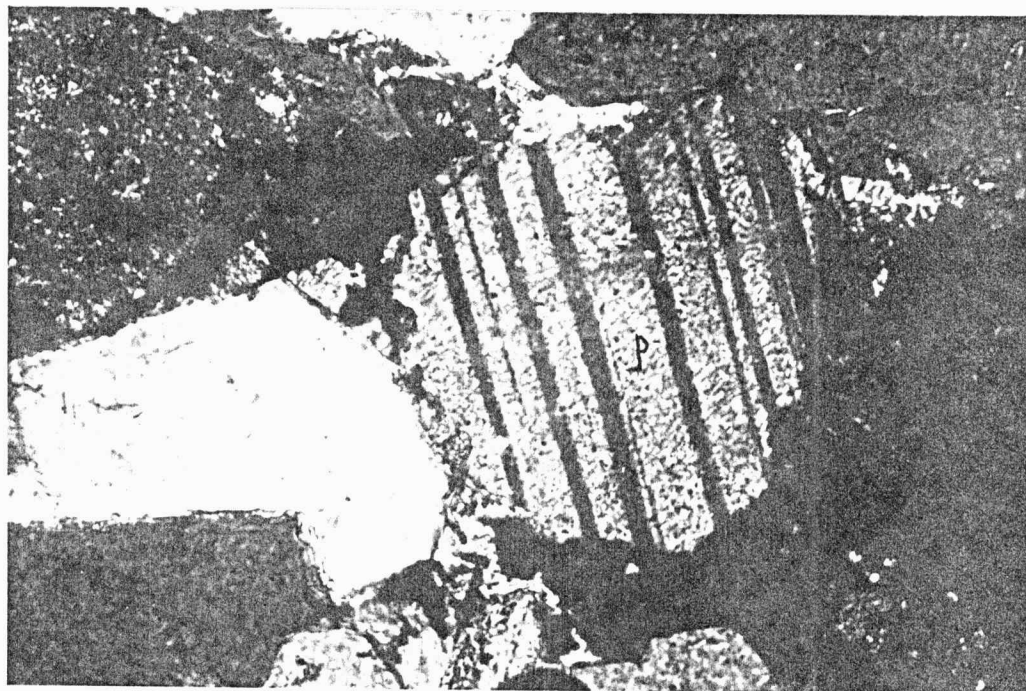


Figure 22. Photomicrograph showing plagioclase feldspar grain (P) with albite twinning. Crossed polarizers. Sample H7-3.



grains, suggesting that they were deformed during compaction (Fig. 23).

#### Biotite

Biotite occurs as elongate brown laths and displays strong pleochroism in plane polarized light. Biotite grains range in size from coarse silt (0.05 mm) to medium sand (0.42 mm). Biotite composes up to 4.1 percent of the bulk rock.

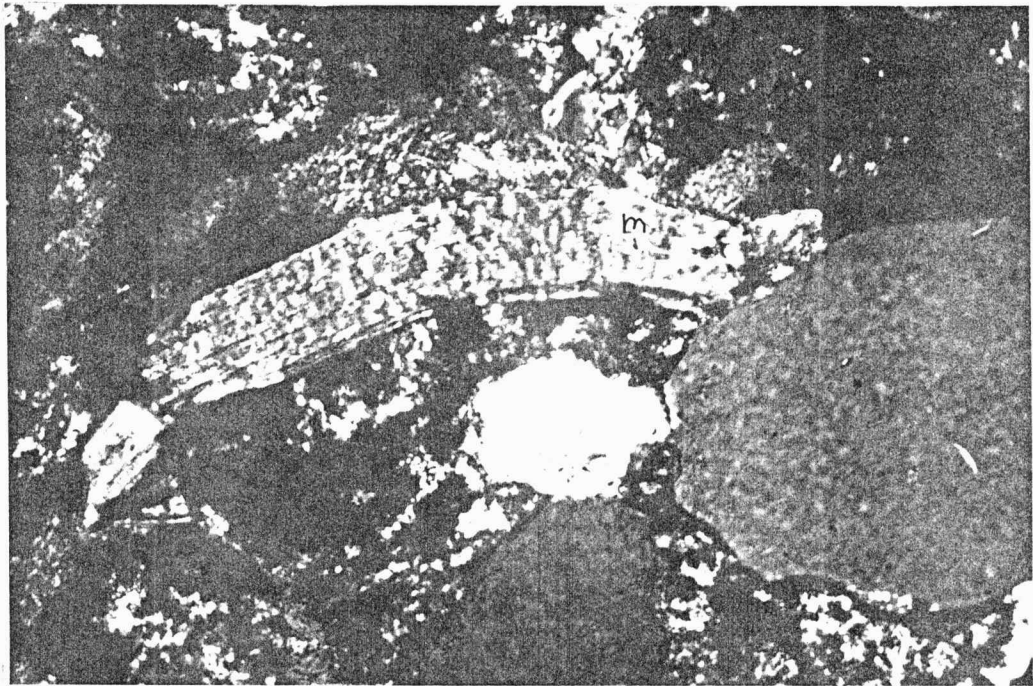
#### Chlorite

Chlorite occurs as pale green laths that range in size from very-fine (0.06 mm) to medium sand (0.35 mm). Chlorite composes up to 10.5 percent of the bulk volume. Chlorite may have formed as an alteration product of biotite or may be detrital grains from the weathering of low-grade metamorphic rocks.

#### Glaucanite

Glaucanite was distinguished from chlorite by its high birefringence. Glaucanite occurs as pellets in small amounts, composing up to 1.2 percent of the bulk rock in the core (OSH-1A) and one outcrop sample. Grain size is approximately the same size as the associated quartz. The grains commonly occur between quartz grains and show signs of compaction. This deformation is probably due to

Figure 23. Photomicrograph showing elongate muscovite grain (m) displaying moderate birefringence in crossed polarized light. Grain is bent due to mechanical compaction. Dark areas are calcite cement stained with iron oxide. Sample H7-2.



glaucconite being more plastic than the surrounding quartz grains.

#### Rock Fragments

Rock fragments occur as minor constituents of the rocks in abundances up to 5.7 percent of the bulk rock. Rock fragments include siltstone, schistose metamorphic rock fragments, and chert.

The sedimentary rock fragments occur as siltstone clasts and chert that range in size from very-fine (0.07 mm) to medium (0.25 mm) sand. The clasts are subangular and have low sphericity. The sedimentary rock fragments compose up to 4.8 percent of the bulk rock.

Metamorphic fragments compose up to 1.9 percent of the bulk rock. The fragments range in size from very-fine (0.07 mm) to fine (0.13 mm) sand. The grains are subangular and display parallel layers of quartz and muscovite.

#### Heavy Minerals

Zircon was present in trace amounts, and ranged in size from (0.04 mm) to (0.07 mm) in maximum diameter.

#### Authigenic Minerals

The authigenic minerals observed in the specimens include: silica, ferroan dolomite, calcite, and iron oxide cements, and a trace of clay (possibly sericite) on an

altered feldspar grain. Quartz overgrowths are common in the observed specimens and form the silica cement. Ferroan dolomite and calcite also occur as void filling cement. Iron oxide cement occurs as a coating around grains and fills pore spaces. Iron oxide is more abundant in the thin-sections from the surface than in the thin-sections from the core. The iron oxide is therefore most likely a modern weathering product, possibly forming by the leaching of soils, or the alteration of iron-bearing minerals, such as chlorite or ferroan dolomite.

#### Discussion

The abundance of quartz and scarcity of feldspar suggest a high degree of compositional maturity. The grain sphericity and roundness are low, suggesting relative textural immaturity. In general the abundance of mica minerals decreases toward the top of the sequences analyzed.

All four sandstones are mineralogically similar, but each specimen analyzed contains different amounts of each mineral. The result is a moderate range of compositions (Fig. 18).

Compositionally, the "Walter Johnson" Sandstone specimens (OSH) are the most similar, both plotting as sublitharenites. The two OSH specimens are the only two of all the specimens observed to be cemented with ferroan

dolomite. The grains are moderately well-sorted fine sand, and are well-cemented, with no observable porosity. Grains commonly "float" in the ferroan dolomite cement, suggesting that cementation preceded compaction and that the grains were loosely packed prior to cementation (Fig. 20). Quartz overgrowths were observed in these specimens, but are not as plentiful as in the other specimens. The quartz grains in these specimens are commonly etched by the ferroan dolomite.

Compositionally, the Hepler "A" Sandstone specimens are somewhat dissimilar, plotting as a quartz arenite (H7-1) and sublitharenites (H7-2, H7-3). The major difference among the three specimens analyzed is that specimen H7-1 contains less rock fragments. Generally, the rocks are poorly sorted, well-cemented, and have no porosity (Table 1). Grain size is mostly fine sand.

Compositionally, the Hepler "B" sandstone specimens are somewhat similar, plotting as a quartz arenite (H8-5) and a subarkose (H8-6) within fairly close range of one another. Minor differences in the amounts of quartz and rock fragments account for the differences in composition. Both specimens analyzed were well-cemented with calcite and silica, had no porosity, were poorly sorted, and contained a high percentage of iron oxide.

Compositionally, the Hepler "C" sandstone specimens analyzed are somewhat dissimilar, plotting as a quartz arenite (H1-2) and a sublitharenite (H1-3). The greater

percentage of quartz and the lack of rock fragments in specimen H1-2 account for the difference in composition. Both specimens contain a high percentage of iron oxide, were moderately well-sorted, and had low porosity.

The specimens representing the various sandstone units are not dissimilar enough to make them petrographically distinguishable from one another, at least with this small number of samples.

#### Provenance

Patterns of the sandstone isolith for the Hepler "C" sandstone suggest that the sandstones had either a northeastern, southeastern, or both northeastern and southeastern source. Although not petrographically analyzed, the "Knobtown" sandstone isolith map indicates that the sandstone had a northeastern source. The likely northern source was the Canadian Shield. Sediments from the Canadian Shield might have been of two rock types, igneous and low grade metamorphic, which would account for the presence of both igneous and metamorphic constituents in the rock. A likely southern source for the Hepler "C" sandstone would have been sediments from the Ouachita-Marathon Mountains.

## DEPOSITIONAL ENVIRONMENTS

### "Walter Johnson" Sandstone

Orlopp (1964) suggested that the environment of deposition of the Walter Johnson Sandstone was deltaic. The delta was built by a river that flowed south across Iowa and emptied into the northern side of the Pennsylvanian Seaway in Kansas and Missouri. During this time there may have been two siliciclastic point sources accounting for the deposition of siliciclastic rocks in southeastern Kansas, one from the northeast and one from the south. This may explain the thinning of siliciclastics in the central portion of the study area observed on the Lake Neosho Shale to Nuyaka Creek Shale isopach map (Fig. 11).

### Hepler "A" Sandstone

The Hepler "A" sandstone was deposited during regression at the end of the Norfleet Limestone deposition. Hepler "A" Sandstone was probably deposited in a deltaic environment during the maximum regressive phase within Lenapah deposition. The southward thinning and loss of sand between Uniontown East (H-7) and Prong Creek (H-8) shows that this delta lobe came from the northeast.

### Hepler "B" Sandstone

Regression at the end of the Lenapah deposition resulted in the deposition of shales and sandstones probably as part of a deltaic system during the deposition of the Mound Valley Formation.

### Hepler "C" Sandstone

Deposition of the Hepler "C" sandstone was in a series of deltaic environments developed during the late regressive phase of Lost Branch deposition. The Hepler "C" sandstone represents the thickest and cleanest of the "Hepler" sandstones in southeastern Kansas. During the early phases of sedimentation, muds entered the seaway through a fluvial system possibly to the northeast, southeast, or both northeast and southeast of the study area, and were deposited under quiet, distal prodeltaic marine conditions. As regression continued, the delta prograded southwestward in response to continued sediment supply. As the river waters flowed out of the distributary mouth over the denser marine waters, the less dense river waters lost velocity depositing silts over the prodeltaic sediments. With continued progradation, very fine- to fine-grained sands winnowed of mud were deposited over the prodeltaic muds. These sediments were deposited as delta-front and marine-bar sands. A distributary channel system had developed on the

delta plain, and the shifting of the distributary channels produced channel cut-offs.

The sandstone deposits are coincident with the northeast to southwest trends of greater thickness for the Nuyaka Creek Shale to Mound City Shale interval.

#### "Knobtown" Sandstone Horizon

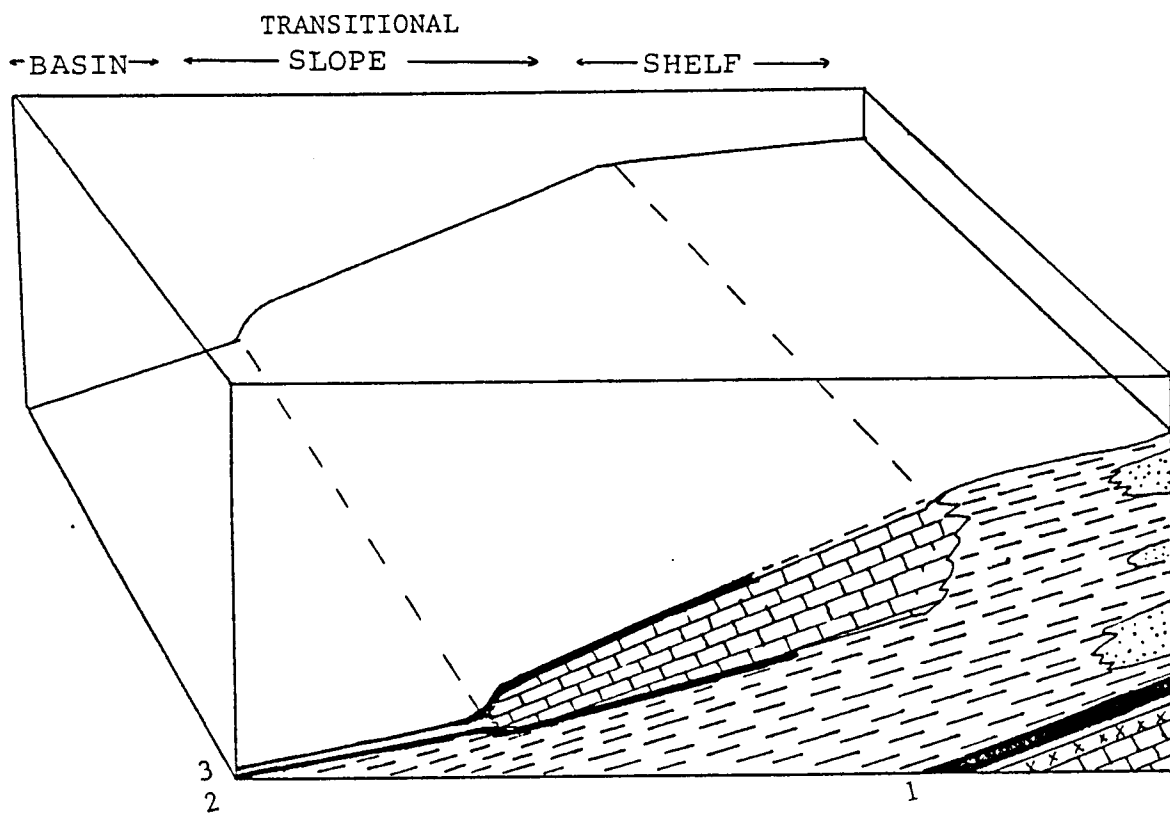
The "Knobtown" sandstone was deposited as part of a delta system along the Pennsylvanian Seaway during a regressive phase of cyclic sedimentation. The siliciclastic point source was northeast of the study area. These sediments were deposited under conditions of alternation between suspension deposition during low flow stages and sand transport during floodtime in a distal delta-front environment, or the shifting of channels across the delta plain, producing the interbedding of shales and sandstones.

The carbonate rocks in the southern portion of the study area were deposited away from detrital influx, possibly along a transitional slope as Underwood (1984) found for the Bourbon flags, or on local topographic highs as suggested by the algal mound complex at South Mound, Kansas quarry (Fig. 24).

#### Depositional History Summary

Figure 25 summarizes of the depositional history of the interval that was studied. The Lake Neosho Shale is

Figure 24. Idealized model for deposition of "Knobtown" sandstone and associated carbonates.

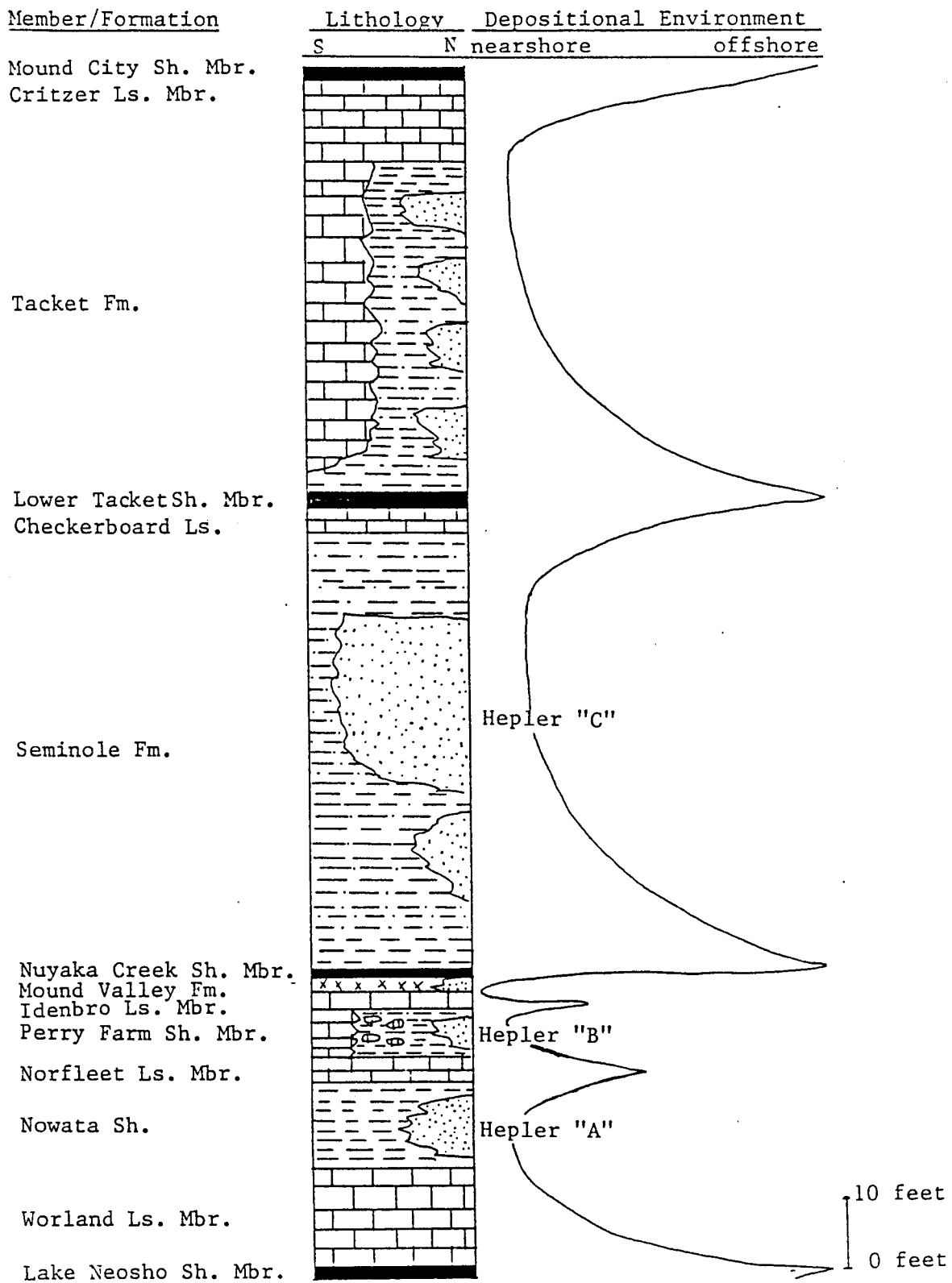


- 1 Nuyaka Creek Shale
- 2 Lower Tacket Shale
- 3 Mound City Shale

interpreted to be deposited under widespread quiet offshore conditions at maximum transgression (Schenk, 1967). The Worland Limestone is interpreted to have been deposited during a regressive phase of cyclic sedimentation (Schenk, 1967). The Nowata Shale sequence is interpreted to have been a prodeltaic mud that was deposited during maximum regression. The shales were deposited under quiet-water conditions from suspension, while the sandstones of the "Walter Johnson" were deposited during delta progradation under higher energy conditions. The Lenapah Limestone was found by Parkinson (1982) to consist of two relatively minor transgressive-regressive cycles. The Perry Farm Shale and Hepler "A" sandstone separates the lower (Norfleet) Member from the upper (Idenbro) Member of the Lenapah Formation. The Perry Farm Shale and the Hepler "A" sandstone are interpreted to have been deposited as part of a deltaic system during an early regressive phase of Lenapah deposition. The Mound Valley Formation and Hepler "B" sandstone were deposited during maximum regressive phase after Lenapah deposition. The Nuyaka Creek Shale is interpreted to be deposited under widespread quiet offshore conditions at the following maximum (Lost Branch) transgression. The Hepler "C" sandstone, in the Seminole Formation is interpreted to have been deposited as a fluvially dominated deltaic sand during the later regressive phase of Lost Branch sedimentation. The Checkerboard

Limestone was deposited as siliciclastic sedimentation ceased in the study area during a transgressive phase of sedimentation (Ravn, 1981). Above the Checkerboard Limestone, the lower Tackett shale was deposited under widespread offshore conditions at maximum transgression. The "Knobtown" sandstone is interpreted to have been deposited as part of a delta system during the following regressive phase. The Critzer Limestone was deposited as siliciclastic sedimentation ceased in the study area during a more minor transgressive phase of sedimentation. The Mound City Shale was deposited under quiet offshore conditions during the following maximum transgression.

Figure 25. Summary of depositional history for interval of study.



## CONCLUSIONS

Five periods of deltaic progradation during regressive phases of cyclic sedimentation account for the deposition of five sandstone units within the interval between the Lake Neosho Shale and the Mound City Shale in southeastern Kansas.

Field relationships indicate that more than one sandstone unit has been mapped as the Hepler Sandstone within the outcrop belt of southeastern Kansas. The sandstone units occupy positions both above and below the Desmoinesian-Missourian boundary.

Core-well log analysis revealed that core interval OSH-1A, that was thought at one time to be a Hepler Sandstone, is at the stratigraphic horizon occupied by the "Walter Johnson" Sandstone of the Nowata Shale Formation. This sandstone is thin and shaley and is therefore not well-developed within the study area.

Hepler "A", the lowermost of the Hepler sandstones has been recognized between the lower (Norfleet) Member and the upper (Idenbro) Member of the Lenapah Limestone. Higher in the section, the Hepler "B" sandstone apparently occurs above the Idenbro Limestone within the Mound Valley Formation.

Hepler "C", the uppermost of the three Hepler sandstones, lies above the Desmoinesian-Missourian boundary and is the thickest and cleanest of the Hepler Sandstones in southeastern Kansas. The Hepler "C" occupies the stratigraphic position accorded the Hepler elsewhere in Kansas and Missouri.

The "Knobtown" sandstone horizon represents a delta complex in northeastern Kansas and adjacent Missouri. Southward and seaward of the siliciclastic sediments, carbonates formed along a transitional slope and perhaps on topographic highs in the basinal areas.

Isopach and isolith maps of the stratigraphic intervals that contain the sandstone units show that these units occupy positions within lobate sedimentary thickness trends. Thickness trends suggest that the point sources for the siliciclastic sediments were from northeast, southeast, or both northeast and southeast of the study area.

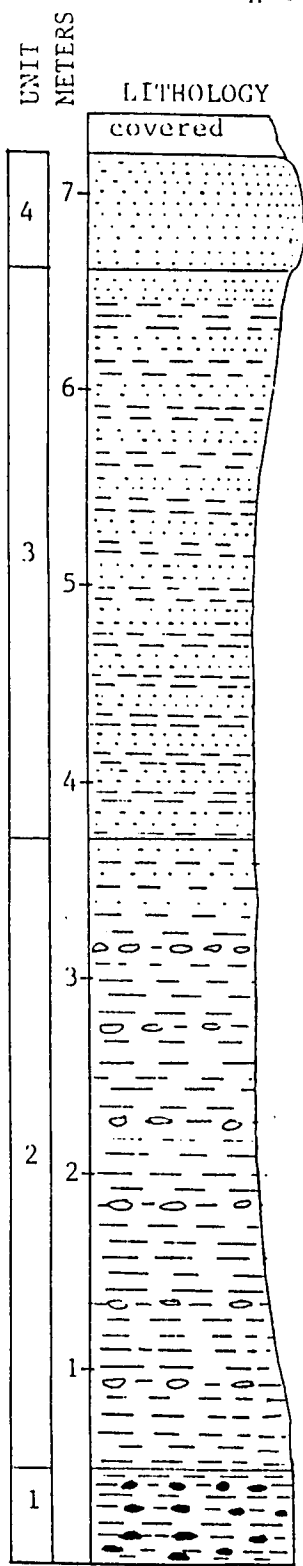
The sandstone are quartz arenites, sublitharenites, and subarkoses, according to the classification of Folk (1974). The samples analyzed were very fine- to fine- grained and well-cemented with quartz overgrowths, iron oxide, ferroan dolomite, and calcite. The composition of the sandstones suggests low-lying cratonic sources for the detritus. A likely northern source was the Canadian Shield area. A likely southern source of detritus was the Ouachita-Marathon

Mountains. The specimens representing the various sandstone units were not dissimilar enough to make them petrographically distinguishable from one another, at least with the small number of samples analyzed.

APPENDIX A

MEASURED SECTIONS

H-1 TRADING POST  
 LINN CO., KS  
 NW<sup>1</sup>/<sub>4</sub> NW<sup>1</sup>/<sub>4</sub> SW<sup>1</sup>/<sub>4</sub>, sec. 5, T21S, R25E



Unit 4 (6.6-7.2 M) Sandstone; fine-grained; thinly bedded; ripple-laminated; gradational basal contact.

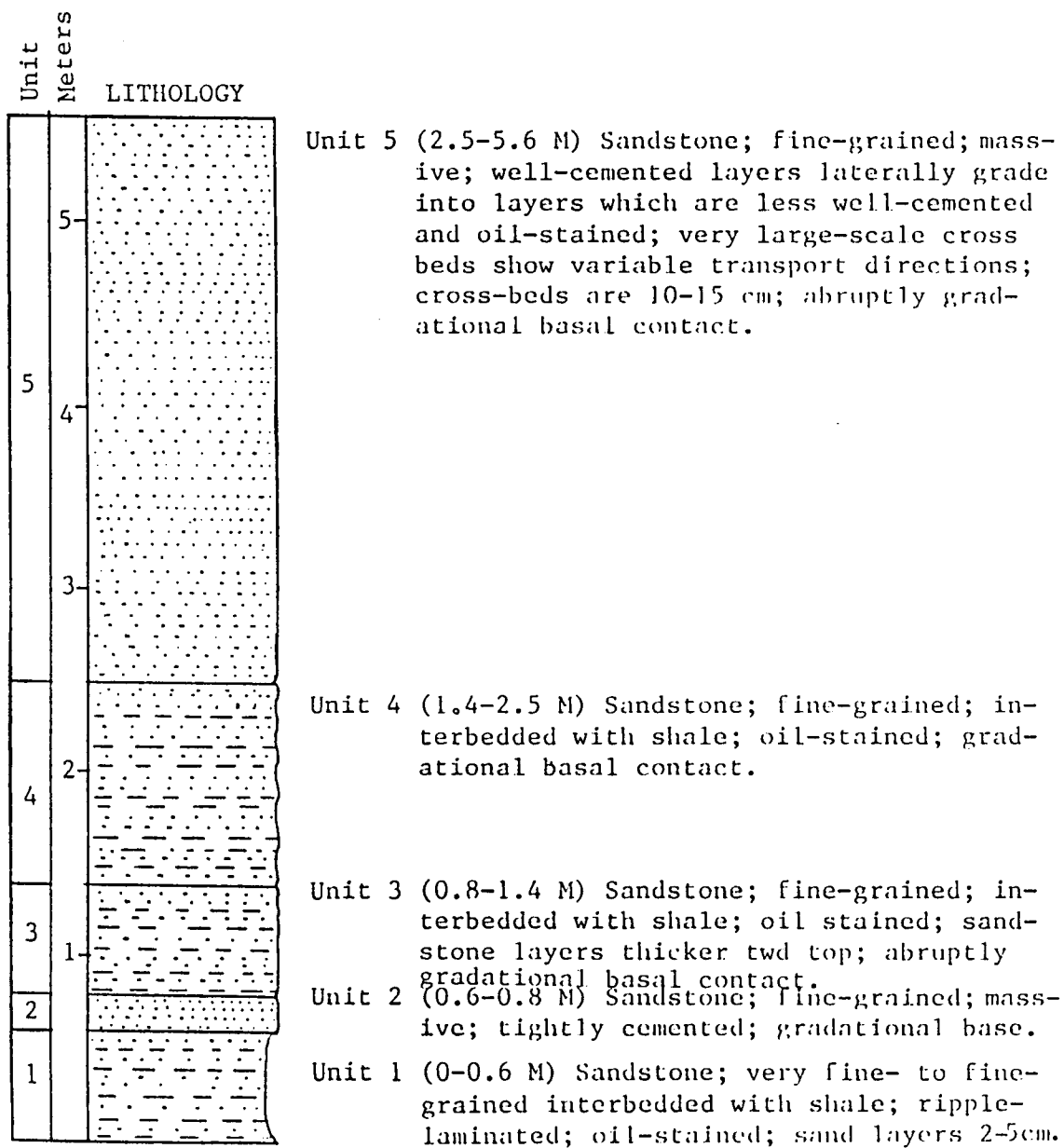
Unit 3 (3.7-6.6 M) Sandstone; very fine-grained interbedded with shale; shale-sandstone layers vary in thickness 2-10 cm.; gradational basal contact.

Unit 2 (0.5-3.7 M): Shale; clayey; medium gray; ironstone concretions in layers; very fine-grained sandstone toward top; gradational basal contact.

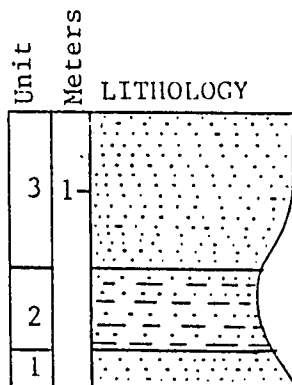
Unit 1 (0-0.5 M): Shale; black with phosphate nodules; Nuyaka Creek bed; base not exposed.

Hepler "C"  
 Lost Branch Formation

H-2 QUARRY NORTHWEST OF PLEASANTON  
 Linn Co., KS  
 NE $\frac{1}{4}$  SW $\frac{1}{4}$  NE $\frac{1}{4}$  sec.25 T21S R24E



H-3 EAST OF PLEASANTON  
 Linn Co., KS  
 NE $\frac{1}{4}$  NW $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 3 T22S R25E

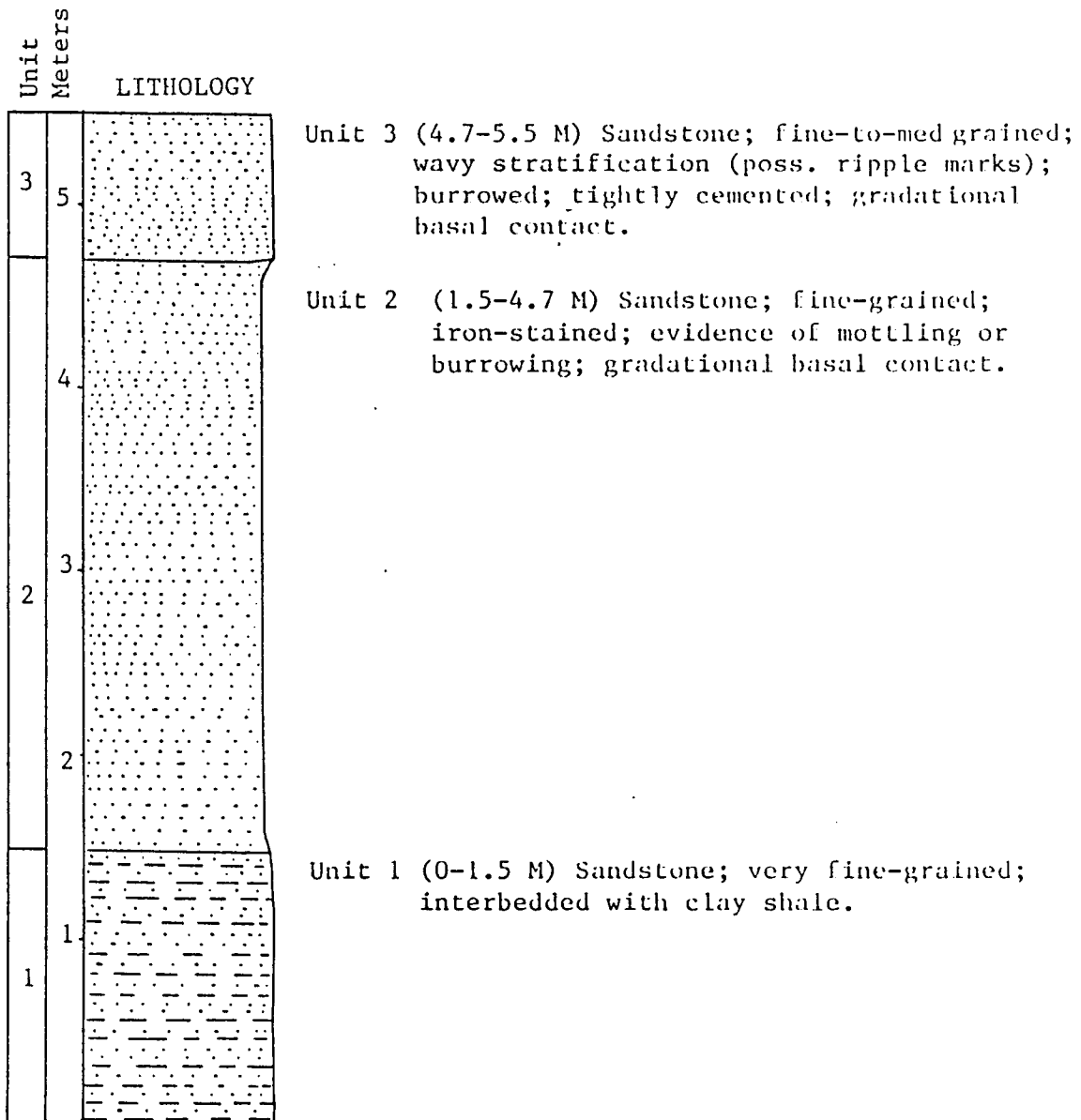


Unit 3 (0.6-1.4 M) Sandstone; fine-grained; massive; gradational basal contact.

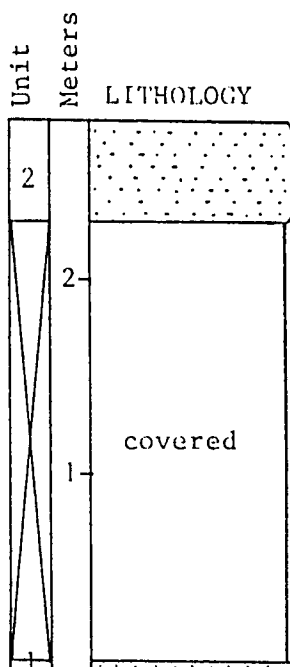
Unit 2 (0.2-0.6 M) Sandstone; very fine-grained; friable; interbedded with shale; gradational basal contact.

Unit 1 (0-0.2 M) Sandstone; well-cemented; resistant;

H-4 SOUTHEAST OF PLEASANTON  
 Linn Co., KS  
 NE $\frac{1}{4}$  SE $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 9 T22S R25E

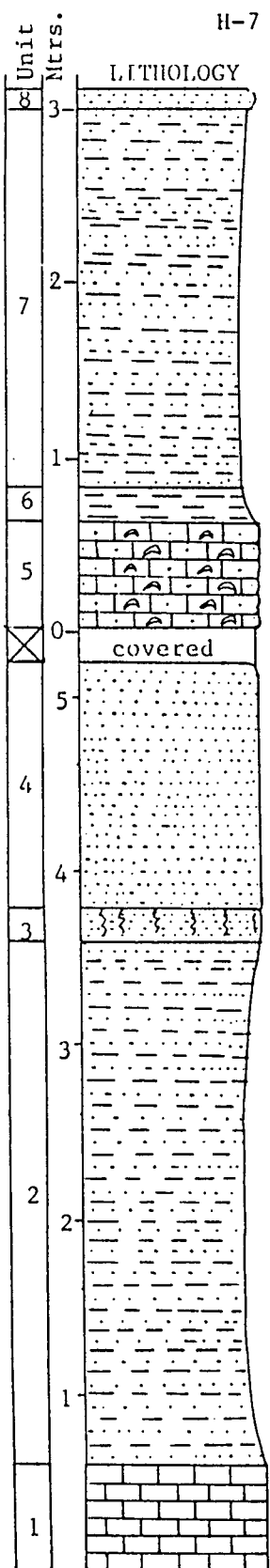


H-6 SOUTH OF PLEASANTON  
 Linn Co, KS  
 NW $\frac{1}{4}$  SW $\frac{1}{4}$  NW $\frac{1}{4}$  sec. 18 T22S R25E



Unit 2 (2.3-2.8 M) Sandstone; fine-to-medium grained; massive; tightly cemented; iron-stained; covered base.

Unit 1 (0-0.1 M) Sandstone; fine-grained.



H-7

UNIONTOWN EAST

Bourbon Co., KS SE<sup>1</sup>/<sub>4</sub> SE<sup>1</sup>/<sub>4</sub> SW<sup>1</sup>/<sub>4</sub>, sec. 23, T25S, R22E

Unit 8 (3.0-3.1 M) Sandstone fine-grained; micaceous; gradational basal contact.  
 Unit 7 (0.8-3.0 M) Sandstone; Very fine-grained interbedded with micaceous shale; gradational basal contact.

Unit 6 (0.6-0.8 M) Shale; medium gray; gradational basal contact.

Unit 5 (0-0.6 M) Limestone; sandy; fossiliferous; nodular; base covered. (Idenbro)

Unit 4 (3.8-5.2 M) Sandstone; fine-to-medium-grained; ripple-laminated and some lg. scale cross-stratifications; abruptly gradational basal contact.

Unit 3 (3.6-3.8 M) Sandstone; fine-grained with micaceous shale partings; horizontal burrows; gradational basal contact.

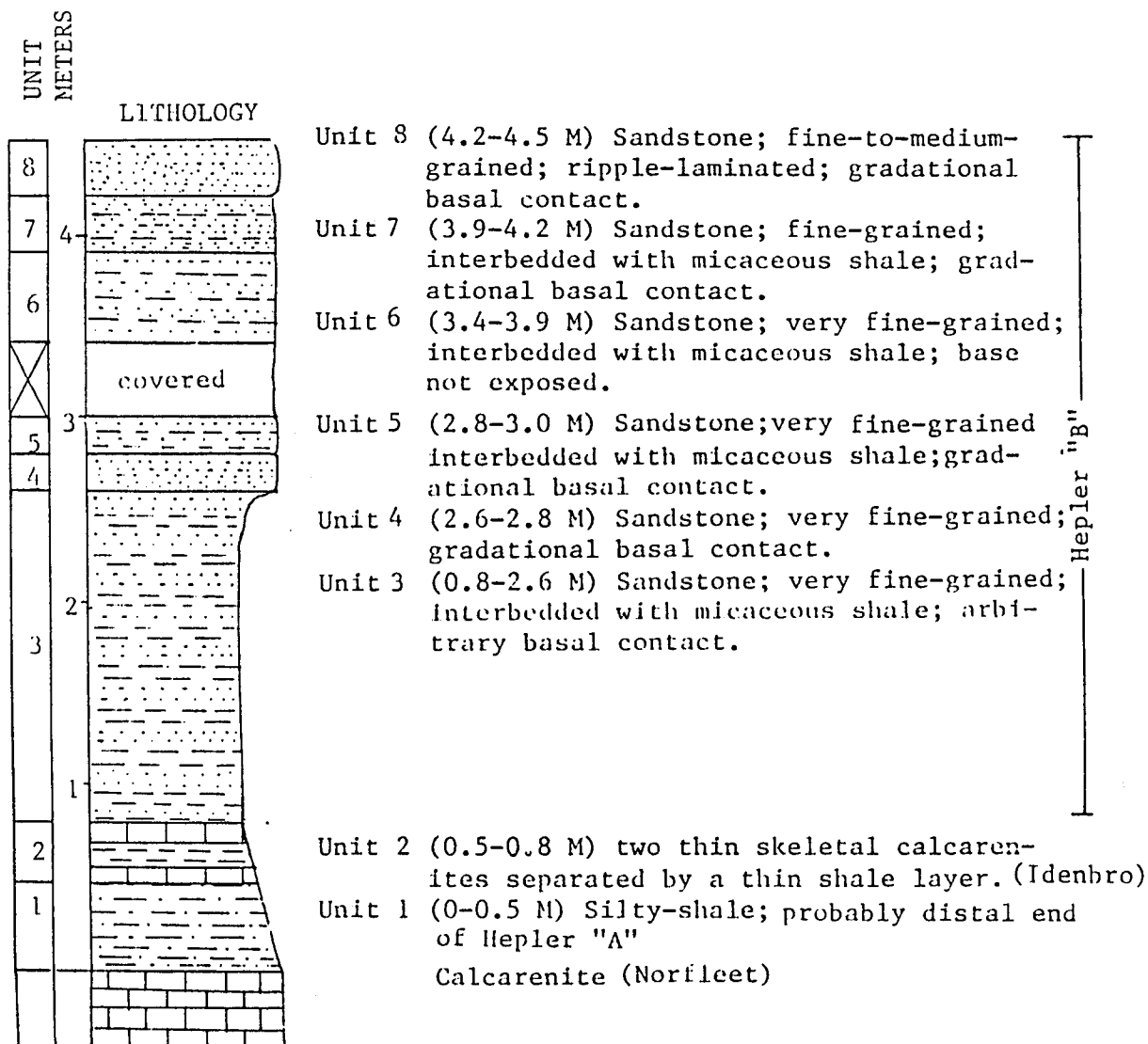
Unit 2 (0.6-3.6 M) Sandstone; very fine-grained; interbedded with shale;

Unit 1 (0-0.6 M) Calcarenite; base not exposed. (Norfleet)

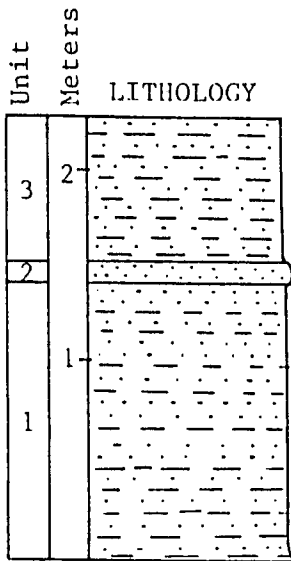
Hepler "B" ss.

Hepler "A" ss.

H-8 PRONG CREEK  
 Bourbon County, KS  
 NW¼ NW¼ NE¼, sec. 10, T27S, R22E



H-9 PRONG CREEK  
 Bourbon Co., KS  
 NE $\frac{1}{4}$  NW $\frac{1}{4}$  NE $\frac{1}{4}$  sec. 10 T27S R22E



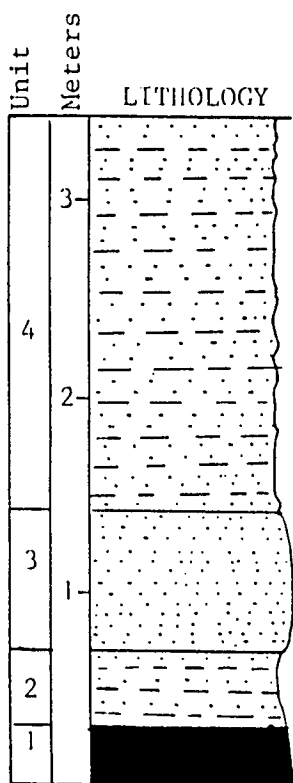
Unit 3 (1.5-2.3 M) Sandstone; fine-grained; inter stratified with shale partings; plant matl present; higher sand to shale ratio twd top gradational basal contact.

Unit 2 (1.4-1.5 M) Sandstone; fine-grained; well-cemented; continuous for 50M; grad. base.

Unit 1 (0-1.4 M) Sandstone; very-fine grained; interbedded with micaceous shale partings.

Hepler "C"

H-10 PUMPKIN CREEK  
 Labette Co., KS  
 SW $\frac{1}{4}$  SW $\frac{1}{4}$  SEC. 20 T33S R18W



Unit 4 (1.4-3.4 M) Sandstone; fine-grained; interstratified with micaceous shale partings; small-scale ripple laminations (0.5 to 2.0 cm); contains large plant fragments gradational basal contact.

Unit 3 (0.7-1.4 M) Sandstone; fine-grained; with some carbonaceous and micaceous shale partings; flaser bedding; more massive toward top; abruptly gradational basal contact.

Unit 2 (0.3-0.7 M) Sandstone; very-fine grained; interbedded with med. gray clay shale; wavy to lenticular bedding; sharp base.

Unit 1 (0-0.3 M) Coal; black.

Hepler "C"

## APPENDIX B

## KANSAS WELL-LOG DATA

KEY

QQQSNTSRE: WELL LOCATION

QQQ: SECTIONAL QUADRANTS

SN: SECTION NUMBER

TS: TOWNSHIP SOUTH

RE: RANGE EAST

MCS: MOUND CITY SHALE

NCS: NUYAKA CREEK SHALE

LNS: LAKE NEOSHO SHALE

L-M: LAKE NEOSHO SHALE - MOUND CITY SHALE

L-N: LAKE NEOSHO SHALE - NUYAKA CREEK SHALE

N-M: NUYAKA CREEK SHALE - MOUND CITY SHALE

CS: HEPLER "C" SANDSTONE THICKNESS

KSC: "KNOBTOWN" SANDSTONE-CARBONATE THICKNESS

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000231616	876	1018	1056	180	38	142	0	14
000021618	615	750	784	169	34	135	7	7
000281618	572	702	728	156	26	130	9	2
000111621	392	530	556	164	26	138	6	0
000121621	400	532	575	175	43	132	4	8
000241621	390	523	566	176	43	133	6	15
000251621	353	486	528	175	42	133	6	7
000261621	369	500	542	173	42	131	6	2
000351621	358	490	530	172	40	132	10	27
000311622	374	504	546	172	42	130	6	8
000311622	367	498	543	176	45	131	7	6
000311622	396	524	568	172	44	128	6	0
000361623	221	370	434	213	64	149	6	10
000111624	257	416	435	178	19	159	9	22
000201624	263	404	464	201	60	141	6	9
000311624	173	323	386	213	63	150	5	8
000311624	165	310	374	209	64	145	16	44
000311624	157	301	362	205	61	144	5	7
000311624	000	305	366	000	61	000	8	16
000311624	000	306	371	000	65	000	8	18
000311624	000	368	431	000	63	000	0	8
000311624	158	302	364	206	62	144	0	18
000311624	113	260	325	212	65	147	8	12
000261625	124	298	355	131	57	174	6	9

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000051717	643	789	825	182	36	146	8	19
000121720	294	434	462	168	28	140	8	6
000071721	320	452	480	160	28	132	7	10
321101721	330	462	490	160	28	132	7	27
000141721	275	000	434	000	00	159		
000161721	210	336	371	161	35	126		
000251721	000	315	352	000	37	000	7	30
342261721	194	314	344	150	30	120	15	10
333011722	198	336	398	200	62	138	6	13
000031722	244	376	429	185	53	132	12	54
113041722	377	509	540	163	31	132	10	40
000051722	369	497	541	172	44	128	7	21
000051722	384	512	549	165	37	128	7	16
000061722	373	502	548	175	46	129	8	2
000081722	388	516	546	158	30	128	6	17
000121722	208	345	407	199	62	137		
000161722	370	498	534	164	36	128	10	64
000231722	192	336	370	178	34	144	5	21
000231722	192	326	370	178	44	134	4	10
000251722	226	354	402	000	00	000	9	20
000311722	182	310	345	163	35	128	8	19
000111723	218	372	436	218	64	154	8	12
000201723	194	000	336	142	00	000	5	2
000241723	141	300	365	224	65	159	6	37
000061724	230	383	446	216	63	153	7	2

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000061724	250	405	466	216	61	155	5	22
000061724	243	400	452	209	52	157	6	7
000111724	194	000	340	000	00	146	9	74
000301725	205	352	415	210	63	147	4	11

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000311811	1541	1650	1704	163	54	109		
000321812	1358	1480	1528	170	48	122	33	0
123061816	782	920	961	179	41	138	8	6
000061817	663	810	848	185	38	147		
000121820	348	490	516	168	26	142	6	0
000131820	372	514	540	168	26	142	5	39
000241820	350	500	526	176	26	150	7	31
000011821	196	326	360	164	34	130	10	23
000171821	244	383	416	172	39	133	10	48
003231821	182	316	351	169	35	134	27	91
000041822	120	252	292	172	40	132	5	5
000041822	122	258	298	176	40	136	0	18
000081822	182	314	352	172	38	134	5	42
000091822	144	280	314	170	34	136	2	14
000101822	128	264	299	171	35	136	10	25
000121822	101	239	276	175	37	138	6	6
000011823	92	252	307	215	55	160	4	23
000041824	195	341	408	213	67	146	11	90
000161824	143	297	363	220	66	154	40	91
000161824	126	279	342	216	63	153		
000171824	69	231	296	227	65	162	6	29
000181824	57	228	274	217	46	171	0	14
000211824	112	264	327	215	63	152	2	12

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000231910	1516	1630	1681	165	51	114	0	8
000021912	1275	1397	1443	168	46	122	0	20
000041912	1351	1469	1517	166	48	118	0	38
000261912	1210	1338	1386	176	48	128	2	12
000241913	1149	1276	1323	174	47	127	0	62
000271913	1166	1294	1339	173	45	128	0	8
000281913	1122	1252	1296	174	44	130	11	43
000341913	1127	1258	1302	175	44	131	4	20
000011914	1036	1172	1216	180	44	136	7	36
000271914	1070	1204	1246	176	42	134	21	44
000301914	1082	1216	1264	182	48	134	25	42
000341914	1057	1192	1236	179	44	135	8	14
000051915	1034	1167	1214	180	47	133	6	48
000061915	1023	1158	1202	179	44	135	5	26
000141922	110	256	293	183	37	146	8	2
000351922	188	347	383	195	36	159	38	4
000011923	26	178	229	203	51	152	0	55

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000102010	1594	1708	1766	172	58	114	0	0
000182010	1758	1870	1922	164	52	112	0	26
000202010	1786	1898	1951	165	53	112	0	22
000302010	1830	1939	1992	162	53	109	0	20
000322010	1811	1926	1973	162	47	115	34	12
000152011	1418	1544	1594	176	50	126	0	35
000082012	1320	1443	1490	170	47	123	25	46
000172012	1364	1486	1530	166	44	122	17	10
000012013	1070	1198	1247	177	49	128	35	19
000272013	1104	1246	1283	179	37	142	19	11
000362013	1077	1216	1260	183	44	139	6	65
000092014	1012	1151	1196	184	45	139	11	9
000162014	1009	1146	1190	181	44	137	8	8
000252014	928	1068	1116	188	48	140	12	67
000112015	000	1117	1170	000	53	000		
000332015	886	1036	1086	200	50	150		
000052016	937	1080	1127	190	47	143		
001252019	406	570	601	195	31	164	10	27
313132020	292	450	484	192	34	158	19	30
231332021	233	390	426	193	36	157		
111222022	130	288	320	190	32	158	8	20
333042023	75	226	276	201	50	151	5	36
443302024	44	183	236	192	53	139	12	75

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000082110	1703	1818	1870	167	52	115	14	38
000192110	1654	1763	1806	152	43	109	0	23
000252111	1432	1557	1603	171	46	125	0	31
000032112	1300	1425	1466	166	41	125	0	69
000322112	1350	1478	1518	168	40	128	22	0
000012113	1085	1210	1272	187	62	125	0	49
000102113	1102	1234	1281	179	47	132	15	13
000112113	1138	1278	1323	185	45	140	0	73
000142113	1168	1306	1350	182	44	138	13	54
000232113	1100	1240	1286	186	46	140	7	40
000242113	1112	1258	1304	192	46	146	11	40
000252113	1108	1248	1294	186	46	140	7	33
000262113	1114	1256	1302	188	46	142	0	75
000352113	1155	1291	1335	180	44	136	18	32
000362113	1136	1267	1314	178	47	131		
000032114	985	1125	1174	189	49	140	7	21
000102114	994	1130	1179	185	49	136	10	15
000112114	922	1062	1111	189	49	140	9	23
000162114	1074	1212	1259	185	47	138	20	15
000192114	1084	1221	1270	186	49	137	7	21
000222114	1006	1148	1194	188	46	142	0	43
000302114	1101	1238	1286	185	48	137	10	3
000312114	1112	1242	1291	179	49	130	13	18
000342114	1058	1192	1242	184	50	134	10	20
000112115	844	994	1041	197	47	150	25	41

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000162115	807	952	1003	196	51	145		
000312115	924	1066	1116	192	50	142		
000202118	1251	000	1430	179	00	000		
111132119	320	488	521	201	33	168	10	49
000222119	430	596	627	197	31	166	10	68
000222119	438	602	635	197	33	164		
001222119	417	582	615	198	33	165		
000222119	320	488	521	201	33	168		
434352119	000	607	640	000	33	000	10	55
311352119	450	604	635	185	31	154		
113142120	411	572	597	186	25	161	19	19
124152120	000	594	624	000	30	000		
000152120	000	594	624	000	30	000	20	0
422172120	000	559	590	000	31	000		
001042121	204	369	406	202	37	165	2	24
104042121	202	368	403	201	35	166	4	32
341042121	202	368	404	202	36	166	2	20
323042121	201	367	403	202	36	166	6	32
100042121	201	367	404	203	37	166	14	54
100042121	205	360	406	201	36	155	10	43
323042121	000	370	406	000	36	000	0	0
021082121	254	407	440	186	33	153	6	3
332282121	000	322	356	000	34	000		

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000012210	1498	1612	1656	158	44	114	0	36
000102210	1768	1878	1923	155	45	110	0	7
113072211	1589	1704	1749	160	45	115	1	30
000322211	1422	1550	1592	170	42	128	6	58
000112213	1152	1285	1332	180	47	133	17	14
000212213	1200	1336	1379	179	43	136	11	0
000262213	1134	1272	1320	186	48	138	16	39
000102214	1022	1160	1208	186	48	138	6	7
000272214	988	1130	1177	189	47	142	8	23
000132215	780	934	978	198	44	154	4	73
000142215	826	979	1023	197	44	153	10	68
000252215	693	850	895	202	45	157	40	64
000292215	903	1052	1098	195	46	149	9	39
000362215	700	855	897	197	42	155	26	60
000112216	660	818	854	194	36	158	9	61
000192216	662	818	861	199	43	156	8	71
000212216	649	799	838	189	39	150		
000222216	640	780	830	190	50	140		
000272216	624	780	819	195	39	156	15	108
000282216	626	782	824	198	42	156	14	99
000302216	685	842	887	202	45	157	5	87
000312216	712	870	914	202	44	158	24	59
000292217	590	752	786	196	34	162	14	8
323282218	462	621	659	197	38	159	0	47
000292218	456	620	656	200	36	164	10	16

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
324032219	443	604	636	193	32	161	16	23
422082219	449	613	646	197	33	164	27	37
144092219	465	630	662	197	32	165	25	37
433152219	472	655	696	224	41	183	24	19
004162219	458	625	656	198	31	167	28	40
000162219	456	617	650	194	33	161	28	40
024162219	451	617	650	199	33	166	28	40
003212219	469	638	678	209	40	169	19	40
001222219	404	568	601	197	33	164		

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000042310	1708	1821	1867	159	46	113	0	29
000132310	1550	1676	1719	169	43	126	0	43
000192310	1812	1923	1971	159	48	111	0	66
000222310	1592	1716	1761	169	45	124	0	36
000032311	1396	1525	1566	170	41	129	0	35
000092312	1182	1315	1354	172	39	133	0	9
000202312	1242	1375	1412	170	37	133	0	9
000232313	1075	1209	1255	180	46	134	8	11
000292313	1060	1204	1244	184	40	144		
000092315	814	966	1005	191	39	152	12	49
000312315	838	986	1024	186	38	148	7	6
000012316	571	731	766	195	35	160	26	75
000062316	674	827	869	195	42	153	52	44
000102316	574	735	774	200	39	161	12	20
000112316	580	735	774	194	39	155	11	34
000122316	558	718	755	196	36	160	26	75
000132316	556	720	756	201	37	164		
000132316	550	714	750	200	36	164	11	21
000132316	547	710	746	199	36	163	11	21
000132316	553	718	754	201	36	165	11	21
000202316	000	843	884	000	41	000		
000332316	666	824	868	202	44	158	24	57
000302317	522	684	722	200	38	162	12	3
141062318	460	618	656	196	42	158	18	93
142272318	420	595	634	214	39	175	12	50

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
141292318	406	569	604	198	35	163	7	69
243042319	342	511	552	210	41	169	15	12
043122319	382	561	596	214	35	179	28	55
232142319	376	549	587	211	38	173	18	33
331042321	210	389	422	212	33	179	13	43
331042321	214	394	422	208	28	180	13	43
242052321	203	382	416	213	34	179	10	47
114092321	148	319	358	210	39	171	12	20
001342321	92	254	292	200	38	162	16	26

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
313342409	1806	1917	1962	156	45	111	2	49
000082411	1501	1634	1666	165	32	133	5	18
000172412	1167	1308	1349	182	41	141	6	35
000022413	912	1059	1097	185	38	147	11	46
000132415	778	926	971	193	45	148	12	34
000332415	765	925	967	202	42	160	8	35
000022416	634	796	838	204	42	162	11	23
313022418	375	545	586	211	41	170	20	39
114332420	225	410	446	221	36	185	19	20
132342420	218	404	438	220	34	186	43	27
241352420	215	403	438	223	35	188	29	44
444252421	119	243	289	170	46	124	20	56
242262421	114	262	306	192	46	148	27	73
411362421	103	226	273	170	47	123	25	53
002062422	94	246	290	196	44	152	21	62
433082422	88	232	273	185	41	144	17	40
032112422	52	164	209	157	45	112	6	25
234142422	73	178	226	153	48	105	12	46
133302422	113	238	285	172	47	125	17	61
432242424	62	199	243	181	44	137	22	73

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
423252504	2193	2286	2344	151	58	93	0	31
231122514	827	994	1038	211	44	167	9	62
444062516	554	712	758	204	46	158	9	50
132242516	460	620	663	203	43	160	5	0
324232517	380	539	576	196	37	159	0	25
000022518	248	433	472	224	39	185	19	19
343142519	252	440	480	228	40	188	17	21
332282519	258	440	476	218	36	182	35	48
442332520	210	399	430	220	31	189	21	50
421122521	155	262	312	157	50	107	0	29
111182521	202	350	395	193	45	148	14	26

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
341032605	2153	3343	2310	157	68	89	0	46
142132605	2170	2252	2300	130	48	82	6	54
244262605	2291	2366	2437	146	71	75	0	42
414352605	2281	2334	2406	125	72	53	0	33
003282606	0000	2380	2438	000	58	00		
432222607	2233	2328	2382	149	54	95	13	52
111262607	2204	2288	2344	140	56	84	2	65
341102608	1996	2095	2149	153	54	99	0	45
411292608	2184	2282	2331	147	49	98	0	22
114132609	1462	1566	1612	150	46	104	0	60
144232609	1531	1640	1690	159	50	109	11	0
333072610	1510	1613	1662	152	49	103	0	53
411182610	1458	1566	1617	159	51	108	0	78
223242611	1204	1334	1376	172	42	130	0	33
321082612	1167	1286	1331	164	45	119	9	63
441112612	990	1105	1148	158	43	115	8	31
332302612	1204	1335	1378	174	43	131	0	29
021362612	1045	1131	1175	130	44	86		
021362612	1046	1131	1175	129	41	85		
242132614	645	768	817	172	49	123	12	17
142192615	756	870	919	163	49	114	12	15
000222617	252	413	450	198	37	161	28	20
442242617	324	468	506	182	38	144	10	57
443022618	224	397	433	209	36	173	25	14
222052619	241	420	458	217	38	179	23	64

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
321072619	000	401	441	000	40	000		
413182621	148	279	317	169	38	131	0	44
000192622	131	237	269	138	32	106	0	44

QQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
241352704	2216	2284	2350	134	66	68	0	19
242152705	000	2409	2473	000	64	000		
000272705	000	2422	2492	000	70	000	13	48
213082706	2271	2363	2420	149	57	92		
023282706	2207	2291	2354	147	63	84	32	18
221332706	2268	2348	2416	148	68	80	0	33
022352706	1887	2008	2059	172	51	121		
324142707	2172	2298	2364	192	66	126	0	19
313202707	2228	2345	2406	178	61	117	10	70
414202707	2228	2343	2402	174	59	115		
424132708	1793	1937	1988	195	51	144		
141182709	1794	1928	1977	183	49	134		
043062710	1553	1686	1735	182	49	133	0	20
013072711	1247	1384	1430	183	46	137	27	25
034292713	938	1028	1074	136	46	137	12	43
314202714	714	803	854	140	51	89	25	24
002142715	466	550	603	137	53	84	16	31
121062716	479	581	628	149	47	102	10	29
232182716	499	604	648	149	44	105	15	62
000042717	426	549	587	161	38	123	14	35
041192717	474	573	617	143	44	99	11	33
121112718	172	350	378	206	28	178	28	99
131222718	174	324	361	187	37	150	0	36
000192719	184	348	386	202	38	164	0	35
000332719	000	263	303	000	40	000		

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
242082720	146	297	335	189	38	151	9	33
112122721	52	152	184	132	32	100	0	25
322192721	164	231	272	118	41	67	0	41

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
000012805	0000	2404	2473	000	69	000	0	43
004052806	2289	2362	2430	141	68	73	0	25
242092806	2222	2312	2376	154	64	90	0	63
331012807	2242	2354	2416	174	62	112	0	46
221022807	2195	2308	2369	174	61	113	0	42
332032807	2244	2357	2417	173	60	113	0	65
444262812	964	1061	1112	148	52	96	26	42
000032813	855	955	999	144	44	100	35	41
431342813	745	843	892	147	49	98	12	54
114242815	380	485	539	159	54	105	10	64
111232816	402	506	555	153	49	104	21	55
111162817	350	469	517	167	48	119	16	41
433042818	251	384	424	173	40	133	40	63
222182818	000	385	429	000	44	000		
222242818	165	284	328	163	44	119	29	68
331192819	159	276	320	161	44	117	25	62

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
123152902	2750	2836	2889	139	53	86	8	52
000022904	2337	2423	2499	162	76	76	3	48
334232904	2481	2563	2642	161	79	82	0	64
011182905	2475	2556	2634	159	78	81	0	57
003292905	2384	2462	2534	150	72	78	0	52
214162906	2290	2375	2442	152	67	85	36	38
003142907	2211	2294	2358	147	64	83		
000192908	2195	2268	2334	73	66	91	23	35
231342909	1692	1780	1844	152	64	88	31	40
031132910	1394	1501	1556	162	55	107	47	44
421342910	1358	1439	1500	142	61	81	10	25
114172911	1337	1436	1484	147	48	99		
314122912	1062	1094	1145	83	51	90	10	7
000202913	1058	1154	1203	145	49	96		
022232913	763	867	917	154	50	104	44	59
332012914	522	567	616	94	49	45	21	11
024112916	262	378	427	165	49	116	31	76
311122916	212	329	376	164	47	117	8	69
134242917	232	352	401	169	49	120	38	66
341302917	246	361	410	164	49	115	27	78
311362917	268	384	429	161	45	116	35	70
002022920	000	80	125	000	45	000	41	0

QQQSNTRSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
441023003	2688	2769	2858	170	89	81	0	48
312103003	2422	2502	2580	158	78	80	0	56
032243003	2660	2740	2820	160	80	80		
332013004	2401	2473	2552	151	79	72	10	53
312113004	2391	2466	2556	165	90	75	6	50
244133004	2462	2534	2609	147	75	72	2	43
000153004	2426	2500	2578	152	78	74	12	56
004233004	2478	2557	2635	157	78	79	1	45
423333004	2467	2533	2615	148	82	66	4	60
114333005	2420	2491	2567	147	75	71	8	51
111193006	2363	2430	2505	142	75	67	9	42
342313006	2428	2495	2569	141	74	67	4	55
321123007	2162	2242	2317	155	75	80	17	50
444293007	2308	2393	2464	156	71	85	12	61
443103008	2223	2307	2376	153	69	84	10	54
033253008	1948	2036	2106	158	70	88	7	56
112093009	1827	1916	1981	154	65	89	25	43
324093009	1952	2036	2103	151	67	84	14	36
412353009	1698	1784	1852	154	68	86	11	62
443143010	1350	1440	1505	155	65	90		
111263010	000	1466	1526	000	60	000		
043303011	000	1366	1429	000	63	000		
444153012	933	1016	1072	139	56	83	19	47
000083013	844	932	988	144	56	88		
421333013	794	896	953	159	57	102	9	75

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
441343014	648	682	739	91	57	34	27	0
244253016	000	386	439	173	53	120	20	93
332263016	245	340	394	149	54	95	15	67
243013017	284	407	452	168	45	123	33	80
311223017	291	409	456	165	47	118	23	88
134323019	148	202	250	102	48	54	0	25

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
022293103	2710	2780	2856	146	76	70	0	46
213363104	2480	2554	2645	165	91	74	0	60
241203105	2384	2456	2538	154	82	72	0	51
113213105	2484	2558	2640	156	82	74	0	59
002363105	2478	2548	2630	152	82	70		
034363105	2532	2596	2685	153	89	64	9	34
444073106	2375	2448	2524	149	76	73	22	0
313313106	2625	2590	2678	152	88	64	13	26
223143107	2243	2334	2413	170	79	91	7	76
233033108	1088	2172	2246	158	74	84	2	61
124163108	2165	2215	2296	131	81	50	2	15
322163109	1665	1756	1830	165	74	91	4	64
314173109	1692	1780	1853	161	73	86		
113103110	1434	1452	1525	91	73	92	13	66
143153111	1214	1314	1380	166	66	100		
123293111	1330	1423	1494	164	71	93		
123293111	1404	1423	1494	90	71	19	14	69
412173113	985	1008	1072	93	64	29	17	79
000233113	743	772	832	89	60	29	4	4
032203114	704	734	800	96	66	30		
441263114	690	720	784	94	64	30		
311103115	401	434	488	87	54	33	11	9
113143115	412	447	500	88	53	35		
341233115	440	475	525	85	50	35	6	8
000023116	265	316	372	107	56	51	8	17

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
234233116	273	326	380	107	54	53	15	21
000053117	295	412	459	164	47	117	15	77
133303117	240	292	347	107	55	52	18	5
000343117	000	201	253	000	52	000		

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
314363202	2797	2874	2967	170	93	00	0	55
344023203	2674	0000	2830	156	00	00	0	58
314093203	2690	2764	2852	162	88	74	0	51
332153204	2510	2593	2680	170	87	83	6	60
012223204	2508	2590	2674	166	84	82	9	58
003133205	2530	2586	2683	153	97	56	0	44
321333205	2573	2641	2728	155	87	68	6	35
142053206	2470	2530	2624	154	94	60	0	47
143103207	2298	2379	2465	167	86	81	12	25
244213207	2311	2370	2464	153	94	59	0	37
411183208	944	1000	1071	127	71	56	7	17
211343208	1808	1871	1944	136	73	63	15	22
134133209	1575	1616	1687	112	71	41	3	17
323173209	1716	1760	1839	123	79	44	2	10
442203209	1689	1728	1803	114	75	39	2	27
113023210	1403	1466	1543	140	77	63	3	43
444043210	1432	1496	1596	137	73	64	4	41
004283210	1389	1432	1505	116	73	43	10	17
214063211	1271	1340	1415	144	75	69	4	46
121173211	1296	1358	1431	135	73	62	7	40
134203211	1240	1296	1373	133	77	56	10	35
232313211	1327	1368	1445	118	77	41	8	16
211033212	913	981	1044	131	63	68	14	41
032143212	858	886	959	101	73	28	12	8
441063213	904	957	1027	123	70	53	25	10

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
322263213	828	884	958	130	74	56	9	13
211323214	634	683	757	123	74	49	9	28
014063215	628	657	718	90	61	29	16	6
234353215	388	415	482	94	67	27	13	3
114163216	344	389	450	106	61	45	20	12
422193216	262	298	360	98	62	36	16	9
123023217	150	200	253	103	53	50	25	10
332033217	142	196	248	106	52	54	27	4
311093217	157	214	269	112	55	57	29	3
113343218	67	132	174	107	42	65	51	3

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
432083308	1923	1956	2052	129	96	33	8	6
331213308	2180	2211	2292	112	81	31	4	4
442253308	1712	1784	1855	143	71	72	0	36
004053309	1662	1703	1778	116	75	41	4	11
131073309	1744	1786	1859	115	73	42	2	6
023143309	1708	1730	1807	99	77	22	0	15
001143309	1594	1668	1740	146	72	74	10	24
114023310	1388	1424	1500	112	76	36	8	11
111193311	1271	1290	1371	100	81	19	7	2
322303311	1276	1306	1380	104	74	30	12	0
002143312	875	900	970	95	70	25	10	4
421253313	700	736	820	120	84	36	8	4
334133314	520	548	636	116	88	28	14	2
442353314	581	618	696	115	78	37	14	0
241113315	412	438	516	104	78	26	17	0
031193315	490	000	606	116	00	000	52	0
213193315	470	496	582	112	86	26	15	1
222033316	148	196	256	108	60	48	10	1
111113316	176	226	286	110	60	50	13	7
000193316	390	420	500	110	80	30	20	0
444233317	402	428	508	106	80	26	12	0
443293317	39	86	149	110	63	47	17	4
024323317	17	68	131	114	63	51	20	3

QQQSNTSRE	MCS	NCS	LNS	L-M	L-N	N-M	CS	KSC
432023411	1012	1031	1108	96	77	19		
333063412	985	1002	1086	101	84	17	5	0
241173412	914	934	1010	96	76	20	6	0
024043413	417	444	528	111	84	27	20	0
141063413	948	964	1035	87	71	16	5	0
003083413	752	795	864	112	69	43		
002073414	624	644	736	112	92	20	13	0
113353414	641	662	765	124	103	21	12	0
414013415	372	401	482	110	81	29	20	1
423113415	337	366	450	113	84	29	17	0
332203415	450	476	568	118	92	26	17	1
000243415	294	322	408	114	86	28	24	1
000083416	346	380	462	116	82	34	28	1
421173416	307	339	430	127	91	36		
442053417	000	38	98	000	60	00		
022053417	000	35	96	000	61	00		
441173417	18	67	148	130	81	49	18	2

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